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CONTENTS

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SELECTION OF PLANTING STOCK FOR VINEYARDS

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Vines can be multiplied by seeds or by buds. Seeds are used only in the origination of new varieties. Commercial vineyards consist of clonal varieties multiplied by buds, the only way in which vines of the desired variety can be obtained.

Growers propagate vines by means of "cuttings." A vine cutting is a segment of mature one-year-old wood including one or more buds. The vine from which the cutting is taken is called the "mother vine" or "parent" and the vine which grows from the cutting, the "daughter vine" or "progeny." Most grape growers and their advisers believe it is necessary for the best results to make a careful selection of the cuttings to be used for propagation. Some act upon this belief and choose a good healthy vineyard noted for the size and quality of its crop, avoiding vines which have borne few or poor grapes.

REASONS FOR SELECTION

The reasons for making this selection are to obtain a daughter vine (1) which will have the desirable qualities of the parent, and (2) which will develop rapidly.

These reasons are based on the beliefs (1) that a bud carries the qualities of the parent, and reproduces them in the offspring, and (2) that the ease and rapidity with which the bud grows depend on its size, maturity, food reserevs and other factors of condition as regards health, vigor and nourishment. While all observers concur in a general way in these beliefs and there is little uncertainty regarding the most favorable conditions for growth and the methods of determining and making use of them, there are some fundamental differences of view regarding the degree to which the characteristics of the parent vine are reproduced in the offspring.

BASES OF SELECTION

We can consider the differences which distinguish two vines as belonging to two classes:

1. Those which distinguish the variety, e.g., the round, black, seedless berries of the Corinth and the elongated, large, white berries of the Olivette. These are heritable or, more properly, transmissible to the offspring by bud or vegetative propagation.

2. Those which lie within the normal range of the variety, e.g., the black color of the Emperor when grown near the coast and the red color of the same grape when grown in the hot interior. These are usually considered as not transmissible. This means that a cutting taken from an Emperor bearing red fruit in Tulare County will produce a vine bearing black fruit if planted in Sonoma County.

The difficulty comes in deciding whether a certain difference belongs to one class or to the other. We have no doubt that the difference between the elongated, asymetrical berry of the Pizzutello and the regular, oblate spheroidal berry of the Palomino is varietal, and therefore transmissible, because, however many berries we examine of either, there is never any doubt to which variety each belongs. This is not the case with the nearly spherical berries which are supposed to characterize the Muscat Gordo Blanco and the obovoid berries which are supposed to characterize the Muscat of Alexandria, because both forms may occur on the same vine. There is doubt, therefore, whether these are different varieties.

Some try to resolve the difficulty by saying that there is only one variety but two "strains" and that if you grow a new vine from a cutting taken from a mother vine which has produced spherical grapes the daughter vine will produce spherical grapes. In other words, the difference observed is transmissible and characteristic of a certain "strain."

However, if the difference is transmissible, it is equivalent to a varietal character and differs only in degree from other undoubted varietal characters.

It is here the whole problem lies—is the difference transmitted by the bud from the mother vine to the daughter vine? In some cases, where there is a distinct difference of kind, this is very easily determined by the growth of offspring. In other cases where there is simply a difference of degree, it is much more difficult. Whether the differences which distinguish the various shades of red exhibited by the Tokay in different localities and even by different vines in the same vineyard are heritable or not can be determined only by long and careful investigation and well controlled experiments. The reason of this is that the character we are dealing with is greatly influenced by environmental factors such as soil, water and climate.

The most important case and perhaps the most difficult to decide is the ''heritability'' or transmissibility of degrees of productiveness. To obtain a heavy bearing Muscat vine, are we assisted at all by taking our cuttings from a Muscat mother vine which has borne heavy crops? A belief that we are is the basis of a large part of the bud selection of vines and other fruiting plants which has been practiced in the past. It has been the common advice of books and specialists to keep ''performance records'' of individual plants of a variety and to use as a source of scions the individuals having the highest records for bearing.

A publication issued in 1906* states that: ''A vineyard of pedigreed vines of all our most desirable varieties would be a most valuable acquisition for the State. Such a vineyard might be started with cuttings in the way described and each variety gradually brought up to its highest possible bearing capacity by grafting all the vines of each variety with cuttings taken from the vine of that variety which has shown the best and most regular bearing qualities during a term of years.''

The Department of Agriculture of Victoria in 1924** gives the following advice:

> ''The improvement of the fruit-growing capacity of a variety by means of careful selection of cuttings is no new discovery; it has repeatedly been recommended by different officers of this Department, and its importance is now very generally recognized. It is a point, however, which was for many years much neglected by the majority of Victorian vine-growers, with the result that several of our vine varieties show more or less marked deterioration in their yield of fruit.
>
> ''In order to secure prolific scions, the best individual vines in a block of any given variety should be carefully marked—quality and quantity of fruit, as well as general health and vigor, are the essential points to be considered in the selection of these scion-bearing vines, which may best be carried out immediately before vintage. Only fruit-bearing canes on the vines thus selected should be used as scions.''

This advice is evidently based on *a priori* reasoning from false analogy. The difference in egg production of two hens of the same breed is analogous to the difference in productiveness between two seedlings of a vine variety. In each case, the progeny individuals

* Bioletti, Frederic T. Selection and preparation of vine cuttings. California Agr. Exp. Sta. Circ. 26:4. 1906.

** Planting and reconstitution of vineyards. Unnumbered Circ. Dept. Agr. Melbourne, Victoria. Apr. 15, 1924.

are the result of a blend or assortment of the qualities of two parents (or with the plant of the reassortment of the qualities of a single heterozygous parent) and qualities of either parental factor may appear in the offspring. In a vine grown from a cutting, there are no parents in this sense. The new vine is not a new individual in the same sense as a chicken hatched from an egg. It is simply a part of a single individual—the clonal variety—which originated from a seed. All the millions of Muscat of Alexandria vines which are now growing in five continents are, from the point of view of heredity, simply parts of a single plant which originated from a seed, probably in Southwestern Asia many thousands of years ago.

The *a priori* assumption, therefore, should be that any bud taken from any vine of Muscat of Alexandria will produce a vine having all the possibilities of any and all vines of this variety. It follows from this assumption that a bud from a Muscat vine which has never borne a crop is just as likely to give us a heavy-bearing daughter vine as a bud from a Muscat vine which has a long record of large crops. The *onus probandi* lies with those who maintain the contrary.

The only demonstrated basis for the contrary conclusion is the possibility of bud mutations.

Occasionally there appears among Muscat vines, as among plants of other clonal varieties, an individual or unit showing some marked difference from the varietal complex of characters. Such a difference is, or may be, heritable in the sense that it is persistent and can be propagated by cuttings. Established cases of this kind are however rare in *Vitis vinifera* and only one well authenticated case has been noted in California among the 100,000,000 vines of the Muscat growing here. This is a case of "gigantism," similar cases of which have been observed in California with several other varieties of *Vitis vinifera*. The black and red variations of the Muscat of Alexandria may have originated as seedlings.

The great persistence of the characters of the Muscat is evident. What hope, therefore, is there that the bearing of Muscat vines can be improved by a careful selection of planting stock from mother vines having a high record for heavy bearing, and what danger is there from neglecting this selection?

INVESTIGATION

In the hope of obtaining an answer to these questions, an investigation was started at the Kearney experimental vineyard in 1911. A block of 1200 Muscat vines grown from unselected cuttings rooted in a nursery in 1910 was planted in a piece of fairly uniform soil and a record of the crop of each vine kept for five years, 1914–18. In 1920, cuttings were taken from each of the 115 vines having an annual record of over 29 pounds (30 pounds–38 pounds) and of the 86 vines having an annual record under 16 pounds (7 pounds–15 pounds). These cuttings were rooted in the nursery and planted in a plot of very uniform soil in the Davis experimental vineyard in 1921.

The plot consists of 18 rows of 35 vines each. Every fourth row commencing with row 1 was planted with the progeny of low-bearing vines and the intermediate groups of three rows with the progeny of heavy-bearing vines. They were arranged so that the vines of lowest-bearing parentage adjoined the vines of highest-bearing parentage, i.e., vine 1 of rows 1, 5, etc., originated from a 7 pound parent and vine 1 of rows 2, 6, etc., from a 38 pound parent, and so on.

The four groups of four rows were made as nearly replicas as possible except that the largest and most vigorous rootings of both heavy and light bearing parentage were planted in the first rows, and the following rows planted with rootings in order of gradually diminishing size and vigor. There was, therefore, a continuous and gradual reduction in the size and vigor of the rootings from rows 1 and 2 to rows 17 and 18.

CORRELATION OF CROP AND PLANTING STOCK

This arrangement makes it possible to note any differences due to: (1) Bearing of the parent vines, and (2) quality of the rootings.

Effect of quality of rootings.—Before taking up the influence of the parent vines, the influence of the rootings will be considered.

There was a noticeable difference in the size and apparent quality of the rootings, but none of them were poor. Only two failed to grow and all the rest grew well. To a cursory glance, at the end of the second growing season, there was little difference of growth visible between the two ends of the plot.

The first crop worth harvesting was weighed in 1923, when the vines were in their third year. The result of the weighings by rows is shown in chart A.

Omitting rows 1 and 18, there is a fairly regular decrease of crop from one end of the plot to the other with no obvious influence ascribable to the parent vines. The influence of the size and quality of the rootings, on the other hand, is marked. The average crop of the vines in row 2, where the best rootings of heavy-bearing parentage were grown, was 23 pounds, while that of the vines in row 16, where the poorest rootings of heavy-bearing parentage were grown, was only 11.7 pounds. *A similar contrast is shown by the vines of low bearing* parentage.

The best rootings (row 2) therefore yielded a crop of over 3 tons to the acre more than the fair rootings (row 16). The value of the extra crop was much greater than the total cost of the best rootings.

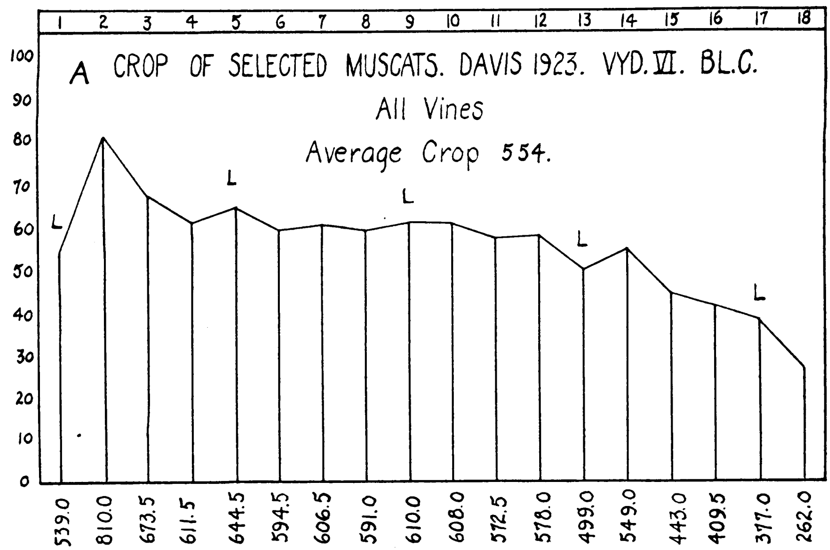

CHART A.—First (1923) crop of progeny vineyard. Rows of low-bearing parentage marked L.

All the vines looked strong and healthy so that it is probable that the difference is simply one of quicker development. Later crops have indicated strongly that the vines from the poorer rootings will finally produce as well as those from the best. The loss is merely one of time. The difference in development is shown by the average circumference of the vines in the spring of 1924 as appears in table I where it is compared with the corresponding difference in crop.

This table shows that the average circumference of the vines drops off from the north to the south of the plot. If we calculate the crop for each row in the ratio of the cube of the average circumference, we obtain a curve almost parallel with the actual crop curve except with the end rows 1 and 18. These rows are evidently abnormal in the amount of crop gathered, possibly on account of greater exposure to wind during the blossoming season. There is plainly a direct correlation of both crop and size of vine with the size of the rooting at planting. This is made evident by the approach to parallelism of the crop and growth curves in chart B.

TABLE I

MEAN CIRCUMFERENCE OF TRUNK AND CROP OF VINES

Rows	Circumference, cm.		Crop in pounds per row			
			Actual		Calculated*	
1**	L 12.64		539.0		636	
2	12.82		810.0		664	
3	12.79	−12.72	673.5	−698	659	−649
4	12.56		611.5		624	
5	L 12.79		644.5		659	
6	12.44		594.5		607	
7	12.59	−12.23	606.5	−597	629	−581
8	11.67		591.0		508	
9	L 12.32		610.0		589	
10	12.26		608.0		581	
11	12.15	−12.11	572.5	−586	565	−560
12	11.92		578.0		534	
13	L 12.08		499.0		556	
14	11.98		549.0		542	
15	11.30	−11.64	443.0	−467	455	−518
16	12.09		409.5		557	
17	L 11.61		377.0		493	
18**	11.64		262.0		497	
Means	12.21		573.5		570	

* The figures in this column are what would have been obtained if the crop had been in proportion to the cube of the diameter.

** Rows 1 and 18 appear abnormal and are omitted in the calculation.

The influence of the quality of the rootings on the first crop is shown very clearly by chart B. The figures give the average crop of 35 vines for each of the 5 lots of vines with heavy bearing parents and of the 5 lots with light bearing parents. Each lot of the heavy bearers consisted of 3 rows except the 5th lot (row 18).

The lower solid line of the chart represents the crop of the vines of heavy-bearing parentage, the upper that of the vines of low-bearing parentage. They are very nearly parallel except at the upper end and to a less degree at the lower. The probable cause of these exceptions has already been discussed. The fact that the line of the vines of low-bearing parentage is higher than that of the others and drops less at the lower end is probably due to selection of rootings. Only one-third as many "poor bearers" as "heavy bearers" were planted and there was, therefore, a better selection of rootings. All the heavy bearers were planted, but there was a surplus of the poor bearers, which resulted in the rejection of the poorest rootings.

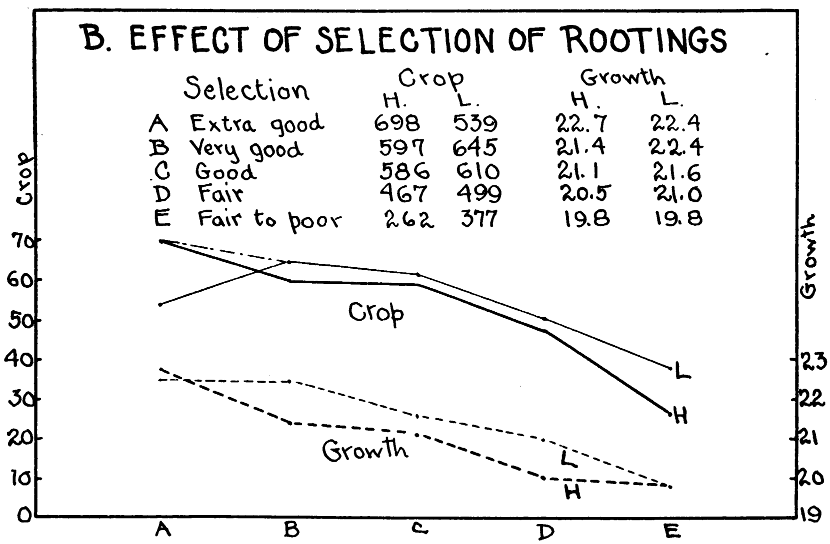

CHART B.—Effect of selection of rootings.

The dotted line at the upper end of the line for vines from poor bearers represents about the position that it would have taken if the first row had conformed with the general increase of bearing from south to north. It is assumed that the best rootings in the two cases were equally good.

Effect of the parent vines.—More than one crop is necessary to come to a definite conclusion regarding the influence of the parent vines on the bearing of the progeny, but it is interesting to find that there is no sign of any influence in the first crop. This can be seen clearly in chart C.

The solid line on the left shows the crops of vines of heavy-bearing parentage from row 2 to row 18. The average crops of the corresponding parent vines are shown by the dotted line below. A similar comparison is made for the vines of low-bearing parentage by the lines on the right. (The crops of the progeny vines are shown on a scale 3.5 times as large as that used for the parent vines.)

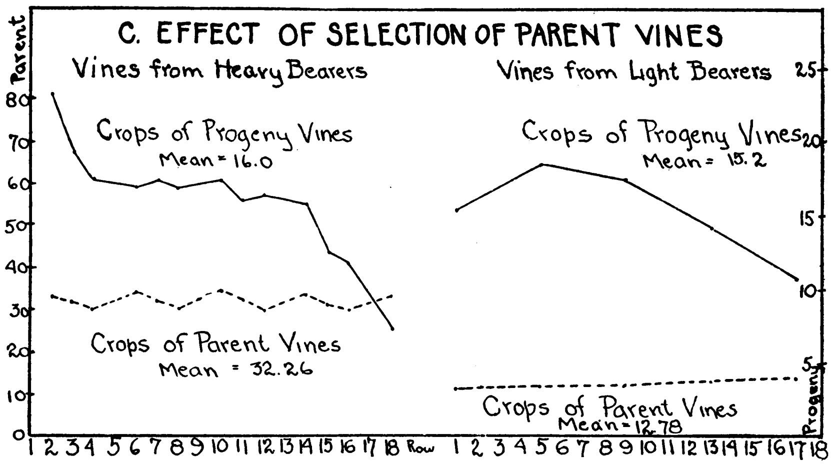

CHART C.—Effect of selection of parent vines.

There is an almost imperceptible falling off of crops of the heavy-bearing parent vines from north to south (left to right) and a more marked falling off from row to row of each lot of three, but there is no correspondence with the much greater falling off in the same direction shown by the crops of the progeny vines.

With the light-bearing parent vines, there is a slight increase of bearing from north to south coinciding with the marked decrease of bearing of the progeny vines.

RESULTS OF LATER CROPS

With the vintage of 1925, the progeny vineyard had yielded three crops. Table II shows the average crop in pounds per vine for each row, for each year, and for the three years.

The data of this table show evidence (1) of a general tendency to an annual alternation of higher and lower crops, (2) of a gradual recovery of the crops of the vines grown from the less vigorous rootings, and (3) a complete lack of correlation between the yields of the parent vines and those of the progeny.

Alternation of crops.—A distinct tendency to an alternation between heavier and lighter crops is shown by chart D(a). Row 18 which produced only 49 per cent of the average in 1923—the smallest crop of the year—produced 117 per cent in 1924—the largest for this year except row 8. This indicates that the smallness of the crop of row 18 in 1923 was not due to any defect of soil, but simply to the inferiority in size and vigor of the rootings planted, which delayed their development, and perhaps to some evanescent defect of position. With the second crop, this handicap had apparently been overcome. The small crop of 1923 allowed the vines to acquire the size and vigor necessary for the large crop of 1924. Similar and proportionate effects are shown by 15, 16 and 17, the other rows planted with the poorer rootings.

TABLE II

CROPS OF PROGENY VINEYARD, 1923, 1924 AND 1925. (MEAN CROP PER VINE FOR EACH ROW AND EACH YEAR.)

Row	1923	1924*			1925	Means of 1923–24	Means of 3 years
		a	c	b			
1 L	15.4	13.3	19.6	6.3	17.4	17.5	17.5
2	23.1	12.5	16.8	4.3	22.7	20.0	20.9
3	19.4	13.3	18.7	5.4	20.2	19.1	19.4
4	17.5	11.3	18.3	7.0	22.0	17.9	19.3
5 L	18.4	11.9	17.4	5.5	19.5	17.9	18.4
6	17.0	13.2	17.9	4.7	20.5	17.5	18.5
7	17.8	15.1	19.8	4.7	22.0	18.8	19.9
8	16.9	14.6	20.3	5.7	22.2	18.6	19.8
9 L	17.4	12.0	18.1	6.1	20.5	17.8	18.7
10	17.4	10.0	15.9	5.9	20.2	16.7	17.8
11	16.3	10.5	15.3	4.8	19.8	15.8	17.1
12	16.5	8.2	12.3	4.1	18.7	14.4	15.8
13 L	14.2	9.2	13.9	4.7	18.8	14.1	15.6
14	15.7	9.1	14.3	5.2	20.3	15.0	16.8
15	12.7	10.1	15.9	5.9	22.1	14.3	16.9
16	11.4	10.0	16.6	6.6	19.4	14.0	15.8
17 L	10.8	10.2	18.2	8.0	20.8	14.5	16.6
18	7.7	13.3	20.1	6.8	18.4	13.9	15.4
Means	15.9±.54 σ 3.41		17.2±.31 σ 1.92		20.3±.23 σ 1.42	16.5±.30 σ 1.94	17.8±.24 σ 1.51

a=1st crop, b=2nd crop, c=total=1st+2nd crops, for 1924.

* A spring frost in 1924 injured many of the first shoots. The first crop was consequently light. The loss was made up, at least in great part, by a second crop nearly half as large as the first. The second crop is borne on lateral shoots and main shoots which grow after the frost. It was negligible in 1923 and 1925 and was not weighed.

On the other hand, row 2 which produced 145 per cent of the average in 1923—the largest crop of the year—produced only 98 per cent in 1924.

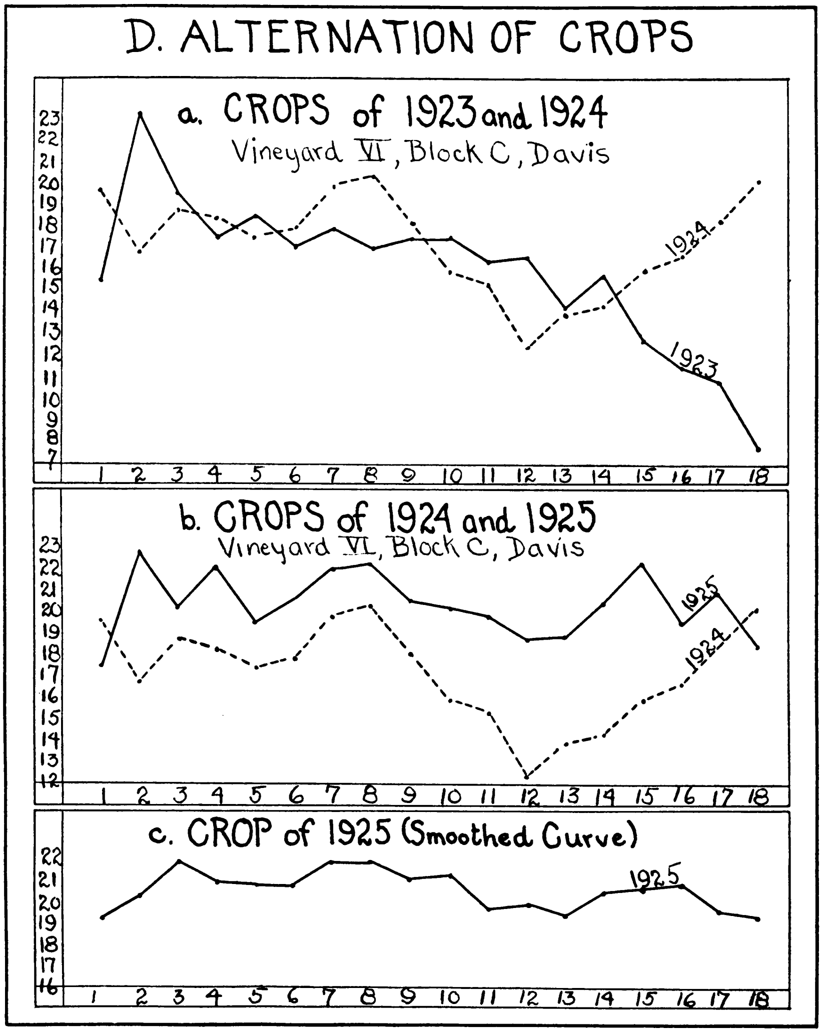

CHART D.—Alternation of Crops.

The case is not quite so clear with the intermediate rows, 3 to 14 inclusive, probably because the crops of these rows were nearer to the average, which may perhaps be considered the normal for the vines in these rows, where the alternation, due to over—or under—bearing, would be reduced to a minimum and thus be masked by the effects of other factors which influence the crop. The graph indicates, however, that the 107 per cent of the average produced in 1923 by rows 6–9 planted with vigorous vines was less than their normal and, consequently, that they produced more than their normal or 111 per cent of the average in 1924. The reverse seems to have been the case with rows 10–14 planted with less vigorous vines which produced more than their normal or 101 per cent of the average in 1923, and, consequently, less than their normal or 83 per cent of the average in 1924.

Chart D(b) showing the crops of 1924 and 1925 indicates that the alternation of crops had to a great extent been overcome in all the rows with full development of the vines and by differential* pruning. The differences of crop shown by the different rows in 1925 are probably due chiefly to variable factors which affect the vines irregularly, such as frost, and defects of pruning and irrigation. The continued deficiency of crop in the neighborhood of row 12 may indicate some constant unfavorable factor such as a less suitable soil. A defect of exposure or other factor of position may account for the deficiency in average crop shown by row 1 as compared with rows 2, 3 and 4, and of row 18 as compared with rows 15, 16 and 17.

Ultimate effect of vigor of rootings.—It has been shown (see chart A) that there was a high correlation between the quality (vigor and size) of the stock rootings when planted and the first full crop, at the end of the third season of growth.

Table II shows that the deficiency in the yield of the vines grown from small rootings, marked in the first crop, tends to disappear in the second and third crops. This is indicated by the gradual decrease in magnitude of the standard deviation of 3.41 for the first crop to 1.92 for the second and to 1.42 for the third. (See table II.) This is shown graphically by chart D(c) which indicates little or no variation of crop at the third harvest ascribable to the original quality of the rootings.

Correlation of yield of parent with yield of progeny.—The second and third crops have confirmed the evidence of the first that the yields of the parent vines have no perceptible influence on the yields of the progeny vines. This appears clearly in table III in which the three crops of the progeny of low-yielding parents and of the progeny of high-yielding parents are segregated and compared.

* Differential pruning is the means used in pruning to increase the crop on vigorous vines and thus utilize their possibilities, and to decrease the crop on weaker vines and thus renew their vigor. It consists in pruning more or less severely inversely as the vigor of the vine. See: Some Common Errors in Vine Pruning and Their Remedies. California Agr. Exp. Sta. Circ. 248:4, 5. 1922.

The vines of high-yielding parentage produced in the three years an average annual crop of .5 pounds to the vine (3 per cent) more than the vines of low-yielding parentage. This difference is not significant because the coefficient of variability of all the vines was 1.51 ÷ 17.8 or 8.48 per cent. (See table 2.)

If we compare the crops of the vines derived from the highest-yielding parents with those derived from the lowest-yielding parents, we obtain a result of similar magnitude, but in the opposite direction.

This is shown in table 4 which compares the average crops of the progeny of the 37 and 38 pound parent vines with the progeny of the 7, 8, 10 and 11 pound parent vines. The difference in this case is .3 pounds or 1.5 per cent in favor of the vines of low-yielding parentage.

Mutations of productivity.—It is plain that mass selection of parent vines for productivity has had no perceptible influence on the yields of the progeny vines. No significant difference was found between the average yields of 540 vines derived from 30–38 pound parents and the average yields of 172 vines derived from 7–15 pound parents.

It remains to inquire whether among these high- and low-yielding parents one or more may represent a mutation of productivity. For this purpose, table 5 has been prepared showing (1) the performance of the progeny of the highest- and lowest-yielding parents, and (2) the parentage of the highest- and lowest-yielding progeny.

An examination of table 5 shows under A that the progeny of the 6 most fruitful parent vines having average crops of 37 or 38 pounds varied in average crops from 25 pounds to 5.8 pounds, and under B that the progeny of the 5 least fruitful parent vines having average crops of from 7 pounds to 10 pounds varied in average crops from 23.7 pounds to 10.1 pounds.

TABLE III

Crops of Progeny of Low-Yielding and of High-Yielding Parentage. Average Yield in Pounds per Vine

	1923	1924	1925	3-year mean
Rows 1, 5, 9, 13, 17 (low-yield parents)	15.2	17.4	19.4	17.4
All other rows (high-yield parents)	16.2	17.1	20.6	17.9

TABLE IV

CROPS OF PROGENY COMPARED WITH CROPS OF PARENTS

Parent vines		Progeny vines				
Mean crops for 5 years		Mean crops for 3 years				
Vines*	Crop	Vines*	1923	1924	1925	Mean
Heavy bearers:						
46:12	38	2:1	16	22	25	21
46:12	38	6:1	16	17	24	19
46:12	38	10:1	11	17	22	17
46:12	38	14:1	12	9	22	14
46:12	38	18:2	7	9	12	9
43:18	38	2:2	24	17	30	24
43:18	38	6:2	19	32	23	25
43:18	38	10:2	15	21	18	18
43:18	38	14:2	20	12	25	19
37:19	38	2:3	20	22	32	25
37:19	38	10:3	12	15	16	14
37:12	38	6:3	21	12	28	20
46:15	37	2:4	26	19	23	23
46:15	37	6:4	13	12	35	20
49:17	37	2:5	27	23	26	25
49:17	37	6:5	13	29	17	20
49:17	37	10:4	13	22	23	19
49:17	37	14:3	12	14	20	15
49:17	37	18:3	0	8	10	6
45:21	37	2:6	21	23	28	24
45:21	37	6:6	19	32	24	25
45:21	37	10:5	11	31	21	21
Means	37.6		15.8±.90	19.0±1.04	22.9±.85	19.3±.73
			σ 6.25	σ 7.25	σ 5.93	σ 5.05
Light bearers:						
22:23	7	1:1	9	11	20	13
22:23	7	5:1	21	10	22	18
22:23	7	9:1	6	6	19	10
22:23	7	13:1	10	10	33	18
16:17	8	1:2	18	27	27	24
16:17	8	5:2	16	19	16	17
21:22	8	1:3	15	30	17	21
21:22	8	5:3	20	27	25	24
21:22	8	9:2	6	15	32	18
16:15	8	1:4	19	17	25	20
29:18	10	1:5	12	27	21	19
33:1	11	5:5	21	16	32	23
33:1	11	13:2	16	19	30	22
33:1	11	1:9	23	20	21	21
50:7	11	5:4	15	21	14	17
41:23	11	1:8	26	26	32	28
Means	9.4		15.8±.98	18.8±1.19	24.1±1.18	19.6±.63
			σ 5.81	σ 7.08	σ 6.10	σ 3.70

* The numbers give the position of the vines in the experiment vineyards.

Table 5 shows further under C that the parents of the 9 most fruitful progeny vines having crops from 29 pounds to 25.3 pounds varied in average crops from 35 pounds to 13 pounds, and under D that the parents of the 9 least fruitful progeny vines having crops of from 1.3 pounds to 7.7 pounds varied in average crops from 33 to 13 pounds.

TABLE V

COMPARISON OF INDIVIDUAL PROGENY YIELDS WITH CORRESPONDING PARENT YIELDS

A. *Yield of progeny of the heaviest yielding parents*

Yield of parents	38	38	38	37	37	37	
Yield of progeny	20.8	23.4	24.3	22.4	25.0	24.1	
	19.1	25.0	13.7	19.3	19.3	24.7	
	16.3	17.7	20.0		19.1	17.4	
	14.2	18.7			15.1		
		9.2			5.8		
Means	17.6	18.8	19.3	21.4	16.9	22.1	Mean 18.9

B. *Yield of progeny of the lightest yielding parents*

Yield of parents	7	8	8	8	10	
Yield of progeny	13.3	23.7	20.3	20.2	18.7	
	17.1	16.7	23.5			
	10.1		17.3			
	17.4					
Means	14.5	20.2	20.4	20.2	18.7	Mean 18.0

C. *Yield of parents of the heaviest yielding progeny*

Yield of progeny	29.0	28.0	28.0	27.7	27.3	27.0	25.7	25.7	25.3	Mean 27.1
Yield of parents	14.0	13.0	33.0	33.0	30.0	31.0	33.0	31.0	35.0	Mean 28.1

D. *Yield of parents of the lightest yielding progeny*

Yield of progeny	1.3	1.7	3.0	6.0	6.6	7.0	7.3	7.7	7.7	Mean 5.36
Yield of parents	13.0	31.0	30.0	33.0	33.0	30.0	30.0	14.0	32.0	Mean 27.3

None of the 6 most fruitful parent vines gave rise to any of the 9 most fruitful progeny vines (see tables 5A and C) and none of the 5 least fruitful parent vines gave rise to any of the 9 least fruitful progeny vines (see tables 5B and D).

It might be contended that the easiest place to detect a mutation of high productivity would be in the part of the vineyard where the average crops were lowest, though this would be to give up the whole case of the "pedigree bud selectors."

Chart E shows the parent vineyard at Kearney. The part of the vineyard from about row 13 to row 24 has many missing vines, and many with records of low yields. Only four of the vines with high records are found in this area. These are shown on the chart by two crosses and two stars.

Table 6 shows the records of the progeny of the three of these vines from which progeny were obtained, and for comparison the records of the progeny of the three parent vines with low records growing nearest to the three high-yielding parents.

TABLE VI

CROPS OF PROGENY OF HEAVY-BEARING PARENTS FROM POOR AREA

Parents: Vine	Parents: Crop *Pounds*	Progeny: Vine	Progeny: Crop *Pounds*	Means
20.6	30	16:14	13.7	
20.6	30	16:15	16.4	
20.6	30	13:5	11.6	13.9
20:8	35	10:23	17.9	
20:8	35	6:23	22.4	
20:8	35	2:23	25.4	21.9
21:8	33	7:13	18.3	18.3
Mean	32.7	Mean	18.0	

CROPS OF PROGENY OF LIGHT-BEARING NEIGHBORING VINES

Parents: Vine	Parents: Crop *Pounds*	Progeny: Vine	Progeny: Crop *Pounds*	Means
22:9	12	1:19	19.8	
22:9	12	5:15	15.7	
22:9	12	13:6	16.7	17.4
19:10	12	1:16	21.8	
19:10	12	5:12	20.2	
19:10	12	9:8	21.8	21.3
21:5	14	13:24	13.7	
21:5	14	17:12	15.7	
21:5	14	9:30	17.0	15.5
Mean	12.7	Mean	18.0	

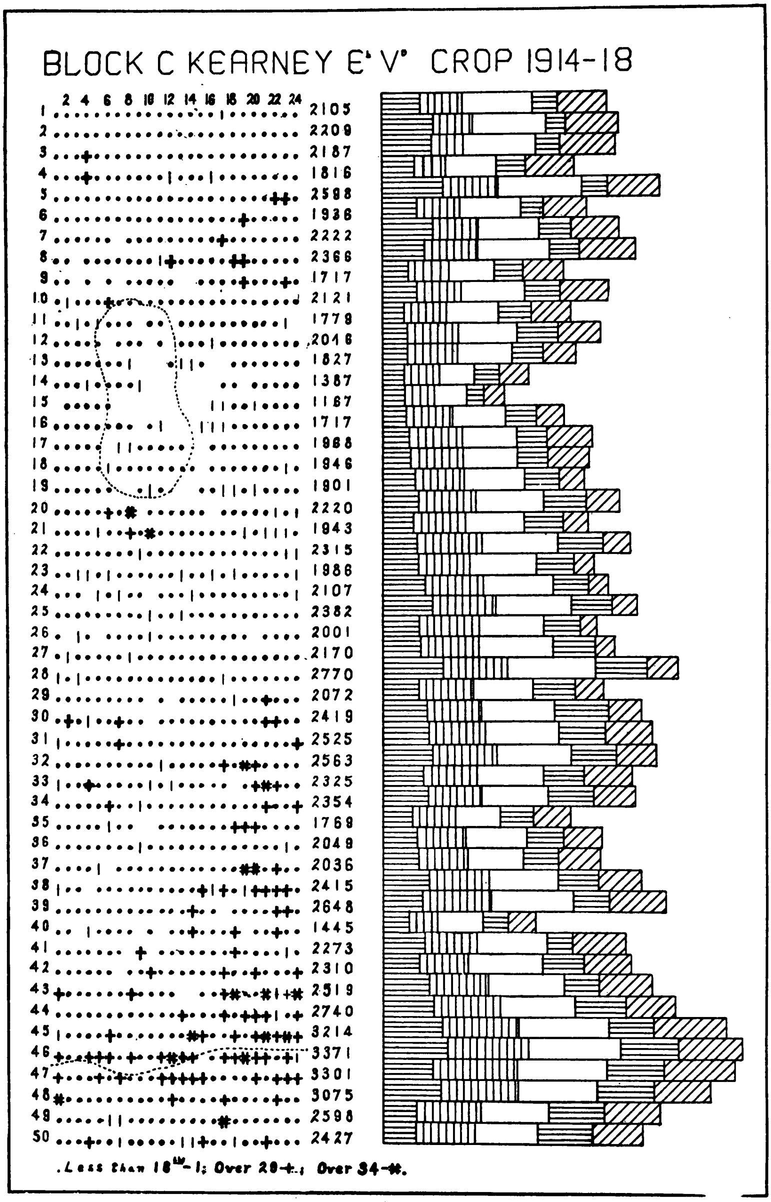

CHART E.—Parent vineyard at Kearney. The 5 crops are shown by variations of shading.

The high-yielding parents had records of 35, 33 and 30 pounds, the low-yielding parents 12, 12 and 14 pounds. The average yields of the progeny were 18 pounds in the case of the progeny of the high-yielding parents and the same—18 pounds—for the progeny of the low-yielding parents. The fact that the progeny of one of the high-yielding parents have the highest mean record—21.9 pounds—is offset by the fact that the progeny of another of the high-yielding parents have the lowest mean record—13.9 pounds. This record of 21.9 pounds is, moreover, considerably lower than the 28-pound record of the highest-yielding progeny which originated from an 11-pound parent. (See table 4.)

There is no evidence in this investigation, therefore, that the yield of the progeny vineyard would have been affected in the least weather the cuttings from which it was started had been taken from the heaviest-yielding vine in the parent vineyard or from the lightest.

SUMMARY

1. All commercial vineyards consist of clonal varieties propagated by buds.

2. It is the general belief of growers and of their advisers that a careful choice of "mother vines" on the basis of performance in the matters of yield, quality and other characters is necessary to maintain, and useful to improve, the fruitfulness and general utility of the variety.

3. It is generally recognized that the use as planting stock of a bud cutting or rooting which is well grown and well nourished gives the best results. Opinions differ as to whether vines from weak stocks which grow will finally equal vines grown from strong stocks.

4. To test the validity of these beliefs an investigation was started in 1910 at the Kearney experiment vineyard and continued at the Davis experiment vineyard until 1925.

5. An experiment plot of 1200 Muscat vines was planted at Kearney in 1911 with rootings grown from stock of unselected vines rooted in a nursery in 1910. This was called the "parent vineyard," and a record was kept of the yield of each vine during the 5 seasons of 1914–1918. (See chart E.)

6. In 1920, cuttings were taken from the 115 most productive vines in this parent vineyard and from the 86 least productive. The mean annual yield of the former was from 30 to 38 pounds and of the latter from 7 to 15 pounds. These cuttings were rooted in a nursery at Davis.

7. In 1921 an experiment plot of 627 vines was planted at Davis with the rootings obtained from the cuttings from the Kearney parent vineyard. This was called the ''progeny vineyard.''

8. Of the rootings of high-yielding parentage, 452 were planted in 4 groups of 3 rows each and 1 group of 1 row; and of the rootings of low-yielding parentage, 175 were planted in 5 groups of 1 row each, alternating with the groups of high-yielding parentage.

9. All rootings were carefully graded and arranged in planting according to quality, i.e., size and perfection of form. There was thus a continuous and gradual reduction in the quality of the rootings from one end of the plot to the other.

The arrangement was such that (*a*) the vines of highest-yielding parentage were contrasted directly with the vines of lowest-yielding parentage, and (*b*) the complication of vigorous vines growing near weak vines was avoided.

10. *Effect of quality of stock.*—

(*a*) The first crop of the vines from the strongest 25 per cent of the rootings was about 50 per cent larger than the first crop of the vines from the weakest 25 per cent. This difference was in great part reversed by the second crop and there was little difference in the third crop.

(*b*) The advantage of the strongest rootings was in reaching nearly full bearing the third season instead of the fourth as with the weaker rootings. The poorest rootings were all equal to what are usually considered No. 1 quality. With more imperfect rootings such as are very commonly planted, the difference would undoubtedly have been greater.

(*c*) The larger crop of the vines from vigorous rootings was accompanied by a larger diameter increase of the trunk.

11. *Effect of mass selection of parent vines.* No correlation was found between the crops of parent vines and the crops of progeny vines. Mass selection on the basis of yielding records had no perceptible effect. The average yields of vines derived from low-yielding parents were virtually equal to the average yields of vines derived from high-yielding parents and showed the same order of variability.

12. *Effect of individual selection of parent vines.* From the 6 highest-yielding parent vines were grown 22 progeny vines. Not one of the 9 highest-yielding progeny vines was among these 22.

From the 5 lowest-yielding parent vines were grown 11 progeny vines. Not one of the 9 lowest-yielding progeny vines was among these 11.

DISCUSSION AND CONCLUSIONS

The testimony of this investigation is that:

1. Exceptionally large and well formed vine rootings developed more quickly and produced a full crop one year sooner than ordinary good rootings.

2. The differences in bearing represented simply differences in rapidity of development and they almost disappeared with the third crop. With very inferior rootings they might never have disappeared, especially where rootings of various degrees of size and vigor were planted together. In such a case, the weak vines would be likely to be permanently inferior owing to competition with their more vigorous neighbors. This would bring about an irregularity of the vineyard which would probably persist and detract from its value. This is what occurs where missing vines are replaced in a vineyard even as early as the second year.

3 Mass selection of vine cuttings on the basis of the yields of the parent vines was of no value in improving or maintaining productivity.

4. The attempt to increase the bearing of a variety of vine by the selection of buds from a parent vine which has been distinguished by continuous and heavy bearing superior to that of the average or of any of the vines of the same variety but which shows no other distinguishing character is fruitless.

5. The attempts of nurserymen and others to preserve or to improve the productivity of clonal varieties of fruit trees by bud selection based exclusively on yield records of the parent plants would be wasted efforts if applied to vines. That it is of any use for this purpose for other fruit trees is doubtful.

OPPOSING EVIDENCE

The last two conclusions are opposed to the opinion of some investigators. Some hold directly contrary opinions, which, however, appear to be founded on a wrong interpretation of the evidence. Two of the most notable cases are those of Davis* who studied bud selection in apples, and those of Shamel who studied citrus fruits, especially oranges and lemons. Shamel** *et al.* in a recent account of an investi-

* DAVIS, M. B. The possibility of the transmission by asexual propagation of the high-yielding ability of individual apple trees. Scientific Agr. 2:120–124. 1921.

** SHAMEL, A. D., C. S. POMERY, and R. E. CARYL. Bud selection in the Washington Navel orange. Jour. Hered. 16:371–374. 1924.

gation of the results of bud selection of the Washington Navel orange states, "These results indicate that the quantity and quality of fruits produced by citrus trees are transmissible characters occurring as bud variations and as such are capable of perpetuation through budding." It is not quite clear what the authors mean by this statement. If their meaning is simply that the productivity of a clonal variety is transmissible to new plants propagated by buds, their statement is merely a truism. The whole practice of growing plants by vegetative multiplication is based on the well established belief that productivity in common with all other characters is a quality inherent in the bud and of the growth arising from this bud whether the growth is made in the form of a branch on the tree where it originated or in the form of another tree produced by budding, grafting or any method of propagation by vegetative segments.

If, on the other hand, they mean that all, or most, or many of the variations in yield of individual plants of a clonal variety are certain or even likely to appear in new plants propagated vegetatively from buds of these individuals, their opinion is ill-supported by the evidence they present.

If a Washington Navel orange gives rise to a branch of markedly different habit of growth with fruit of plainly different quality and yields inferior to those of the type, as in Shamel's experiment, it is an example simply of an ordinary and easily recognized "bud sport" or mutant. If these characters were not transmitted, it would be worthy of remark and require explanation. That they are transmitted does not render even probable that differences of yield unaccompanied by other appreciable differences would be transmitted in the same way. And yet this seems to be the only evidence submitted in support of the advice on which commercial bud selection associations have acted in keeping continuous and expensive records of individual trees for the purpose of improving the productivity of clonal varieties of orchard trees.

If the mutation is evident without yield records, they are unnecessary If the yield records are the only evidence of mutation, they are in the present state of our knowledge incompetent for the purpose. Yield records are not a means of detecting a mutation, but of testing the value of a mutation after it has been found by other means.

In Davis' experiments scions were taken from three Wealthy apple trees with mean annual yield records of 105, 79 and 41 gallons respectively. No other differences in the trees were noted except that the light-yielding tree was smaller and weaker than the others.

The scions were root grafted on Crab seedlings and planted in parallel rows—the row of low-yielding parentage between the other two rows. The results were:

1. Of the heavy bearers 24 per cent died, of the medium 18 per cent and of the light bearers 35 per cent.

2. The relative order of the progeny trees in regard to bearing was the same as that of the parent trees.

Yield records of the trees—

Actual differences:	Heaviest	Medium	Lightest
Parent trees—mean annual crop in gals.	105	79	41
Progeny trees—mean annual crop in gals.	57	48	35
Percentage differences:			
Parent trees—mean annual crop	100	75	39
Progeny trees—mean annual crop	100	84	61

Under the new conditions, the progeny of the heaviest-bearing tree have fallen off in yield 46 per cent, the progeny of the medium tree 39 per cent and the progeny of the lightest-bearing tree only 15 per cent. That the differences have not disappeared entirely may very plausibly be ascribed to the fact that the scions of the low-bearing tree were probably weak like the tree from which they were taken, as indicated by their greater death rate, and probably made less growth during the first two or three years than their more robust neighbors. The fact that the row of weak trees was planted between the rows of strong trees would tend to maintain their disadvantage in later years.

In the tests at Davis with Muscat, it required four years for fairly vigorous vines to overtake very vigorous vines growing under similar conditions. With apple trees which are slower in development and of less vigorous recuperative powers, it might require several years longer for a weak plant to overtake its stronger competitors. In the experiments described by Davis, it might never overtake them because of the difficulty of overcoming the handicap of a bad start in the proximity of its vigorous neighbors which would quickly take possession of more than their share of the soil and space available.

The evidence indicates that the higher yields of the progeny of the high-yielding parent trees was due to their higher initial vigor and that the difference tends to disappear. Davis' results are an argument in favor of vigorous propagation stock, but give little support to the theory that he was dealing with mutations of productivity.

These two cases of bud selection of fruit trees which are supposed to have resulted in the increased productivity of a clonal variety and which appear to have been conducted with an approach to the requirements of equal conditions and control checks are more probably to be explained in the one case as an ordinary bud mutation where, as usual, many characters varied and in the other as an example of delayed development, due to a start with ill-nourished stock and continued inferiority due to unfavorable conditions. In neither case is there any evidence of a bud mutation of productivity unaccompanied by any other difference or of the possibility of detecting such a mutation by crop records if it did exist.

The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.
3. The Formation of Sodium Carbonate in Soils, by Arthur B. Cummins and Walter P. Kelley. March, 1923.
4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.
7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.
8. Effect of Salts on the Intake of Inorganic Elements and on the Buffer System of the Plant, by D. R. Hoagland and J. C. Martin. July, 1923.
9. Experiments on the Reclamation of Alkali Soils by Leaching with Water and Gypsum, by P. L. Hibbard. August, 1923.
10. The Seasonal Variation of the Soil Moisture in a Walnut Grove in Relation to Hygroscopic Coefficient, by L. D. Batchelor and H. S. Reed. September, 1923.
11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.
12. The Effect of the Plant on the Reaction of the Culture Solution, by D. R. Hoagland. November, 1923.
13. Some Mutual Effects on Soil and Plant Induced by Added Solutes, by John S. Burd and J. C. Martin. December, 1923.
14. The Respiration of Potato Tubers in Relation to the Occurrence of Blackheart, by J. P. Bennett and E. T. Bartholomew. January, 1924.
15. Replaceable Bases in Soils, by Walter P. Kelley and S. Melvin Brown. February, 1924.
16. The Moisture Equivalent as Influenced by the Amount of Soil Used in its Determination, by F. J. Veihmeyer, O. W. Israelson and J. P. Conrad. September, 1924.
17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.
18. Factors Influencing the Rate of Germination of Seed of Asparagus officinalis, by H. A. Borthwick. March, 1925.
19. The Relation of the Subcutaneous Administration of Living Bacterium abortum to the Immunity and Carrier Problem of Bovine Infectious Abortion, by George H. Hart and Jacob Traum. April, 1925.
20. A Study of the Conductive Tissues in Shoots of the Bartlett Pear and the Relationship of Food Movement to Dominance of the Apical Buds, by Frank E. Gardner. April, 1925.