GRAPE BREEDING: SIZE, WEIGHT AND SPECIFIC GRAVITY OF THE SEED AS CORRELATED WITH GERMINATION AND VIGOR OF THE SEEDLING.

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The term plant breeding as commonly used signifies the growing of plants with the purpose of improving them. In the improvement of plants selection plays a very important part. When a tendency to vary in some desirable direction is discovered, or produced, the plant breeder proceeds to perpetuate and strengthen such tendency by selecting those individuals which shall be used for continuing the breed. Both the rate of progress and the ultimate degree of success in developing the wished for type depend to a very considerable degree upon the intelligence which is exercised in selections. They also depend upon the available opportunities for making selections. Intelligent selection must be based upon knowledge of the facts about plants and of the relation of those facts to the various activities of the plant. It requires also a knowledge of the peculiar characteristics and activities of that particular group of plants with which the breeding operations are being conducted.

Increasing the number of individuals which are brought under observation certainly tends to increase the opportunities for selection. The advantage of working with large numbers in breeding plants has come to be generally recognized. Generally speaking plant improvement has made the greatest progress and the differentiation of special characters has developed farthest with those kinds of plants which may be readily grown to maturity in large numbers. With some species, as for example certain florists' plants and garden vegetables, a single grower may bring to maturity in one season thousands or even hundred of thousands of plants of a kind. On the other hand with species which require two or more seasons to reach maturity, as for example with most of the pomaceous fruits, this cannot so readily be done. Especially in breeding such plants as these a comparatively great advantage is gained by beginning the selection at the earliest period possible. While it is generally impracticable for one to bring to maturity seedling apples, or peaches, or even grapes by the thousands and hundreds of thousands, breeding work may be carried on with greatly larger numbers of the seeds of such kinds of plants than of the seedlings and with greatly larger numbers of the seedlings than of the mature fruit bearing trees or vines. How is it possible to practice intelligent selection either with seeds or with young seedlings? What facts have been observed which help to guide one to an intelligent decision in such matters? To what extent do the popular notions about selection of seeds and seedlings have a sound basis in fact?

These are questions of practical importance which often arise and which are worthy of rigid investigation.

At the international plant breeding conference of 1902 in New York the writer presented the subject of correlation between different parts of the plant in form, size and other characteristics with reference to the significance which may attach to such correlation in plant breeding. Attention was called to observed correlations of these kinds, as, for example, between the color of the cane and of the fruit in certain raspberries; between the color of the root and of the flower in certain carnations; between the size of the leaf and of the fruit in certain peaches, gooseberries and grapes, and between the lobing of the leaf and the sex in certain grapes. The conclusion was that certain correspondences between different parts of the plant may often, if not always, be found and that a knowledge of this general principle and of the peculiar correlations in a given group of plants will greatly lessen the work of the plant breeder; also it will make possible a more rapid progress and a more certain outcome of the work.

In view of the foregoing considerations it has seemed desirable in our investigations concerning grape breeding to seek to learn whether any characters appear which are so correlated as to make it possible to begin intelligent selection not only with the young seedlings but even with the seed, and if there are such correlations in what characters and to what extent do they exist. These investigations have been carried on for several years at the New York Agricultural Experiment Station at Geneva. Much of the data has not yet been critically studied. This paper, which calls attention to some of the apparently important results is presented as a preliminary account of the work. Let us first examine some of the data concerning the selection of seed.

The Investigations Were With Seeds of Known Parentage.

It is important to observe at the outset that among variations which appear in seedlings those which arise from differences in parentage are by no means unimportant. Witness the fact that plant breeders resort to crossing to induce variation. But how often is this fact ignored by those who have engaged in investigations on seed selection! In much of the work on this subject which has been reported the workers appear to have had no particular knowledge of the plants which bore the seed that they used in their work; in the comparatively few cases in which the mother plant has been known how often do the workers appear to have had no knowledge whatever of the male parent! The importance of knowing both the female and male parent of the seeds used in investigating the principles of seed selection is readily shown. In the seed of a self fertile grape like Concord, the male and female parent may be united in the same parent vine but if the blossoms were open to

cross pollination there is no certainity that such is the case. In the seed of such a variety as the Black Eagle one may be sure that the male and the female parent are not identical since the Black Eagle is self sterile. The seeds produced by such a vine under natural conditions may represent many different varieties in the male parents. In certain of our experiments with grape seeds having the same mother plant but different male parents, decided differences have been seen between the groups of seedlings from the different lots of seeds. These differences, which are both taxonomic and physiological are so marked in certain cases as to characterize each group in distinction from other groups having the same female parent but different male parents.

In selecting seeds for the studies which are here reported particular pains have been taken to eliminate variations which might arise from differences in the parentage of the seeds under observation. In every case here reported both parents are known.

Methods of Grading the Seeds and the Seedlings.

In these experiments no attempt has yet been made to determine the exact volume of any of the seeds under observation. The shortest dimension has been determined by sifting the seeds with a series of sieves of german silver. The sieves were made by cutting rectangular holes in the sheet metal with steel punches. These holes were of uniform size for each sieve. They were long enough to permit the longest grape seed to pass through. The width varied from 2 mm. in the sieve having the narrowest slots by a constant difference of ½ mm. through the series up to 4½ mm. in the sieve having the largest slots. After the seeds were separated by sifting differences in volume could commonly be seen between individual seeds in each class. The grading was then usually carried one step further by separating the seeds by the eye into two grades. The one containing the smaller seeds was called grade "A"; that containing the larger seeds was called grade "B."

Each class thus obtained has been planted and given a distinct label in the seed bed. For each group the rate of germination has been recorded and observations have been made on the resulting seedlings as to the apparent vigor and size of the whole plant and the caliper of each plant at the collar. The rate of germination and the caliper have been determined accurately, but the vigor and size of the plant were necessarily rated by an estimate of their relative standing, with reference to these characters.

Correlation Between Size of Seed and Germination.

A comparison of the size of seed and rate of germination is seen in the case of some pure seeds of the 1901 crop of a vine of the variety called Canada. The classification by size and the rate of germination are shown in the following tabular statement.

TABLE I. Canada Seed. Size correlated with rate of germination.

Grade of Seed mm	No. of Seeds	Rate of Germination
> 2	0	0
2-2½A*	2	0
" B	1	0
2½-3A	71	1 to 18
" B	31	1 to 8
3-3½A	148	1 to 5
" B	59	1 to 4
3½-4A	11	1 to 2
" B	13	1 to 4
Total No. seeds	336	

* A designates the smaller grade, and B the larger.

In this case the rate of germination increases pretty uniformly with the increase in the size of the seeds. Such a tendency also appears in the case of some pure seed of a grape called Station 797 as shown in the following table.

TABLE II. Station 707 Seed. Size correlated with rate of germination

Grade of Seed mm.	No. of Seeds	Rate of Germination
2	1	0
2 to 2½ A	77	0
" B	29	0
2½ to 3 A	414	1 to 16
" B	172	1 to 21.5
3 to 3½ A	744	1 to 7
" B	424	1 to 6
3½ to 4 A	246	1 to 7
" B	198	1 to 5.5
4 to 4½ A	16	1 to 3
" B	10	0
Total No. seeds	2331	

But not in all cases has the rate of germination increased as uniformly as it has in the instances just cited. For example, in a lot of pure seed of a variety called "Station 818" the optimum size for germination is found in the medium sized seeds, as shown in the following table, while the larger seeds show a lower rate of germination.

TABLE III. Station 818 Seed. Size correlated with rate of germination.

Grade of Seed mm.	No. of Seeds.	Rate of Germination.
2	0	0
2 to 2½ A	4	0
" B	1	0
2½ to 3 A	85	1 to 3
" B	22	1 to 2
3 to 3½ A	158	1 to 3
B	54	1 to 8
3½ to 4 A	7	1 to 7
" B	5	1 to 2.5
4 to 4½	0	

Total No. of seeds 336

Some other cases were found which were similar to this but in general whenever approximately normal germination has been secured the rate of germination has shown a noticeable increase corresponding with the increase in the size of the seeds. The question then naturally arises whether there has also been a correspondence between the size of the seed and the size and vigor of the seedling grown from such seed?

Before examining the data bearing on this question it should be remarked that differences in environment may account for some of the differences between the individual seedlings as also may differences in the natural adaptability of the plant to its particular environment and also its ability to resist disease.

Correlation Between Size of Seed and Vigor of Seedling.

At the close of the first season the seedlings were dug and divided into a series of primary grades according to the caliper at the collar. The first or lowest grade included all those vines which calipered 2mm. or less, the other grades rising in succession with a uniform difference of 2 mm. between the successive grades. Each grade was further separated by the eye into two smaller classes in a manner corresponding to that already described for separating the seeds, one class called A including the smaller and the other called B including the larger vines. The rating of these classes may be fairly compared by assigning to each group A the lower number of millimeters and to the corresponding group B the larger number of millimeters which designate the primary grade divisions. Then assuming that the different vines are similar solids, and that they are to each other as to the cubes of their like dimensions a numerical rating may be made by which the vines may be readily compared as to size and vigor.

A statement of the rating of pure seedlings of the Pierce grape made in the manner above indicated is here given.

TABLE IV. Pierce. Size of seed correlated with size and vigor of seedling.

Seeds.		Vines.	
Grade by size mm.	av. wt. mg.	Number	Average rating at 1 yr.
2		0	0
2 to 2½		0	0
2½ to 3	23.3	0	0
3 to 3½	46.3	18	7.5
3½ to 4	55.6	31	16.3
4 to 4½	64.2	5	5.2

Many exhibits similar to the above might be taken from our records of other lots of grape seedlings. With no notable exception these show a like general correspondence between the size of the seed and the size and vigor of the seedling notwithstanding the fact that individual exceptions are found and that considerable differences in rating are seen not only between different vines from the same primary grade but even between those from the secondary grades of the seeds. The general tendency is for the rating of the vines to increase with the increase in the size of the seed from which they spring, till the maximum is reached with the vines from the large seeds, then it declines with the vines from the largest seeds. In this particular the Pierce seedlings show no exception to the general results. **It appears from this, contrary to the popular idea, that the maximum size with seeds does not give the optimum for seedlings so far as the size and vigor of the resulting seedlings are concerned.** It would be indeed interesting to know how far this holds true for seeds in general.

We have seen that there is a general correspondence between the size of the seed and the size and vigor of the seedling. Observations made with vines at 2 years and again at 4 years show that this general tendency persists throughout these periods. No observations on this point have been made with vines more than 4 years old.

Before passing to the consideration of correspondences between the charactrs of the seedling and physical characters of the seed other than size your attention is called to a brief statement of correspondences between the rate of germination of grape seed and the size of the fruit in which that seed is produced.

Correlation Between Size of Fruit and Both the Size and Weight of the Seed and the Germination and Vigor of the Resulting Seedlings.

Muller Thurgau in 1892 called attention to the fact that in general the size of the grape berry bears a direct relation to the

number of seeds contained, seedless berries being smaller than one seeded berries and with the increase in the number of seeds there is a corresponding increase in the size of the fruit. [1] Stewart who discovered this independently finds that the increase in the number of seeds contained does not always proceed uniformly with the increase in the size of the fruit[2] but that it does proceed more uniformly with some varieties than with others.

In a considerable number of cases I graded on the basis of size the grape berries of one or more clusters of fruit containing seeds of known parentage and planted the seeds from each grade separately. Contrary to expectation, there was sometimes a distinct advance both in the rate of germination and in the rating at the end of the season of the resulting seedlings, corresponding with the increase in the size of the fruit. Before being planted the seeds had been graded by sifting in the manner already described and the average weight determined for each class. Upon examining these data it was found that in some cases as the size of the fruit increases there is a corresponding increase in the percentages of seeds of larger size with a corresponding increase also in average weight. This is well illustrated in the following tabular statement of the grading of fruit and seeds of a variety called the Canada. The berries were graded into three classes. The class containing the smallest berries is designated X and those of succeeding grades XX and XXX respectively. The grade containing the smallest seeds is designated 1 and the succeeding grades in order 2, 3, 4 and 5 respectively. The table shows for each class of fruit the number of seeds under observation in each grade, also the percentage and the average weight.

TABLE V. Size of berry and size and weight of seed correlated in the variety Canada.

	X Fruit.			XX Fruit.			XXX Fruit.		
Grade of Seeds. mm.	No. Seeds.	per ct.	av wt.	No. Seeds.	per ct.	av. wt.	No. Seeds.	per ct.	av. wt.
2	0			0			0		
2 to 2½	3	4.5	12	0			2	4.6	15
2½ to 3	36	54.6	19	57	25	27.5	8	18.2	28
3 to 3½	26	39.3	31	153	67	35.7	28	65.2	40
3½ to 4	1	1.5	37	18	7.8	45.5	5	11.2	50
4 to 4½	0			0			0		

[1] Einfluss der Kerus etc., Jahrb. deuts. Vers. und Schule Obst-Weis und Gart. 1892.

[2] Proc. West. N. Y. Hort. Socy 1902:44.

The following table gives the ratio of germination of the seeds the first season after planting and the average rating at the close of the season for the resulting seedlings.

TABLE VI. Ratio of germination and rating of seedling vines of Canada.

Fruit. Class.	Seeds. Ratio of Germination.	Seedling Vines Rating.
X	1 : 8	14.3
XX	1 : 5	16.7
XXX	1 : 5.5	19.2

But in other cases these correlations were more obscure. Further observations are needed along this line, but enough has been discovered to show that the size of the fruit is at least in some cases correlated with the weight and size of the seed and also with the size and vigor of the resulting seedling.

Correlation Between Weight of Seed and Both the Germination and the Size and Vigor of the Seedling.

There is a general advance in the weight of the seeds as the size increases but it is far from being uniform. By weighing the individual seeds remarkable exceptions to the general tendency are found. By comparing the different grades of Pierce seeds with reference to the average weight of the seeds in each grade as shown in the following table, it is seen that there is here a general, although not a uniform correspondence between the size and the weight of the seeds. It appears more uniform when the primary grades are compared without separating them into classes A and B; also it appears more uniform when either the A classes or the B classes only are taken into the comparison.

TABLE VII. Pierce seeds.

Grade of seeds mm.	av. wt. mg.	No. of seeds.
2		0
2 to 2½		0
2½ to 3	23.3	9
3 to 3½	46.3	106
3½ to 4	55.6	170
4 to 4½	64.2	27

There is found however a general correspondence between the weight of the seed and the size of the seedling, as shown in table IV.

The case of pure seeds of Empire State, breeding record 10263, table VIII, will serve to illustrate the degree of correspondence that may be found between the weight of the seed and the rate of germination. A general tendency for that rate to increase with increase in weight of the seed is evident but striking exceptions appear. In such cases the specific gravity is abnormal as will be seen later.

Correlation Between the Specific Gravity of the Seed and Both the Germination of the Seed and the Vigor and Size of the Seedling.

Because the size of the individual grape seed bears no constant relation to its weight, Mr. V. A. Clark, my collaborator in a portion of this work, suggested the idea of supplementing the observations relating to the size and weight of seeds with others relating to their specific gravity. Accordingly, with Mr. Clark's assistance, this was undertaken.

It was then found that the correspondence between the weight and the specific gravity of the grape seed is generally close but not uniform nor constant. A good illustration of this is found in the case of some pure Empire State seeds as presented in the following table, from which it appears that the seeds which have the higher weights may in practical work be found by taking those seeds which come within the higher grades of specific gravity although the maximum is reached in weight before it is in specific gravity. The tendency for the specific gravity to increase with the increase in the size of the seeds in general has been pointed out by Schertler.[3]

TABLE VIII. Empire State seeds. Correspondence in weight and specific gravity.

Grade of Seeds IVa. Diameter 3 to 3½ mm.

Specific Gravity	Seeds		Germinations		Vines at close of season	
	No.	av. wt. mg.	No.	Ratio.	No.	avg. rating
> 1	122	15.7	0	0	0	
1 to 1.020	0		0	0	0	
1.021 to 1.030	3	31.8	0	0	0	
1.031 to 1.040	3	34	0	0	0	
1.041 to 1.050	7	35.1	1	1 : 7	0	
1.051 to 1.060	17	35.5	2	1 : 8.5	0	
1.061 to 1.070	42	36.3	4	1 : 10.5	3	12.5
1.071 to 1.080	70	37.4	9	1 : 7.7	3	16.5
1.081 to 1.090	91	38.2	14	1 : 6.5	6	24.8
1.091 to 1.100	52	36.2	5	1 : 10.4	2	7
1.101 to 1.105	3	33	0	0	0	

3 The Application of Specific Gravity, etc. Cited by Wollny. Saat und Pflege, etc,: 246.

In this table the record of germination is also shown. No germination occurred with seeds of less specific gravity than 1.045 and only weak germinations below 1.065. This record of germination is probably incomplete because it covers only the first season after the seeds were planted. It is well known that in many cases grape seeds do not germinate for more than a year after being planted. So far as this record goes there is not in this case a uniform increase in the rate of germination corresponding with the increase in the specific gravity of the seeds. In general, however, whenever a fairly normal rate of germination has been obtained there has appeared not only a definite increase in germination corresponding in general with the increase in the size of the seed, as has already been pointed out, but also taking seeds of the same grade as to size, as in table IX, the increase of germination has corresponded in general with the increase in the specific gravity of the seed except that the maximum rate of germination often appears somewhat before the maximum specific gravity is reached.

Even in the case of the abeyant Empire State given in table VIII with the few seedling vines which were obtained there is seen a general tendency for the rating to increase with the increase in specific gravity until the optimum is reached. The increase of the rating of seedlings corresponding with the increase in the size of the seed has already been pointed out. See table IV.

It is interesting to observe that germination extends into much lower grades of specific gravity with large seeds than with small seeds and also that the rate of germination with seeds of the same specific gravity increases pretty uniformly with the increase in the size of the seed. A good illustration of this is seen in the records of pure Canada grape seeds from medium sized berries exhibited in table IX. The seeds were first graded according to their shortest diameters in millimeters by sifting. Then each grade was subdivided into separates according to specific gravity. The table shows the number of seeds in each separate and the per cent. of germination the first season after planting.