Inheritance of Size and Shape in Beans

THESIS FOR DEGREE OF M. S.

PAUL KWONG FU.

1916

THESIS

THESIS

B[illegible]

B[illegible]

INHERITANCE OF SIZE AND SHAPE IN BEANS.

Thesis for Degree of M.S.

Paul Kwong Fu.

1916.

THESIS

ACKNOWLEDGMENT.

I wish to thank Mr. Frank A. Spragg, Expert in Plant Breeding of the Experiment Station of the Michigan Agricultural College, under whose careful supervision the investigation was carried on, for kindly advice and assistance during the course of the work.

CONTENTS.

INTRODUCTION.

Many farmers like to grow small pea beans, but it has been their opinion that these pea beans tend to become larger and longer as years go by. It is said that many kinds of small pea beans of a decade ago have now become navies of larger types, and in many instances have lengthened into kidneys. There is no data to support these contentions, yet the opinion of men who for many years have handled beans should not be lightly laid aside. For this reason, Mr. F. A. Spragg saw the need of a fuller knowledge regarding the inheritance of size and shape, and suggested that I investigate the reason why beans have become longer and larger thru the years, if this be true.

This paper is the result of observations and statistical studies on the inheritance of size and shape obtainable in one year (part of two season) from crosses between common commercial varieties possessed by the Station. The early work had been done in the Plant Breeding Division of this Station.

Because of the great value of bean crop as food, it has great economic importance. Consummers of beans usually object to colors and certain size and shape in beans (not that they have any correlation with quality, but that it is a mere fashion demanded by them). Thus, colored beans and certain sizes and shapes do not generally find as ready a market nor as good a price as white ones having the sizes and shapes considered desirable. In order that the plant breeder may obviate such troubles and produce the varieties most generally desired by consumers, he needs a better knowledge of bean heredity. It is because of this fact that this work is attempted.

PREVIOUS WORK ON BEANS.

Professor E. A. Emerson did much work on the inheritance of color in the seed coat of beans when he was connected with the Nebraska Experiment station. In his work with bean crosses, he found that all the racial crosses of beans produced, show little variation in the first generation, but pronounced variation in the second and third generations. Under selection, they appeared fairly well fixed in the fourth and fifth generations. The characters of the two parents (atavistic tendencies) were usually reproduced among the offspring of the second or third generation tho often the new tendencies were noticable. Characters different from the parent forms were usually blends in the crosses or united unchanged in mosaics of small or large pattern.

In the study of size and shape in beans, he made numerous crosses between Fillbasket Wax having long flat seeds, Longfellow having long slender seeds, and Snowflake Navy having small round seeds. He then determined the mean, the coefficient of variability for each of their lengths, weights, breadths and thicknesses. He observed that in the first generation, the mean and the coefficient of variability were not materially greater than for parents, but in the second generation, individuals exhibited marked segregation of size and shape. From this, he concluded that "Shape may be definitely inherited. Observations of the second generation bean seeds where the parents differ in size but not in shape indicate that length and breadth are probably not inherited independently of each other. Large round beans crossed with small round ones do not give any long slender beans in the second generation, but only large medium and small round ones. On the other hand, when the parents differ in shape as well as in size, intermediate and parental shape as well as intermediate and parental dimensions occur in the second generation".

Mr. J. Belling, Assistant Botanist of the Florida Experiment Station in an attempt to secure a hybrid that would combine the thin unopening hull of the Velvet bean with the Lyon Beans' smooth pods which do not have the objectional irritating bristles, has also studied the standard deviation and coefficient of variability of the length, breadth, thickness and weight, also the correlation of length and breadth and thickness of the F_2 crosses between the Lyon and Velvet beans. He measured from 50 to 200 seeds of each of this 118 plants and found that they varied between 10.5 and 20.05 mm. in length, and from 8.3 to 13.55 mm. in breadth. In his study of theweights of these seeds, he found that they varied from .5 to 1.9 gm. He then concluded that, "The close agreement of the length and breadth of the hybrid seeds with those of

the Lyon beans and of the thickness that of the Velvet may possibly be genetic or may be due to special conditions of growth". However, he did not investigate the size and shape of beans in general.

W. Johannsen worked with the weights of beans and found his pure line theory. He weighed the seeds of a single variety of beans and planted them separately. They arranged themselves in a normal curve round the weight of greatest frequency where the seeds from the individual plants were harvested separately. The crop from each individual again could be grouped according to their weights in normal curve around the most frequent weight characteristic of each individual. Thus, there was a rough correspondence between the modes for the individual plants and the weights of the individual seeds from which they sprang. The heavier strains on the whole come from the heavier seeds and the lighter from the lighter seeds. But when he selected the heavier and lighter seeds from a single strain and planted them separately, he found that the modal weights were approximately the same for the produce of both the heavier and the lighter seeds. This indicates that selection inside the strain raised from a single seed does not alter the modal weight, i. e., the product of the two selections are the same genetically.

To sum up, it may be said that none of these investigators have told us what sizes are separately inherited, nor the number of inherited factors involved.

Johannsen has shown that there are such factors, because the progeny of homozygous beans belonging to slightly different sizes maintain separate means, and do not regress to the mean of all sizes of beans.

Emerson has shown that length and width are not inherited separately, but togehter as inheritance of sizes of the same shape. Variations in the inheritancd of shape, he finds occur only when the parents differ in shape.

It remains for me to lay some foundation in an investigation of the factors involved.

SOURCES OF MATERIALS.

The Michigan Experiment Station had gathered varieties of beans from different sections of the state and country. These had been selected to eliminate impurities and then tested in variety series where the plats were long and narrow strips side by side. Thus, these varieties had been brought close together in the variety series and exposed to general crossing if beans are so inclined. Beans are normally autogamous (close fertile) yet a very few natural crosses resulted (perhaps not one in ten million). Altho 106 different lots of beans have been given accession numbers by the Michigan Experiment Station and only four of these (viz.:-Nos. 2,4, 36, and 40) have become the mothers of colored crosses, there seems to have been other natural crosses of which accession numbers 61, 87, 88, and 89 have become mothers because segregations are obtained. The following are all that have in any way entered in this investigation:-

MATERIAL FROM WHICH THE MATERIAL FOR THE STUDY OF SIZE AND SHAPE ARE SELECTED.

Accession Numbers.

Accession numbers.	Kind of beans.	Where from.	Year obtained.
2	Medium red Kidney	Michigan	1907
4	White kidney	"	"
13	White navy	"	"
36	" "	"	1910
40	" "	"	"
61	" "	"	1913
62	" "	"	"
65	Large white navy	Portland,Oregon	1914.
67	Pink navy	" "	"
71	Navy	Stockton,Calif.	"
75	Large white navy	" "	"
76	" " "	" "	"
78	" " "	San Francisco,Cal.	"
83	Red kidney	" " "	"
87	Yellow Sweedish navy	Idaho	"
88	White pea	Michigan	"
89	White kidney	"	"
91	Pea bean	"	1913.

Natural Crosses.

Kind of Crosses.	F_1	F_2
Navy - White navy / Acc.#2 Red kidney	Black and brown kidney	White and colored navy and kidney
Navy - White navy / Acc.#4 White kidney	Black kidney	White and colored navy and kidney
Navy - White navy / Acc.#36 White navy	Black navy	Colored navy
Navy - White navy / Acc.#40 White navy	Black navy	White and colored navy.

Out of the plats representing accession numbers 2,4,36 and 40, the station had obtained some black and brown seeds. The result of crosses between these varieties and some navy bean that grew alongside. The source of pollen was slightly uncertain but must have come at least partly from white navy beans in every cross. The first generation of the crosses (F_1) (grown in 1913) gave in all cases either a deep purple (almost black) or brown offspring. The crosses between navy and kidney forms were kidney beans in F_1. The crosses between two navy beans have given navies in all cases. Unfortunately, the F_1 crop was threshed each plat as a whole, and for this reason, we do not know but what there may have been some purple kidney of F_1 having a kidney sire producing all kidneys in crop. The beans grown in 1913 were sorted according to color and shape and the classes counted. Then each such lot was planted separately in 1914.

Growing thus in rows with classes recorded, and stakes attached to each, I harvested the 1914 beans, gathering the seeds of each individual plant separately. The seed from each plant was placed in an envelope and given a selection number in accordance with the system used by the Michigan Experiment Station. This system consists usually of five figures, the first of which stands for the year in which the crop is grown, the second and third of which stand for the number of plat in which the plant belongs, and the fourth and fifth, for the selection number, the only exception to this being, that when the plat number exceeds 99, an extra figure is inserted.

When I took over the material, most of these crosses were in their second generation and were rich in color of various combinations and also sizes and shapes. After they were fully classified it was decided to make selections with a view of studying the size and shape in beans, as the inheritance of color had been well covered by others.

METHOD OF WORK.

In selecting the material, preference was given to white beans because those are the types preferred by the market. I also saved an extra quantity of small white navy and pea beans that the Michigan Experiment Station might have material from which to develop the new varieties most desired by the farmers and the trade. All other sizes and shapes were included in so far as they could be found among the white beans. When a type of size and shape was not represented among the whites, colored beans were selected to represent that type. Also when the data indicated that certain lots were especially apt to furnish the segregations desired, these were included.

From among the 1914 individual plant selections, about 200 were chosen to become mothers of individual progeny plats in 1915. These lots totalled 14280 seeds. Each of the plant sělections was given a plat number and a record of this and pedegree numbers was written on a small card using waterproof ink. These cards were afterwards paraffined and tacked to small stakes located at the end of the row in field. Planting was done on June 12 and 14. The plants from 50500 to 59500 were planted on sandy soil near the poultry plant, while the remainder were planted on loamy soil in field #9.

The season was extremely unfavorablefor beans but most seeds pushed their cotyledons above ground within one week's time. The same kind of culture was given to all, and in one month's time, the stand was beginning to thicken. The number of plants was then taken and found to total 10787 plants. The growth in leaves and stalks was very profuse in some plats and very little in others, and sometimes there was great contrast among plants of the same progeny (i. e. from the same mother plant). As to uniformity of stand among the plats, there was also marked difference.

While they were in the bloom, notes were taken on the color of flowers. There were only a few plats that had entirely white flowers. In the majority of cases, cream colored flowers were also present in the same plat. The presence of light red flowers in red flowered plats was also very common. In some plats flowers were sometimes found of the following colors: cream, light red, and red, and purple.

In general bush beans began to develop pods earlier than the vine types, but they matured about the same time with a few exceptions. The bush beans seemed to be more susceptable to blight and rust, and as a general rule produced fewer pods and seeds per plant.

The cold rainy weather in the latter part of August began to tell heavily on the plants which were soon chilled by light frosts. Diseases got the upper hand and the abundance of moisture supplied by the rain stimulated vegetative growth and the setting of new flowers too late in the season to ripen in time for harvest.

Harvesting began on September 12th and continued daily or nearly so as long as there were ripe plants. They were pulled, tied in bundles, properly labeled and taken to the laboratory between showers. When dry enough, each plant was given a number to indicate the year the plat from which it came and its selection number. Growth had stopped by October 15th and the remainder of the crop was then harvested in so far as it was of any value to this investigation. Notes were taken on such characters as the number of stalks; the weight; whether bush or vine; the manner that the pods were carried; the number of shrunken pods; and the kind of disease with percent of the same. The reason for taking notes along so many lines was to be sure of a thesis in case material for size and shape proved to be insufficient.

Threshing was done by a small home made machine run by a $\frac{1}{2}$ horse power electric motor. A total of 4592 plants were threshed. The seeds of different individuals were then cleaned and counted. Sample types thot to represent all the beans on hand were sorted out and the mean, standard deviation and coefficient of variability were determined for width, length and shape of each type sample the shape being the ratio between length and width. These sample types were arranged in a table according to their mean width. The narrowest was numbered 1 and the widest was numbered 24. There was, however, one exception to this in that #6 type was found impractical. Two new ones that were somewhat narrower than the original #6 took its place. These were called #6 and #6a falling in order of width between #4 and #5. As colors often make the seeds look longer than their true dimensions, white beans are preferable as types to colored ones and were chosen whenever suitable ones could be found, yet types number 9, 14, 16, 17, 18, 19, 20, 21, 22, and 23 had to be colored beans as no whites of these sizes and shapes were found in the collection. The remainder of the individual plants was then given type numbers referred to these types samples, the number being that of the type most nearly approached. The following tables contain the mean, standard deviation, and coefficient of variability of the length, width, and shape of the type samples:-

TABLE A.

Width of Type Samples in Millimeters.

(Giving also plant number and number of seeds.)

Type nos.	Plat nos.	No. of seeds.	M.	σ	C.
1	53006	94	5.521±.0265	.3804±.0187	7.89±.3389
2	52073	124	5.629±.0238	.3929±.0168	6.98±.2990
3	59601	73	5.877±.0300	.3799±.0212	6.46±.3606
4	52043	134	5.978±.0226	.3871±.0159	6.48±.2670
5	59301	47	6.160±.0399	.4052±.0282	6.58±.4576
6	56571	77	6.091±.0231	.2999±.0163	4.92±.2596
6a	53101	23	6.130±.0484	.3444±.0343	5.62±.5589
7	51373	228	6.425±.0143	.3199±.0101	4.98±.1573
8	58508	70	6.557±.0367	.4548±.0259	6.94±.3956
9	53208	36	6.639±.0689	.6049±.0481	9.11±.7241
10	58208	28	6.696±.0753	.5828±.0533	8.70±.7842
11	55603	118	6.712±.0274	.4405±.0193	6.56±.2880
12	52642	63	7.063±.0385	.4532±.0272	6.42±.2858
13	516014	120	7.100±.0241	.3921±.0171	5.52±.2403
14	53514	164	7.165±.0247	.4682±.0174	6.53±.2432
15	57706	62	7.169±.0279	.3257±.0197	4.54±.2750
16	53208	60	7.292±.0568	.6528±.0402	8.95±.5511
17	59328	111	7.518±.0311	.4858±.0220	6.46±.2924
18	53601	105	7.529±.0379	.5752±.0268	7.64±.3556
19	518101	55	7.727±.0462	.5075±.0326	6.57±.4225
20	514720	47	7.915±.0506	.5142±.0358	6.50±.4522
21	53211	169	8.246±.0247	.4760±.0175	5.77±.2117

Type nos.	Plat nos.	No. of seeds.	M.	σ	C.
22	513403	39	8.256±.0478	.4424±.0338	5.36±.4094
23	517901	35	8.414±.0378	.3318±.0367	3.94±.3176
24	514904	21	9.905±.0642	.4364±.0454	4.41±.4646

TABLE B.

Length in Millimeters of Type Samples.

	M.	σ	C.
1	9.851±.0401	.5766±.0284	5.85±.2878
2	7.488±.0261	.4316±.0185	5.80±.2484
3	9.308±.0460	.5824±.0325	6.26±.3494
4	8.112±.0347	.4232±.0174	5.22±.7151
5	10.032±.0610	.6203±.0431	6.01±.4181
6	9.221±.0382	.4967±.0270	5.39±.2929
6a	10.543±.0732	.5203±.0517	4.94±.4912
7	8.632±.0177	.3958±.0125	4.59±.1450
8	12.079±.0512	.6349±.0362	5.26±.2999
9	13.611±.0785	.6981±.0555	5.13±.4078
10	13.964±.1040	.8157±.0735	5.84±.5264
11	8.835±.0368	.5922±.0266	7.11±.3122
12	10.183±.0709	.8343±.0501	8.19±.4921
13	10.508±.0368	.5976±.0260	5.69±.2477
14	11.030±.0287	.5446±.0203	4.94±.1840
15	9.326±.0291	.3400±.0203	3.65±.2211
16	13.908±.1047	1.2020±.0740	8.46±.5221
17	12.144±.0417	.6521±.0295	8.64±.3911

	M.	σ.	C.
18	10.705 ± .0430	.6530 ± .0304	6.10 ± .3923
19	11.745 ± .0567	.6327 ± .0401	5.30 ± .3409
20	12.670 ± .1340	.7169 ± .0947	5.66 ± .3938
21	13.678 ± .0443	.9140 ± .0313	3.84 ± .3738
22	11.526 ± .6553	.5123 ± .0391	4.45 ± .3399
23	15.700 ± .0590	.5174 ± .0417	3.30 ± .2661
24	13.619 ± .0499	.3388 ± .0313	2.49 ± .2623

TABLE C.

Shape (Ratio between Length and Width) of Type Samples.

	M.	σ.	C.
1	1.7890 ± .0080	.1154 ± .0057	6.451 ± .3173
2	1.3239 ± .0145	.2391 ± .0324	5.711 ± .2446
3	1.5866 ± .0087	.1098 ± .0086	6.922 ± .2864
4	1.3590 ± .0041	.0709 ± .0029	5.219 ± .2150
5	1.6300 ± .0103	.1045 ± .0073	6.410 ± .4459
6	1.5170 ± .0086	.1113 ± .0661	7.336 ± .3987
6a	1.7374 ± .0414	.2945 ± .0293	16.532 ± 1.6883
7	1.3457 ± .0028	.0617 ± .0019	4.585 ± .1448
8	1.8481 ± .0103	.1275 ± .0073	6.899 ± .3935
9	2.0630 ± .0185	.1646 ± .0131	7.979 ± .6343
10	1.9564 ± .0307	.2406 ± .0217	12.299 ± 1.1252
11	1.3192 ± .0058	.0936 ± .0041	7.097 ± .2116
12	1.4327 ± .0102	.1203 ± .0072	8.396 ± .5045
13	1.4820 ± .0053	.0866 ± .0038	5.844 ± .2544

	M.	σ	C.
14	1.5420 ±.0047	.0889 ±.0033	5.761 ±.2146
15	1.3040 ±.0051	.0595 ±.0036	4.563 ±.2764
16	1.9160 ±.0137	.1569 ±.0097	8.188 ±.5041
17	1.6200 ±.0073	.1139 ±.0052	7.033 ±.3184
18	1.4285 ±.0075	.1136 ±.0053	7.955 ±.3702
19	1.5245 ±.0102	.1118 ±.0073	7.330 ±.4714
20	1.6072 ±.0122	.1240 ±.0086	7.713 ±.5366
21	1.6620 ±.0055	.1065 ±.0039	6.409 ±.2351
22	1.3964 ±.0080	.0741 ±.0057	5.310 ±.4055
23	1.8660 ±.0084	.0738 ±.0059	3.957 ±.3190
24	1.3762 ±.0158	.1072 ±.0112	7.787 ±.8105

Bringing together the data of all the plats segregating between the types #7 and #11 (Table D) the totals show that one is as likely to occur as the other and the probabilities are that these belong to the same genetic class.

TABLE D.

Showing Types #7 and #11 All of One Type.

(All except 55700, 56000, 510500, belong to Acc. #13) Robust

Plat Nos.	No. of Type #7.	No. of Type #11.
50500	35	43
50600	15	39
50700	16	48
50800	42	36
50900	26	18

Plat Nos.	No. of Type #7.	No. of Type #11.
51000	20	33
51100	9	26
41200	35	31
51400	16	33
51500	6	14
51600	38	60
51700	84	28
51800	57	26
55700	3	4
56000	16	16
510500	14	3
Total	476	458
Ratio	2.0385	1.9615

DATAS AND DISCUSSIONS.

TABLE E.

$\frac{\text{Navy}}{\text{Acc. \#2.}}$ Cross.

1. Constant Types. (Arranged according to the order of types)

Plat Nos.	Type Each Belongs.	Total # of Plants.
53000	1	18
54000	3	31
52700	5	8
52800	5	14
54100	5	6
54500	5	11
53600	6	8

Plat Nos.	Type Each Belongs.	Total # of Plants.
53700	6	13
53800	6	16
54200	6	27
58300	6	8
53100	6a	3
53200	9	12
53300	12	3
54700	13	28
512900	13	8
53000	13	20
54600	14	5
58600	14	23
53500	17	24
513200	15	1
513300	21	3
513400	21	3
513500	21	7

2. Segregations of Class #4 and #11 and #7.

Plat Nos.	No. of Type #4.	No. of Type 7 & 11.	Total.
52100	2	6	8
52200	2	10	12
52500	3	3	6
Total	7	19	26
Ratio per 4	1.077	2.923	
Expected	1.000	3.000	

3. Segregations of Class #8 and #10.

Plat. Nos.	No. of #8.	No. of #10.	Total
58200	4	3	7
58400	11	2	13
58500	13	8	21
Total	28	13	41
Ratio per 4	2.732	1.267	
Expected ratio	3.000	1.000	

4. Segregations of Class #7 and #12.

Plat Nos.	No. of #7.	No. of #12.	Total.
513100	8	26	34
517600	20	33	53
Total	28	59	87
Ratio per 4	1.296	2.704	
Expected ratio	1.000	3.000	

5. Miscellaneous Segregations.

	No. of #2	No. of #4	No. of #17&11	No. of #13	No. of #4	No. of #17	No. of #20	Total
52300	2	6	20					28
52400	2	4	14					20
52600				43	3	6		52
54300				7	13	14	7	41

The above listed material comes from a natural cross between white navy and red kidney. According to the notes of this Station, the F_1 of this cross was kidnegs, the F_2 segregated into navies and kidneys, but in F_3 the segregations seem to exist in the absence of dominance, that is, the envelopes containing the seed from individual plants can be classed as navies, intermediates and kidneys. The ratio among these lots is approximately 1:2:1. Such segregations are found in plats 52600, 53800, 53900, 54800, and 58300. Also plat 54300 shows something similar. However, in this plat dominance seems to be somewhat active as there are nearly as many kidney envelopes as intermediate with much fewer navies.

In the 1915 plats #129 to #135 the plants are F_2 progenies from the same kind of cross (i. e. $\frac{\text{Navy}}{\text{Aco.\#2}}$) obtained one year later than others. Plats #129 and #132 are navies, while #130, #131 and #133 show segregations similar to above, and plats #134 and #135 are kidneys. As I was only able to save 10 mature kidney plants out of these two plats and they were not entirely mature, this F_2 data shows unsatisfactory segregation between navy and kidney.

It is certain that nothing has been proven in regard to the manner in which navy-kidney crosses segregate. Mr. Wm. K. S. Sie has become interested in the extension of this investigation to determine this point, and will plant this material as his M. S. thesis.

With regard to sizes, a great many are constants and only a few fall in the segregating classes, 4 and 11, 8 and 10, 7 and 12, and miscellaneous. As there are so few of each kind, it is hard to get even reasonably close approximation to

Mendelian ratios in some of the segregating classes.

TABLE F.

$\frac{\text{Navy}}{\text{Acc. \#40}}$ Cross.

1. Constant Types.

Plat Nos.	Type Nos.	No. of Plants.
59600	3	12
511000	4	3
55600	11	3
55700	11	7
56000	11	32
510500	11	17
511100	12	5
58700	13	3
58800	13	3
511300	13	11
511900	14	2
512100	14	2
56900	15	8

2. Segregation of Types #11 and #15.

Plat No.	No. of #11.	No. of #15.	Total.
57400	4	44	48
57600	25	37	62
57700	10	15	25
58000	21	38	59
58100	5	24	29
Total.	65	158	223
Ratio per 4	1.165	2.835	
Expected ratio	1.000	3.000	

3. Segregation of Types #7 and #12.

Plat Nos.	No. of #7.	No. of #12.	Total.
56600	1	8	9
56800	10	26	36
57000	5	22	27
57100	2	7	9
57200	14	62	76
510200	10	32	42
511500	7	12	19
511700	15	27	42
512000	9	11	20
512700	1	7	8
Total	74	214	288
Ratio per 4.	1.028	2.972	
Expected Ratio	1.000	3.000	

4. Segregation of Types #4 and #11.

Plat No.	No. of Type #4.	No. of Type #7 & 11.	Total
55800	16	35	51
56100	8	35	43
56200	7	19	26
56300	2	30	32
56400	2	12	14
59100	11	34	45
59200	3	9	12
59400	4	8	12
59500	6	18	24
510000	7	19	26
510300	4	8	12
510500	7	9	16
510600	3	3	6
510700	5	5	10
510800	10	34	44
511600	2	8	10
Total	97	286	383
Ratio per 4	1.013	2.987	
Expected Ratio	1.000	3.000	

5. Segregation of Types #6 and #11.

Plat. No.	No. of #6.	No. of #11.	Total.
55500	24	11	35
512200	4	3	7
Total	28	14	42
Ratio per 4	2.667	1.333	
Expected ratio	3.000	1.000	

6. Miscellaneous Segregations (too complex to be interpreted)

Plat No.	Classes, #4,	#6,	#11,	#12,	#13,	#14,	#15,	#17,	#18,	#19,	#20.	Total.
58600			12			9			2			23
59300			9	10		1	5	2				27
511200		2	14	6								22
511400			14	5	1	14	15		7	3		59
512300			11	1	2	1	2		3	3	1	24
512400		8	7	9	1			4				29
512500	2		1	5						4		12
512600					4		4	2				10

The data above are progenies from a navy on navy cross The F_1, F_2 generations gave only navies. The F_3 generation gave mostly navies. However, plats #93 and #124 show a navy-kidney segregation also plats #86, #114, #123 and #125 have a fairly wide range of shapes, from pea beans to approaching kidneys.

As to sizes, classes #7 and #12, #4 and #11, #11 and #15 show segregation in regard to one pair of characters each. Classes #6 and #11 are probably segregations as if more plants belong to these classes are added together, the ratio would come closer to Mendelian ratios.

TABLE G.

1. Progenies of $\frac{\text{navy}}{\text{acc. \#36}}$ cross.

Plat No.	No.of #6	No.of #7 &11.	No.of #12	No.of #13	No.of #14	No.of #18	No.of #19
54900			9				
55300				2			
55000		7	16				
55200			8	4			
55400	3		2			2	
55100			4		4	7	9

The data above comes from a natural cross between white navy and white navy. The F_1 and F_2 generations gave only navies. The F_3 gave mostly navies. However, plat 55100 shows a navy-kidney segregation. As to sizes, besides the two constant plats, they thus segregate along different classes with no two plats alike.

$\frac{\text{Navy}}{\text{acc.\#4}}$ is a cross between white navy and white kidney. The F_1 was kidney, and the F_2 was navies and kidneys. One navy plant of this cross was selected for planting in 1915. It had 382 seeds and produced 333 plants which were all small navies; of these 98 plants were selected, 43 of these fall in class #2 and 55 in class #4.

TABLE H.

1. Accession Number 13.

All seeds except those from the following two plats belong to type #11 (see table C), but the following two plats seem to be segregating between class #4 and #11 probably in two pair of characters. This data is contrary to that found in tables: E_2, F_4, H_4, and also in the summary Table I where a large amount of data has been brought together and the conclusions are quite clear, that there is but one factor present. The small amount of this data and the fact that the small beans may have been immatures, makes it necessary to plant them again before anything can be proven.

Segregation between class #4 and #11.

Plat No.	No. of #4	No. of #7 and #11	Total
51300	6	78	84
51900	8	69	77
Total	14	147	161
Ratio per 16	1.388	14.612	
Expected Ratio	1.000	15.000	

2. Accession Number 61.

Segregations between #11 and #15.

Plat No.	No. of #11	No. of #15	Total
513800	14	13	27
513900	4	24	28
514000	8	11	19
514100	4	24	28
514200	5	32	37
514300	12	9	21

Plat No.	No. of #11.	No. of #15.	Total
514400	3	11	14
514500	8	14	22
514600	11	7	18
Total	69	145	214
Ratio per 4	1.289	2.711	
Expected Ratio	1.000	3.000	

Seeds of plat 137 of this accession number belong to type #7 and is the only one that is constant.

3. Accession Number 87

Only two plats of this number were saved and they fall in classes #19 and #21 as follows:-

Segregation Between Types #19 and #21.

Plat No.	No. of #19	No. of 21.	Total.
518300	7	16	23
518400	3	16	19
Total	10	32	42
Ratio per 4	.952	3.048	
Expected Ratio	1.000	3.000	

4. Accession Number 88.

All the seeds of this accession number fall in class #4 and #7 as follows:-

Plat No.	No. of #4.	No. of #7 and #11.	Total.
515000	9	35	44
515300	9	18	27
515400	6	9	15
515500	5	12	17
515600	4	19	23
515700	14	16	30
Total	47	109	156
Ratio per 4	1.205	2.795	
Expected Ratio	1.000	3.000	

The ratio of this segregation does not approach very closely to 1:3. Probably it would have come much closer to 1:3 had more data of the same kind been available.

5. Accession Number 89.

Seeds of this number are kidneys and all those chosen for planting in 1915 segregate in classes #8 and #10 as follows:-

Segregation Between #8 and #10.

Plat No.	No. of #8.	No. of #10.	Total.
515800	19	6	25
515900	10	5	15
516000	10	3	13
516100	33	5	38
Total	72	19	91
Ratio per 4	3.165	.835	
Expected Ratio	3.000	1.000	

The above data are all that gave segregations of size and shape in the 1915 crop. Those that did not segregate are omitted.

CONCLUSIONS.

On Shapes.

In tracing through the breeding record of the crosses described above it is clear that kidney and navy crosses give kidneys in F_1, navies and kidneys in F_2, and that navies produce navies in F_3, ~~and~~ there is every indication that kidney is dominant over navy probably in a monohybrid ratio. Of the small number of kidneys chosen for the 1915 planting, besides the many deaths, the remaining number was too few to give any proof of the manner of segregation between navies and kidneys. On the other hand, a few of the plats segregate without dominance or with little dominance. This material must be grown another season before the inheritance of shape can be understood. Mr. Wm. K. S. Sie is undertaking this as his thesis.

On Sizes.

A majority of the data on sizes show Mendelian segregations of one pair of characters, large size being dominant. Two plats of accession number 13 differ from the others segregating along the same classes in that they indicate a dihybrid

segregation. Among those segregations too complex for interpretation probably more than one pair of characters are concerned in their inheritance. The segregations of classes #8 and #10 show the reverse of dominance. It is possible that the high death rate among the large late frozen ones may have reversed the results, but in face of the fact that their parents was nearer to #8 than it is to #10, it is more probable that these results show the reverse of dominance, although they are too few in number to be sure of.

The following tables record the classes of segregations in sizes more common among the material mentioned in datas above:

A Showing Segregations in One Pair of Characters, large size being the Dominance.

TABLE I.

Plat No.	No. of Type #4.	No. of Type #7 and 11.
52100	2	6
52200	2	10
52400	6	14
52500	3	3
52800	16	35
56100	8	35
56200	7	19
56300	2	30
56400	2	12

Plat No.	No. of TYpe #4.	No. of Type #7 & 11.
59100	11	34
59200	3	9
59400	4	8
59500	6	18
510000	7	19
510300	4	8
510500	7	8
510600	3	3
510700	5	5
510800	10	34
511600	2	8
515000	9	35
515300	9	18
515400	6	9
515500	5	12
515600	4	19
515700	14	16
Total	144	429
Ratio per 4	1.020	2.979
Expected Ratio	1.000	3.000

TABLE II.

Plat No.	No. of Type #11.	No. of Type #15.
57400	4	44
57600	25	37
57700	10	15
58000	21	38

Plat No.	No. of Type #11.	No. of Type #15.
58100	5	24
513900	4	24
514000	8	11
514100	4	24
514200	5	32
514300	12	9
514400	3	11
514500	8	14
Total	109	283
Ratio per 4	1.112	2.888
Expected Ratio	1.000	3.000

TABLE III.

Plat No.	No. of Type #7.	No. of Type #12.
55000	7	16
56600	1	8
56800	10	26
57000	5	22
57100	2	7
57200	14	62
59200	6	15
59800	2	6
510200	10	32
510400	4	16
511500	7	12
511700	13	27

Plat No.	No. of Type #7.	No. of Type #12.
512000	7	11
512700	1	7
513100	8	13
517600	20	33
Total	117	313
Ratio per 4	1.088	2.912
Expected Ratio	1.000	3.000

Showing The Reverse of Dominance.

TABLE IV.

Plat No.	No. of Type #8.	No. of Type #10.
58200	4	3
58400	11	2
58500	13	8
515800	19	6
515900	10	5
516000	10	3
516100	33	5
Total	3.0303	.9697
Expected	3.000	1.000

These results do not seem to support the contention among farmers that beans become larger and longer thru the years. Instead, they indicate the reverse. It is not probable that the increase in size, if really it has occurred, is due to the elevator screens being so coarse as to allow the smaller pea types of #2 and #4 to get into the rubbish? This would play an important part in causing the beans to become larger and longer thru the years.

BIBLIOGRAPHY.

1. Belling, J., 1911.

Second Generation of the Cross Between Velvet and Lyon Beans.

Florida Station Report. p. 82.

2. Davenport, C. B., 1910.

The Interpretation of Dominance and Some of Its Consequences.

American Naturalist, p. 128.

3. Emerson, R. A.,

a. 1902, Preliminary Account of Variation in Bean.

Annual Rept. of Nebraska, p. 30.

b. 1904, Heredity in Bean Hybrids.

Annual Rept. of Nebraska, p. 33.

c. 1909, Inheritance of Color in The

Seeds of Common Bean, Phaseolus Vulgaris.
Twenty-second Rept. of Nebraska.

d. 1909, Production of White Bean Lacking the Factor for Total Pigmentation
Procedings of American Breeder's Association, Vol. 6, p. 396.

e. 1910, Inheritance of Size and Shape in Plants.
American Naturalist, p. 738.

4. East, E. M., 1910.
A Mendelian Interpretation of Variation That is Apparently Continuous.
American Naturalist, p. 65.

5. East, E. M. and Emerson, R. A. 1913.
The Inheritance of Quantitative Characters in Maize.
Nebraska Research Bulletin No. 2.

6. East, E. M. and Hayes, H. K.

a. 1911, Ineritance in Maize.
Bulletin 167, Connecticut Station.

b. 1915, Further Experiments of Inheritance in Maize.
Connecticut Bulletin 188.

7. Groth, B. H. Alfred, 1914.
The F_1 Heredity of Size, Shape and Member in Tomato Leaves.
New Jersey Bulletin No. 238, 239.

8. Johannsen, W., 1909.

Elements of Exact Study of Heredity.

Review in Nature (London).

9. Little, C. C., Dec. 18, 1914.

A Possible Mendelian Explanation for A Type of Inheritance apparently Non-Mendelian in Nature.

Science Weekly.

10. Owen, Earle J., 1910.

Inheritance Studies With Beans.

New Jersey Rept. p. 277.

11. Weldon, W. F. R., 1902.

Mendel's Law of Alternative Inheritance.

Biometrika, No. 2, p. 228.

ROOM USE ONLY