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MASTER'S
THESIS

Relation Between Size
And Yield of Seed

Dick J. Crosby.
1901

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RELATION BETWEEN SIZE OF SEED AND YIELD

BY

DICK J. *2/8* CROSBY

M.S. 1901

· THESIS

RELATION BETWEEN SIZE OF SEED AND YIELD.

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In actual farm practice is there any relation between the size of seed sown and the resulting yield of grain? Other things being equal, will the farmer who makes a practice of grading his seed oats, beans, peas, and corn, and of sowing only the largest and plumpest kernels, reap correspondingly large crops, or will his neighbor who sows "from the machine" stand an equally good show in the coming harvest? It was to help in answering this question that the series of experiments to be reported in this paper was begun in the spring of 1900. Before fully maturing the plans for his experiments, the writer examined the literature of experiment stations to learn what had been contributed to the subject by others. He found that nearly all phases of the problem had been touched upon, that much of the work had been carefully executed, and that the various experimenters had attempted solutions of the problem from many different points of view. It may be well at this point to state briefly what some of the experimenters have accomplished along this line.

Results Obtained by Others.

Elaborate greenhouse experiments with large and small seed of radishes, conducted in 1895 by B. T. Galloway, chief of the Bureau of Plant Industry, U. S. Department of Agriculture (Agr. Sci., 8 (1895), No. 12, pp. 557-567), gave results showing that the large seed germinated more quickly and certainly and produced marketable plants sooner and more uniformly than the small seed.

Carefully conducted pot experiments by Gilbert H. Hicks and John C. Dabney (U. S. Dept. Agr. Yearbook 1896, pp. 303-322) with heavy and light seed of garden peas, beans,

soja beans, hairy vetch, rye, barley, wheat, and oats showed marked results in favor of heavy seed. This advantage of the heavy seed was noticed in size of plants, number of leaves, earliness of maturity, and amount and quality of product.

At the Maine Agricultural Experiment Station (Maine Sta. Rpt. 1894, pp. 158-160) three series of experiments with large and small radish seed were conducted. The difference in favor of large seed was very marked and the writer concluded: "It is evident that plants from large seed grow larger and mature earlier than those from small seed."

R. Heinrich (Second Report of the Agricultural Experiment Station, Rostock, Germany, 1894, p. 141) found that increased production followed the use of larger seed for seed-ing.

C. A. Zavitz (Ontario Agr. Col. and Expt. Farm Rpt., 1896) grew wheat, oats, and barley for four years from large plump, small plump, shrunken, and cracked grains. The largest yields and largest kernels were obtained from the large plump seed.

W. C. Latta (Indiana Sta. Bul. 32, July, 1890) classed wheat that passed through the seed screen of a fanning mill as small; that which did not pass through, as large. Tabulated data of experiments in 1888 and 1889 show results slightly in favor of the use of large seed.

At the Agricultural Experiment Station, Grignon, France, F. Desprez (Ann. Agron., 21 (1895), No. 12, pp. 545-565) experimented for a number of years with large and small grains of wheat. He selected the largest and the smallest grains of five varieties and sowed them separately. From the grain produced, the largest kernels from the large seed were sown, the smallest kernels from the small seed, and so on. The tabulated results for three years, 1893-1895, show a large increase in yield from sowing large kernels. The experiments were continued and two years later Desprez announced (Jour. Agr. Prat., 2 (1897), No. 37, pp. 416-420) that the results were in favor of the

large seed in every case except two, in which more straw was produced from the small seed.

At the Kansas Station (Bul. 13, August, 1890), light, common, and heavy oats, weighing respectively 19, 28, and 32 pounds per bushel were sown at the rate of $2\frac{1}{2}$ measured bushels per acre on one-twentieth-acre plats and gave an average yield per acre of 21.5 bushels for the light, 24 bushels for the common, and 30 bushels for the heavy. The experiment was repeated in 1890 (Bul. 29, December, 1891) with very different results, the light seed yielding 50.63 bushels, the common, 45.27 bushels, and the heavy, 46.44 bushels. However, at the end of eight years, average results were announced (Bul. 74, pp. 120, 121) as follows: Yield per acre from light seed, 27.5 bushels; from common seed, 28.89 bushels; from heavy seed, 30.9 bushels.

Dr. E. Wollny, director of the Laboratory for Agricultural Physics and Physiology at Munich, Germany, has shown that in the case of winter wheat not only was the yield from large seed greater than that from small seed but also the seedlings from large kernels were better able to withstand the rigors of a cold winter.

F. W. Burbidge in his "Propagation and Improvement of Cultivated Plants" quotes at length from the experiments with large and small seed of peas and beans conducted by Dr. Gustav Marck at the Halle and Leipsic experiment stations, and shows that in every instance the yield from large seed was greater than that from small seed. He also refers to the work of Prof. F. Lehmann, now director of the Agricultural Experiment Station at Göttingen, with peas and beans, and to that of Stephen Wilson with turnip seeds, in which similar results were obtained.

Examples might be multiplied, but enough have been given to show the unmistakable trend of results toward yields varying directly with the weight of kernels sown. Negative results and neutral results are not lacking, it is true, but in every case of this

kind known to the writer they were the result of single experiments or of a series of experiments extending over one year only. In no case was it found that carefully conducted experiments extending over a series of years failed to show larger average yields from large kernels than from small kernels.

With these results as a basis, plans were begun for a series of experiments that should follow the same general lines pursued by others and yet not exactly duplicate the conditions under which they had conducted their experiments.

Two conditions were considered desirable: First, that the experiments be conducted out of doors on plats where field conditions could be approached as nearly as possible; secondly, that, aside from the difference in the size (weight) of kernels sown, all conditions found in one plat be similar to those in every other plat in the experiment; for example, that the soil be homogeneous, the number of seeds sown be such that equal numbers would germinate in each plat, and the light be the same for each plat.

It was not an easy matter to find on the College farm unoccupied land that was both level and homogeneous. Finally, however, a small area at the west end of No. 6, which had been used the previous year for variety tests of sugar beets, was selected as land most likely to be free from differences arising from the presence of unassimilated commercial fertilizers. Unfortunately the ground was not level, a condition that would not have made much difference in an ordinary season, but the season of 1900 was remarkable for the heavy rainfall, and portions of the experiments were destroyed by standing water. The method of laying out the plats and of locating check plats is shown in the following diagram:

Plan of Experiments.

3. Small oats.	4. Ungraded oats.		9. Small corn.	10. Ungraded corn.		15. Small beans.	16. Ungraded beans.
2. Ungraded oats.	5. Large oats.		8. Ungraded corn.	11. Large corn.		14. Ungraded beans.	17. Large beans.
1. Large oats.	6. Small oats.		7. Large corn.	12. Small corn.		13. Large beans.	18. Small beans.

Each large plat was made 20 feet square so that before harvesting the crops a strip 20 inches wide could be cut from each side and leave the plat one rod square. Furthermore, strips 3 feet wide were left unsown between each two sets of plats. These strips were kept clear of weeds, as was also a similar strip around the outside of the whole series of plats. The small plats between oats and corn were 5 feet square and were planted under conditions identical with those in the large plats, so that from them measurements and other observations might be taken from time to time without disturbing the real experiments.

The crops selected for trial were oats, peas, beans, and corn: Oats, because the Kansas experiments with oats were conducted without reference to the number of kernels sown, but rather with reference to the weight of measured bushels; peas, beans, and corn, because but little work of the kind had been done with these crops. A few experiments with butt, middle, and tip kernels of corn had been conducted, but apparently no attention had been paid to the size of kernels, and even if the butt

kernels were largest and the tip kernels smallest, as was probably the case, another element, that of deformed and immature kernels, entered into the problem. Unfortunately for the present series of experiments, the record of yields for peas was accidentally destroyed and results can be given only for oats, corn, and beans.

Large, Ungraded, and Small Kernels of Oats.

The seed selected was from American Banner oats grown on the College farm. These were first run through a fanning mill over a fine screen to remove grass and weed seed, chaff, and oat hulls, after which a portion was set aside for the ungraded seed. The remainder was then put through the mill again and graded into large and small seed. From each lot 200 kernels were counted out, weighed, and tested for germination with the following results:

Germination of Oats.

Kind of seed.	Number of kernels.	Weight reduced to ounces.	Number of kernels germinated.	Per cent of germination.
Large.....	200	0.2081	199	99.5
Ungraded.....	200	.1827	197	98.5
Small.....	200	.1058	190	95.

The oats were sown in drills 8 inches apart at the rate of 64 pounds per acre of large, perfect seed. That is to say, if all the large seed had germinated, 64 pounds per acre, or 9.4 ounces per 400 square feet, would have been sown, but as only 99.5 per cent germinated, 9.45 ounces ($\frac{9.4}{.995}$) were sown. Similar corrections were made for

the ungraded seed and for the small seed. Moreover, corrections were made for the size of seed. The ungraded seed weighed less per kernel than the large seed, likewise the small seed less than the ungraded seed; hence less by weight of ungraded seed and still less of small seed had to be sown in order that each plat should contain approximately the same number of kernels. In both cases the amount of seed sown, after correcting for germination, was determined by computations based on the size of kernels as shown in the above table. Three of the plats were sown May 4 and three May 5. Those sown first began to appear above the ground May 12 and the others on the following day, there being no appreciable difference on account of size of seed. As soon, however, as the plats began to look green, a great difference was apparent, the plats sown to large seed showing much taller and stronger plants. On May 16 measurements were begun in the small plats, the results of which are shown in the following table. Ten plants in each plat were measured and the average height is given in inches.

Growth of Oats in Small Plats.

	Large seed.		Ungraded seed.		Small seed.		Notes taken at the time.
	Height	Gain	Height	Gain	Height	Gain	
May 16	2.35	----	2.2	----	1.90	----	Showery and cool since yesterday Cool weather since May 18. Heavy warm rain May 28.
17	2.77	0.42	2.62	0.42	2.23	0.33	
18	2.95	.18	2.82	0.20	2.36	.13	
23	3.53	.58	3.26	0.44	2.91	.55	
28	5.17	1.64	5.16	1.90	4.66	1.75	
June 2	7.97	2.80	8.09	2.93	7.07	2.41	The plat containing oats from large seed has been covered with standing water several times and the oats are almost at a standstill, hence the measurements are discontinued.
7	11.06	3.09	11.40	3.31	10.20	3.10	

Of the large plats, No. 6, containing oats from small seed, lay adjacent to the small plat containing oats from large seed, and the heavy rains of late May and early June kept a part of it (8 feet, 8 inches by 8 feet, 4 inches) under water so long that the oats nearly stopped growing. At harvest time this drowned area was removed and correction made. The oats were harvested July 20, stored, threshed by flail, run through a fanning mill, and weighed. The results in the following table are given in pounds unless otherwise stated.

Yields from Large, Ungraded, and Small Oats.

Number of plat.	Weight of oats sown.	Yield of grain.			Yield of straw.			Total yield.		
		Large	Ungr'd	Small	Large	Ungr'd	Small	Large	Ungr'd	Small
	Oz.									
1	9.45	6.69	----	----	14.31	-----	-----	21.00	-----	-----
2	8.35	----	5.62	----	-----	10.87	-----	-----	16.50	-----
3	5.03	----	----	4.00	-----	-----	10.00	-----	-----	14.00
4	8.35	----	5.19	----	-----	11.31	-----	-----	16.50	-----
5	9.45	7.28	----	----	10.97	-----	-----	18.25	-----	-----
6	5.03	----	----	7.06	-----	-----	13.68	-----	-----	20.74
Average per square rod..		6.98	5.40	5.53	12.64	11.10	11.84	19.62	16.5	15.56
Average per acre.....		1117.50	865.00	885.00	2022.50	1775.00	1894.00	3140.00	2640.00	2779.00
Gain or loss with ungraded oats.as.unit.		+252.50	-----	+20.00	+247.50	-----	-170.00	+500.00	-----	-150.00
Maximum gain or loss.....		+232.50	-----		+417.50	-----	-----	+650.00	-----	-----
Average bushels per acre.....		34.92	27.03	27.65	-----	-----	-----	-----	-----	-----

In every instance the yield of grain from large seed was greater than that from ungraded seed and also greater than that from small seed, although in no case was the difference very marked. The same was not true of the yield of straw, and yet even here

the averages show greater production from large seed than from small seed. The maximum gain of grain per acre for large seed was 232.5 pounds or 7.27 bushels.

Large, Ungraded, and Small Beans.

White field beans were used and the grading was done by hand after enough had been set aside for ungraded seed. The beans were tested for germination merely as a precautionary measure, because supposedly enough were planted to permit a certain amount of thinning after they had made a good start. As a matter of fact, however, the hailstorm of June 6 and the cutworms of subsequent dates wrought such havoc that on the 11th of June, twelve days after the first planting, it was thought best to re-plant wherever there were less than three plants in the hill. This planting was successful and after a few days the hills were thinned to three stalks each. The beans were planted 16 inches apart in rows 40 inches apart, four beans to the hill. At no time during the season was there such a difference in the plats from different grades of seeds as would be noticed by the casual observer, but careful observations taken on the small plats planted for the purpose showed that there was a marked difference. Beginning with the appearance of the first blossoms, for a little over two weeks the blossoms (and pods as soon as they developed) were counted almost daily. The following table shows how marked was the difference.

Blossoms and Pods of Beans from Large,
Ungraded, and Small Seed.

Date.	Blossoms.			Pods.		
	Small	Ungraded	Large	Small	Ungraded	Large.
July 9	---	5	5	---	---	---
10.....	1	6	12	---	---	5
11.....	4	6	21	1	3	7
12.....	11	16	35	5	14	14
13.....	15	24	47	10	19	27
14.....	17	28	56	18	21	34
16.....	42	55	97	63	64	99
17.....	71	86	131	95	103	149
18.....	75	107	160	103	115	153
19.....	77	119	160	141	164	191
21.....	104	150	193	154	176	203
22.....	135	212	268	195	202	255
23.....	156	227	279	203	221	274
25.....	---	---	---	220	341	411

Yield of Beans from Small Plats.

	Beans.	Straw.	Total.
	Oz.	Oz.	Oz.
Large.....	14.5	11.5	26.0
Ungraded.....	10.5	10.5	21.0
Small.....	7.0	6.5	13.5

The beans on the large plats were harvested in the usual manner, weighed, threshed in a small sample-thresher, cleaned in a fanning mill, and the grain weighed. All that was not grain is called "straw" in the following table, which gives all yields in pounds unless otherwise indicated.

Yields from Large, Ungraded, and Small Beans.

Number of plat.	Weight of beans planted	Yield of beans.			Yield of straw.			Total yield.		
		Large	Ungr'd	Small	Large	Ungr'd	Small	Large	Ungr'd	Small
	Oz.									
13	3.175	6.56	----	----	7.69	-----	----	14.25	-----	-----
14	2.660	----	5.31	----	----	7.44	----	----	12.75	----
15	1.979	----	----	5.19	----	----	7.81	----	----	13.00
16	2.698	----	5.37	----	----	12.12	----	----	17.50	----
17	3.185	7.25	----	----	9.25	-----	----	16.50	-----	----
18	1.884	----	----	5.25	----	----	9.25	-----	----	14.50
Average per square rod.....		6.90	5.34	5.22	8.47	9.78	8.53	15.37	15.12	13.75
Average per acre.....		1105.00	855.00	835.00	1355.00	1565.00	1365.00	2460.00	2420.00	2200.00
Gain or loss with ungraded beans as unit.....		+250.00	-----	-20.00	-210.00	-----	-200.00	+40.00	-----	-220.00
Maximum gain or loss.....		+270.00	-----		-10.00	-----	-----	+260.00	-----	-----
Average bushel per acre.....		18.40	14.25	13.90	-----	-----	-----	-----	-----	-----

In this, as with the experiment with oats, the results were positive in the yield of grain and in the total yield but irregular in the yield of straw. The maximum gain was 270 pounds or $4\frac{1}{2}$ bushels per acre.

Weight per Kernel of the Product.

From the product of each plat of beans and each plat of oats a small sample was taken, and from each sample 1,000 kernels were counted out, weighed, and the average weights of the 2,000 kernels thus taken at random were computed.

Following are the average weights per kernel:

Beans:	From large seed,	3.395 grains
	From ungraded seed,	3.297 grains
	From small seed,	3.256 grains
Oats:	From large seed,	.396 grains
	From ungraded seed,	.394 grains
	From small seed,	.351 grains

From these figures it appears that the largest kernels, as well as the largest yields, were produced from the largest seed. The difference is not great but, coming as a positive support to the results previously given, it is significant.

Large, Ungraded, and Small Kernels of Corn.

Seed corn of a yellow dent variety was secured from the farm of Prof. H. W. Mumford. In selecting kernels for planting, all deformed butt and tip kernels were discarded, then several rows out of each ear were shelled for the ungraded seed, and from the remaining rows were selected the largest and the smallest kernels. The corn was planted May 23 in hills 40 inches apart each way, four kernels to the hill. It came up evenly from May 31 to June 2, and a few days later was thinned to three plants per hill. At no time during the season was there any apparent difference in size, time of blossoming, number of ears per stalk, or time of ripening that could be assigned to difference in the size of the seed planted. When ripe it was cut, cured in the field, hauled to the barn, weighed by plat, husked, and the corn in the ear weighed. In the table of results which follows, the yields are given in pounds unless otherwise indicated. Bushels were computed at 75 pounds of unseasoned corn in the ear.

Yields from Large, Ungraded, and Small Kernels of Corn.

Number of plat.	Weight of corn planted	Yield of corn.			Yield of fodder.			Total yield.		
		Large	Ungr'd	Small	Large	Ungr'd	Small	Large	Ungr'd	Small
	Oz.									
7	1.75	23.25	-----	-----	22.25	-----	-----	45.50	-----	-----
8	1.62	-----	20.00	-----	-----	19.75	-----	-----	39.75	-----
9	1.45	-----	-----	17.75	-----	-----	26.50	-----	-----	44.25
10	1.56	-----	22.00	-----	-----	25.75	-----	-----	47.75	-----
11	1.76	22.00	-----	-----	16.00	-----	-----	38.00	-----	-----
12	1.44	-----	-----	22.25	-----	-----	20.00	-----	-----	42.25
Average per square rod...		22.62	21.00	20.00	19.13	22.75	23.25	41.75	43.75	43.25
Average per acre.....		3620.00	3360.00	3200.00	3060.00	3660.00	3720.00	6680.00	7020.00	6920.00
Gain or loss with ungraded corn as a unit		+260.00	-----	-160.00	-600.00	-----	+60.00	-340.00	-----	-100.00
Maximum gain or loss.....		+420.00	-----	-----	-660.00	-----	-----	-240.00	-----	-----
Average bushels per acre.....		48.27	44.80	42.67	-----	-----	-----	-----	-----	-----

This was the least satisfactory experiment of the series. So far as the yields of corn are concerned the results are mostly positive and the maximum gain of nearly 6 bushels per acre should not be disregarded, but in the yield of fodder and in the total yield the results are reversed. It is not so very surprising that there should be marked variations from the hitherto fairly uniform results, when we take into consideration the fact that the removal of butt and tip kernels from the seed ears left kernels that did not differ much in size, the maximum difference being 0.32 ounces for 144 kernels, or only about two thousandths of an ounce per kernel.

Conclusion.

We come now to a consideration of the results of this series of experiments and of the relation of these results to those obtained by others. In the production of grain the three experiments show the heaviest yields for the largest seed and, with one exception, the lightest yields for the smallest seed; in the production of straw and fodder results vary too much for the drawing of any very definite conclusions. Standing alone the results would have but little significance; the experiments would have to be repeated many times and would have to show a persistent tendency toward variation in some one direction before we would be justified in saying that any result obtained was due to difference in size of seed sown. But with the evidence of many careful experimenters to support our theory and, as in the present instance, with conditions fairly well controlled and none of the variations pointing to other causes than the size of seed sown, we are fairly safe in concluding that variation when it occurs in the amount of grain produced, has a tendency to bear a direct relation to the size of seed sown. In other words, the farmer who makes a practice of selecting the largest and best seed for sowing is much more apt to reap a plentiful harvest than he who selects the smallest seed or makes no selection. True, the difference is small, only a bushel or two per acre, and it may be thought that the trouble is more than the grain is worth, but a bushel or two frequently makes all the difference between profit and loss. The seven bushels of oats gained in this series of experiments would have paid the cost of harvesting and threshing the crop; the four and one-half bushels of beans would have marketed the whole acre of beans; and the six bushels of corn would have put an acre of corn in the crib. An increase of one bushel per acre in the oat crop of the United States for 1891 would have meant a gain to the farmers of 25,500,000 bushels or over \$6,000,000; a similar increase in the corn crop would have meant

\$15,250,000 more to help carry the people of the corn districts over the hard times of 1893 and subsequent years; and a bushel an acre more of wheat would have furnished two extra bushels for each man, woman, and child in the United States. We hear much of the need of improved methods of farming. Here is one place for a beginning. If selection of large, perfect grain for seed will result in ever so small an increase in yield, it is worth trying.

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