METHODS OF DISTINGUISHING CROSSES BETWEEN SIMILAR BEAN VARIETIES

THESIS FOR DEGREE OF M. S.

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1926

THESIS

Beans

Plant-breeding

METHODS OF DISTINGUISHING CROSSES BETWEEN SIMILAR BEAN VARIETIES

Thesis

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INTRODUCTION

There are several varieties of white beans grown in Michigan at present. Of these the Robust is the most consistent high yielder due to disease resistance and hardiness but the beans have glassy seed coats and do not appear as uniform in size as other varieties, such as Early Wonder and Early Prolific. The seed coats of the Early Wonder and Early Prolific varieties are a chalky white which is most disirable, but neither variety yields equally well with Robust. Therefore it is desirable to cross Robust with Early Wonder, Early Prolific, or other early varieties now grown in Michigan in an effort to produce a strain that will be uniform in size, with a chalky seed coat, and at the same time produce a high yield of dry beans per acre.

The identification of a cross in the F_1 generation saves the plant breeder considerable time and labor. While a desirable strain cannot be produced any more quickly by identification in the F_1, the labor saved by eliminating non-crosses is an important item in cutting down the cost of the experiment.

THE PROBLEM

The work covered by this thesis has been done to determine whether or not the F_1 of a cross between two similar strains of white beans differs from the female parent in certain morphological characters. The questions to be answered are these: Are F_1 plants morphologically different from their mother parents in the following characters:

1- size and shape of seed?

2- ratio of width to length of terminal leaflets?

3- ratio of width to length of terminal leaflet times reciprocal of length of petiole?

If the F_1 of a cross is morphologically different, in the characters mentioned above, from the female parent and the difference is measurable, then by statistical measurements and biometrical calculations, a cross can be positively identified.

LITERATURE

J. B. Norton (8) has done several years work on the inheritance of habit of growth in beans giving attention to the stem and branches but has published nothing upon size or shape of leaflets or length of petioles.

The growth of Early Wonder beans is outlined by the New Jersey Experiment Station (4) but deals only with the sequence of growth and not with inheritance.

Dr. R. A. Emerson (1) worked on inheritance of size and shape of seed in bean hybrids. He concludes that size and shape are not inherited separately but together as inheritance of sizes of the same shape. The F_1 of a cross was found to be quite uniform while more variation occurred in the F_2.

The only data given in the literature cited that might be of value in this work is given by Dr. R. A. Emerson (1). If the mother variety produces beans of uniform size and of a different shape from those produced by the pollen parent then a variation in the F_1 would indicate a cross had been obtained.

MATERIAL

The sources from which the material was obtained for this investigation are reported in Tables I and 2 and the various crosses made are recorded in Tables 3 and 4. In Table I, the variety name, Accession number and number of plants selected are given in order. The Robust, Early Prolific and Progeny of Ac 359 were selected in the field before the crop was pulled. The plants of the remaining varieties were chosen in the field after the crop was pulled. Plant selections were again made in the green house in the fall of 1925. This material is listed in Table 2. The Mexican Tree, and Early Wonder listed in Table 2 were taken from bulk seed of the field crop of 1925. The varieties, Miller, Canter, and Putnam were not planted with the January planting.

Table 3 is a list of the F_1 seed of crosses made in the green house during the fall of 1925 while in Table 4 is a list of F_1 seed of crosses made in the green house during the winter of 1926.

METHODS

Plants were selected in the field in the fall of 1925 and taken to the laboratory. The following notes were taken on each plant: type of vine, length of vine, number of beans, weight of beans, and chalky or glassy seed coat.

Fifty beans from each plant were measured for length and width in millimeters. These measurements were made by means of an L-shaped block of wood with a piece of millimeter graph paper glued to it. This permitted both measurements to be read without changing the position of the bean. The mean, standard deviation, coefficient of variation, and coefficient of correlation with the respective probable errors were calculated for each fifty beans.

The beans from each plant were placed in an envelope and given a selection number. All of the material listed in Table I was handled in this manner.

On September 19, 1925 three pots each of Robust, Early Prolific and of ten of the selections of Ac 359 were planted in the green house. Eight-inch pots were used and four beans were planted in each pot. Two pots of Robust were planted on the 23rd, two more on the 25th, and two more on the 28th of September making nine pots of Robust in all. Plantings were made on these different dates to insure pollen at the proper time.

On September 28th the remainder of the varieties listed in Table I were planted. Four-inch pots were used for these and four beans of each variety were planted, two beans in each pot. The entire planting was arranged on the floor of the green house.

A high percentage of germination was obtained and the plants grew rapidly. On October 13, when the plants were about 10 inches high, white flies and red spiders were noticed. The plants were sprayed with a solution of fish oil soap to which was added one teaspoonful of nicotine per gallon. This solution was effective in killing and repelling the white flies but had no visible effect upon the red spiders. The uninfested plants were then moved to the east bench in the green house. These plants soon developed mildew and were dusted with sulphur. The sulphur effectively controlled the mildew.

The plants remaining on the floor were sprayed with Volck for red spiders. Volck was an untried commercial preparation. The sun and Volck were not a good combination and severe burning of the foliage resulted from which the plants never fully recovered. The spray did not affect the insects in any visible way.

Acting upon advice received from the Entomology Department, the plants were sprayed with lemon oil, being sprayed three times at two day intervals. The lemon oil completely controlled the red spiders. These injuries are mentioned because of the effect they may have had on the plant measurements taken.

When the plants began blooming the following leaflet measurements were taken in millimeters:

Length of terminal leaflet,

Width of terminal leaflet,

Length of petiole.

From these data, ratios were computed as indicated in example 2, the ratio of width to length of leaflet, and this result divided by the length of petiole. It was found

necessary to use ratios instead of dimensions due to the differences in size of the leaves at the time measurements were taken. Ten leaflets with their petioles were measured on each plant. The mean, standard deviation and coefficient of variation with their probable errors were obtained for each plant.

Crosses were made during the period from November 19 to December 12. Most of the crosses were unsuccessful. The flowers would abort or the pods would turn yellow and fall off when they were about one inch in length.

The bean has a cleistogamous flower, i.e., hermaphroditic and pollination occurs before the petals open. Therefore it is necessary to open the flower and remove the stamens before pollen is ripe otherwise self-fertilization would result. To open the flower the keel petal is split with a sharp instrument. The stamens are arranged in a whorl of nine with their filaments joined to the style and one outside of this whorl. The anthers can be removed with forceps. It is necessary to remove all of the stamens or autogamy will result. The flower should be examined with a magnifying glass to be sure all of the stamens are out and that there is no stray pollen on the stigma. Great care must be used in extricating the stamens to prevent crushing of the ovary or breaking of the style. The process of removing stamens from a flower is called emasculation. After emasculation, a pollen flower is chosen that has split on the lower side (keel). The flower is opened and the anthers detached and carefully crushed in a small receptacle to liberate the pollen. This pollen is then placed immediately upon the stigma of the emasculated flower. The pollen is transferred from the

the receptacle to the stigma by using a small camel's hair brush or similar instrument. This method was used at first but later the method of using the stigma of the pollen flower as a means of transferring the pollen was tried. This consists of breaking off the stigma of the pollen flower the same day the flower opens and rubbing it on the stigma of the emasculated flower which will absorb the pollen from the first stigma. The anthers remaining in the pollen flower after the stigma has been broken off can be used to pollinate a second emasculated flower by the brush method. The stamens were found to contain considerable unshed pollen and if pollen is scarce it may be conserved in this manner. The stigma method of transferring pollen proved to be the surer method in pollination. After pollination, the flower is tagged with the date, method of pollination, and pollen parent, if more than one variety is used for pollen in a series of crosses. Emasculation may be made the day previous or on the same day pollination is to be made. There has been no data published to show which is best from the stand point of insuring a cross.

The fall planted beans were harvested in December. Measurements of length and width of seed were made in the laboratory.

In December 1925 a second planting was made in the green house. Three pots of Robust were planted to secure early flowers for crossing. They did not grow however due to soil packing. Three plantings of Robust were made before a stand was secured. In January 1926 the material listed in Tables 2 and 3 was planted. Eight-inch pots were used throughout.

Germination was slow probably due to hard seed coats as the beans were kept in a very dry place from the time of harvesting till planting. A good stand was secured but growth was slow. The plants remained thrifty however throughout the growth period.

Crosses were made during the period from March 3, to April 5. A larger percentage of the crosses attempted reached maturity than was the case in the fall crop. This was probably due to the stigma method of pollination and the temperature of the green house being lower than during the time the fall crop was growing.

Leaflet measurements were taken on this crop in addition to measurements for variety comparison. Four Robust plants were marked and each plant was measured four times to determine if the ratio of the measurements would vary with the stage of plant growth. The first measurements were made April 29 and the second one week later or May 6. Plant number M_4 was discarded after the second measurement due to red spider infestation. The other dates of measurements were May 19 and June 2.

The beans were harvested when ripe and seed measurements were made. Measurements were also made on samples of bulk seed of each variety used for crossing. Two hundred fifty seeds of Robust and 50 each of the other varieties were measured. The mean and standard deviation and coefficient of variation with their probable errors were computed for these data.

The field planting was done June 4 and 5. The purpose of this planting was to compare the various varieties with each other and with the F_1, F_2, and F_3 generations from crosses of these varieties. The beans were planted in rows 103 feet long add

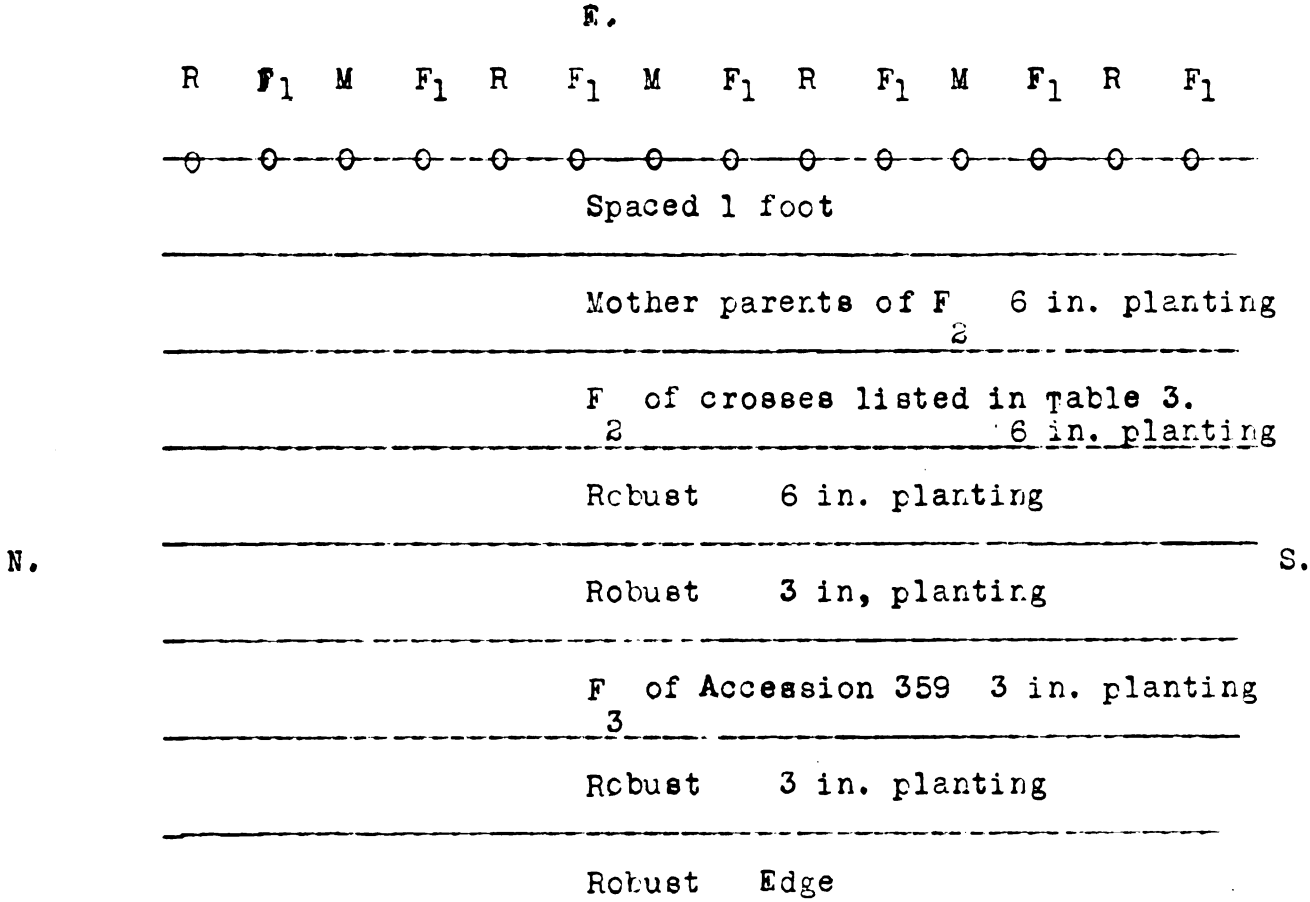
28 inches apart (Figure 1). Beginning at the west, the planting was as follows: one row of Robust for on edge; one row of Robust for test; the F_3 of Ac 359, two more rows of Robust for test; one row F_2 of crosses made in the fall of 1925; one row of the mother parent varieties opposite their respective F_2 progenies; and two rows of the F_1 of the crosses made in the spring of 1926, two feet apart in the row with a Robust and a mother variety alternating between them. In the first four rows the beans were spaced three inches apart, as regular field planting, in the next three rows, six inches apart to allow maximum development of plants; the rest being space one foot apart to compare the F_1 with each parent in as near the same environment as possible.

As the weather was cool, the plants did not grow fast but a high percentage of germination was secured. Wind and sand injured the leaves to such an extent that a few plants died. The first cultivation was on June 29. The weather was dry and the plants became very uneven in size some plants in each variety being much larger than others in the same variety. On July 17 many of the plants were beginning to bloom. The average number of leaves per plant on this date was seven.

Measurements of leaflets began July 26 and were continued until the necessary data had been taken. The mean, standard deviation, and coefficient of variation with their probable errors were computed. The biometric constants were arranged in tables for convenience of comparison and will be taken up in order in the discussion of the data.

Plate I

Plan of 1926 Field Planting.



Rows 28 inches apart.

W.

R- Robust

F1 - F1 listed in Table 4.

M- Mother parent of the F1.

Example 1.

Guess, correction, class range method used to compute biometric constants.

V	f	$\frac{v-g}{w}$	$f\left(\frac{v-g}{w}\right)$	$f\left(\frac{v-g}{w}\right)^2$
6.5	3	-2	-6	12
7	12	-1	-12	12
7.5	25	0	-18	
8	10	+1	+10	10
	50		50)- 8	34
			-.16 = C'	50)32.72
				.6544

$$C = \left(\frac{\Sigma f \frac{v-g}{w}}{N}\right) W = -.16 \times .5 = -.08$$

$$\sqrt{.6544} = .8089$$

$$.8089 \times .5 = .4044$$

$$\Sigma f\left(\frac{v-g}{w}\right) C = -.16 \times -8. = +1.28$$

W = .5
g = 7.5
C = -.08
M = 7.4200 ± .0385

$$\sigma = W \sqrt{\frac{\Sigma f\left(\frac{v-g}{w}\right)^2 - C' \; f\left(\frac{v-g}{w}\right)}{N}}$$

σ = .4044 ± .0273

$$Em = \frac{.6745\sigma}{\sqrt{n}} = .6745 \times .4044 = .2728$$
$$.2728 \div 7.07 = .0385$$

$$E\sigma = \frac{.6745\sigma}{\sqrt{2n}} = .6745 \times .4044 = .2728$$
$$.2728 \div 10 = .0273$$

$$CV = \frac{100\,\sigma}{M} = \frac{40.44}{7.42} = 5.45$$

$$Ecv = \frac{6745CV}{\sqrt{2n}} = \frac{.6745 \times 5.45}{10} = .367$$

Example 2.

Width		Length		$\frac{W}{L}$		Petiole		$\frac{W}{LxP}$
61	÷	84	=	.7261	÷	23	=	.02156
73	÷	95	=	.7684	÷	28	=	.02744
41	÷	53	=	.7735	÷	13	=	.0565
70	÷	98	=	.7142	÷	26	=	.02746
50	÷	68	=	.7352	÷	12	=	.06126
65	÷	86	=	.7558	÷	18	=	.04198
67	÷	93	=	.7204	÷	23	=	.03132
40	÷	57	=	.7017	÷	12	=	.05847
58	÷	75	=	.7733	÷	14	=	.05524
55	÷	70	=	.7857	÷	13	=	.06043

$M(\frac{W}{L}) = .7450 \pm .0057$

$\sigma(\frac{W}{L}) = .0268 \pm .00404$

$M(\frac{W}{LxP}) = .0460 \pm .00304$

$\sigma(\frac{W}{LxP}) = .01428 \pm .00215$

The ratios as shown in this table were computed for each plant and the Standard Deviation and Mean with their probable errors were computed as indicated in example 1.

W--Width of terminal leaflet, in m m.

L--Length of terminal leaflet, in m m.

P--Length of petiole, in m.m.

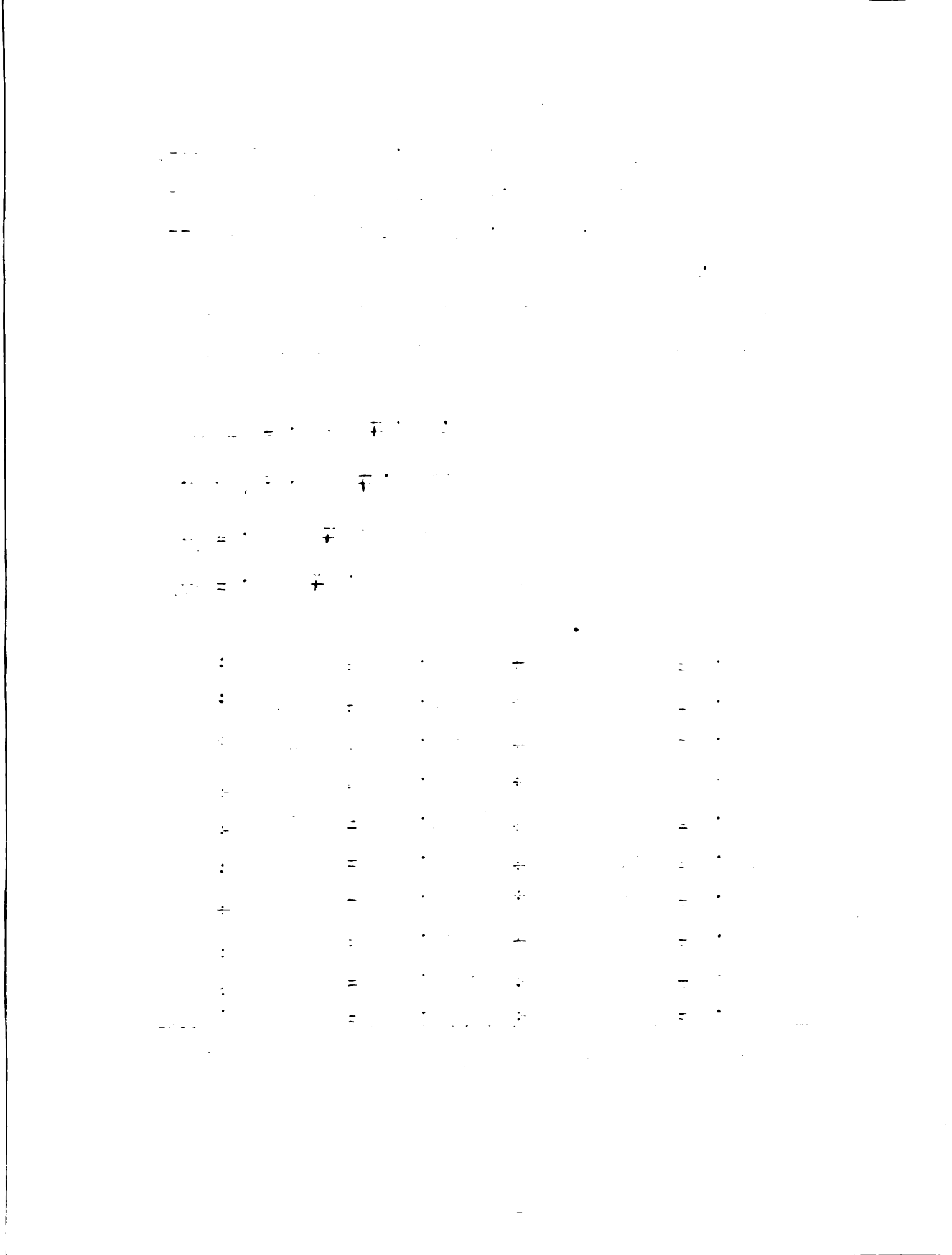


Table I.

Plant selections made in the field from the 1925 crop.

Variety	Accession number	Number of plants selected
Robust	313	6
Early Prolific	306	5
F_1 of Early Prolific x Robust	359	13
Darling	142	4
Crawford	153	4
Hunter	155	4
Putnam	167	4
Greiner	214	4
Canter	221	4
Miller	235	4
Pliter	254	4
1200-1	265	4
Hoggan	266	4
Bingham	358	4

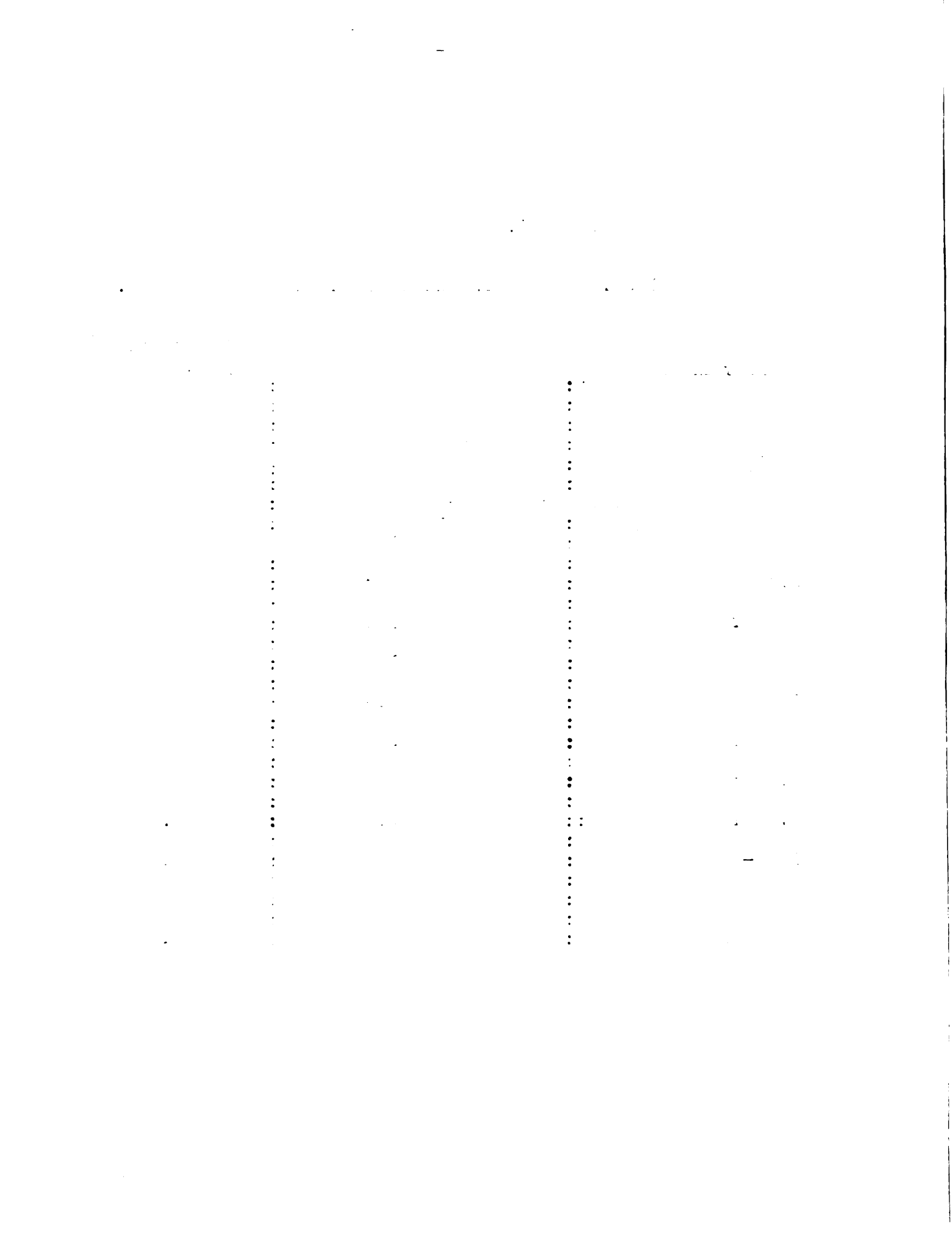


Table 2.

Varieties used in the January 1926 planting.

Variety	Accession Number
Robust	313
Darling	142
Crawford	153
Hunter	155
Greiner	214
Pliter	254
1200-1	265
Hoggan	266
Bingham	358
Early Prolific	306
Early Wonder	223
Mexican Tree	210
F_2 of Ac 359	359

Table 3.

List of crosses made in the greenhouse during November and December 1925.

Parents	Accession of F_1	Number of beans obtained
Crawford x Robust	362	4
Darling x Robust	363	2
Futnam & Robust	364	1
Fliter x Robust	365	1
1200-1 x Robust	366	3
Hoggan (531602) x Robust	367	4
Hoggan (531603) x Robust	368	2
Bingham (531501) x Robust	369	8
Bingham (533502) x Robust	370	3
Greiner x Robust	371	5
Canter x Robust	372	8

Table 4.

List of crosses made in the greenhouse during March and April 1926.

Parents	Accession of F_1	Number of beans obtained
Early Prolific x Robust	375	17
Darling x Robust	376	10
Hunter x Robust	377	8
Crawford x Robust	378	37
1200-1 x Robust	379	72
Mexican Tree x Robust	380	7
Greiner x Robust	381	35

Table 5.

Mean widths and lengths of Robust seed, measured in groups of 50 beans taken from bulk seed of the 1925 field crop.

a..

Group #	Width	CV	Length	CV
1	6.820 ± .0140	2.16 ± .146	8.630 ± .0629	7.56 ± .509
2	7.050 ± .0335	5.16 ± .347	8.949 ± .0682	7.91 ± .533
3	6.870 ± .0397	5.96 ± .401	8.630 ± .0779	9.37 ± ,631

b.. Means of 50 seeds taken from individual plants selected in the fields in 1925.

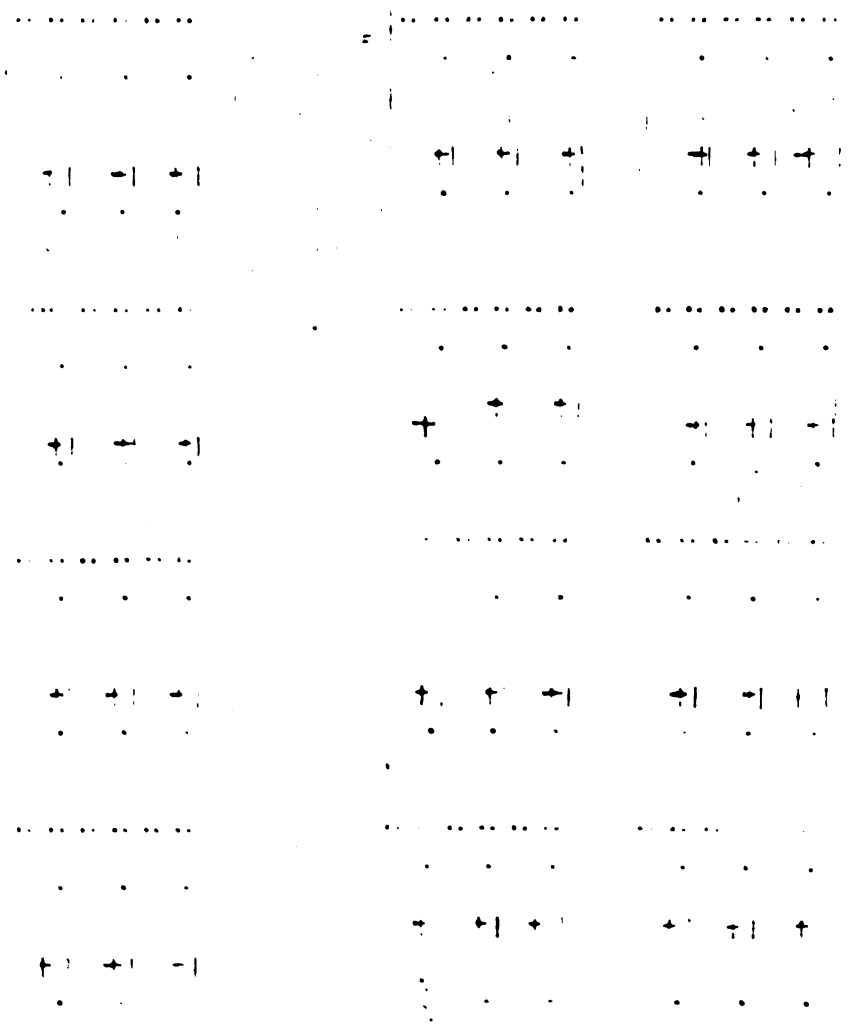
	Robust			Early Prolific	
Plant #	M Length	CV		M. Length	CV
01	9.290 ± .0525	5.38 ± .362		8.830 ± .0400	4.75 ± .320
02	9.120 ± .0426	4.84 ± .326		8.820 ± .0430	4.77 ± .321
03	8.620 ± .0450	5.41 ± .364		8.750 ± .0390	4.79 ± .319
	M. Width				
01	7.090 ± .0430	6.40 ± .431		6.260 ± .0330	5.58 ± .376
02	8.860 ± .0400	6.18 ± .416		6.260 ± .0440	7.34 ± .494
03	6.250 ± .0430	7.20 ± .485		6.230 ± .0330	5.61 ± .378

M-- Mean

CV-- Coefficient of Variation.

Measurements in millimeters.

Table 5 is a list of biometrical constants computed from seed measurements. Section (a) deals with bulk seed. Three groups of 50 beans each were taken at random. The mean widths and mean lengths are given. Section (b)is a comparison of Robust and Early Prolific plants. Fifty beans were measured from each plant and computations were made. While the range



in means of both length and width is a trifle greater for Robust the means of the Early Prolific fall within the range with one exception, the mean width of plant #03. From the stand point of the coefficients of variation there is no significant difference in the two varieties.

Table 6.

Coefficients of correlation of length to width of Robust beans taken from plants selected in the field in 1925.

Plant #	Coefficient	Plant #	Coefficient
01	.8606 ± .0370	.04	.3900 ± .0816
02	.8606 ± .0370	.05	.4369 ± .0779
03	.2400 ± .0900	.06	.8980 ± .0187

The coefficients of correlation given in this table were calculated from field selected plants, 50 beans being measured from each plant. As the range is from (06) .8980 ± .0187 to (03) .2400 ± .0900 the variablilty in the correlation coefficient is too great to be of any value for use as a criterion of identification.

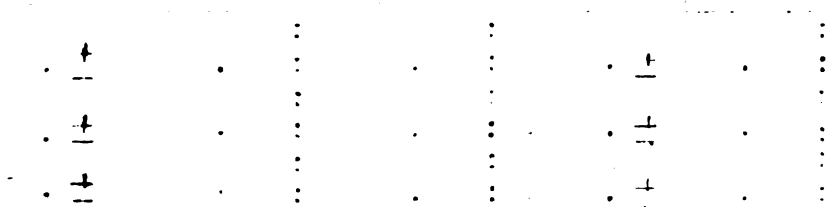


Table 7.

Biometric constants taken from leaflet and petiole measurements made in the green house upon Robust, 1200-1, and F_1 plants.

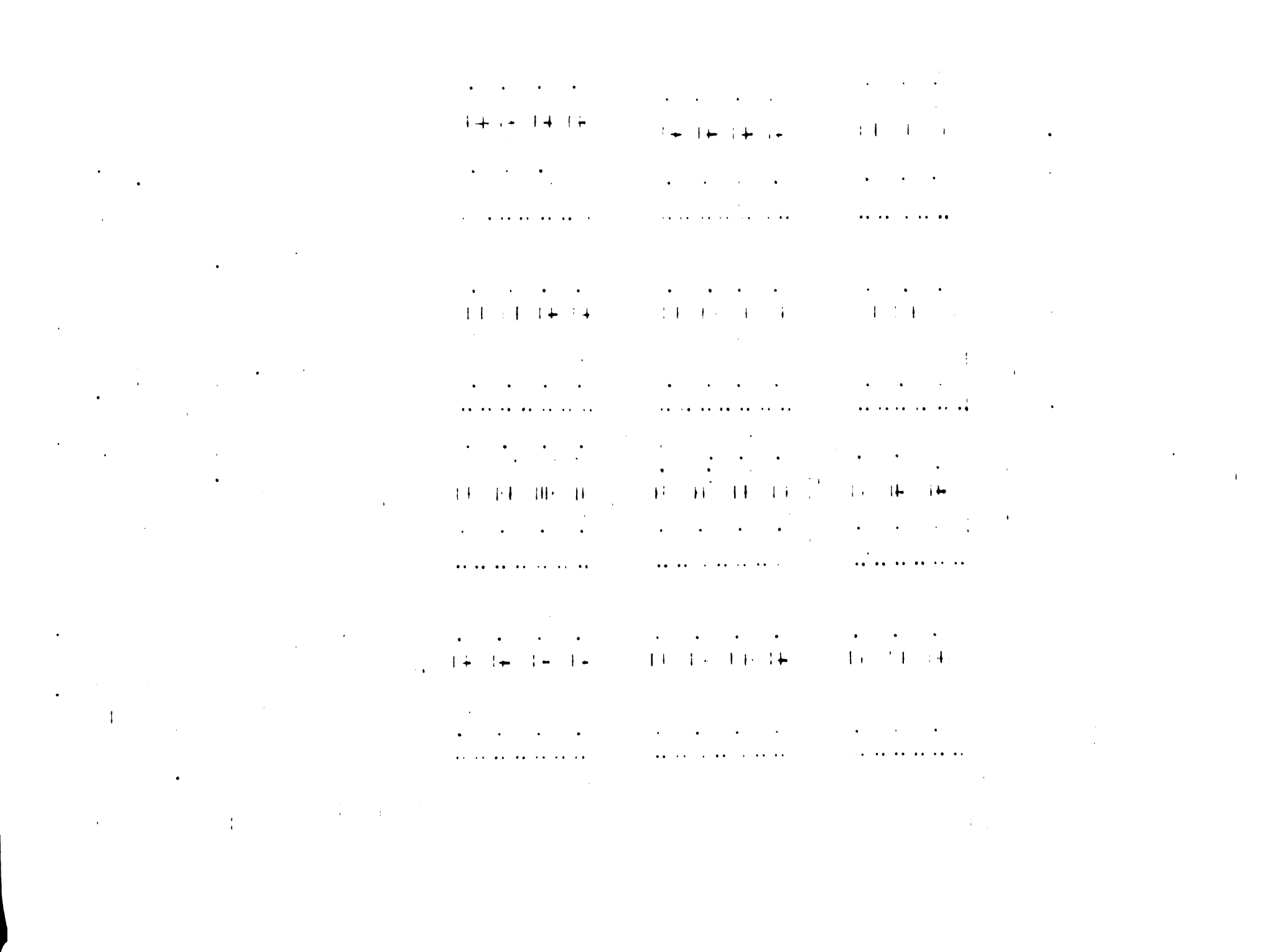
Plant #	M $\frac{W}{L}$	CV	M $\frac{W}{LxF}$	CV
		Robust		
60201	.7400 ± .0117	7.43 ± 1.12	.0500 ± .0040	40.00 ± 6.51
60202	.7000 ± .0140	9.55 ± 1.44	.0440 ± .0030	34.09 ± 5.75
60203	.6250 ± .0220	17.87 ± 2.75	.0600 ± .0030	29.16 ± 4.82
		1200-1		
60801	.7300 ± .0226	10.74 ± 1.62	.0725 ± .0077	35.03 ± 5.92
60802	.6750 ± .0164	8.07 ± 1.21	.0925 ± .0056	20.71 ± 3.23
60803	.7084 ± .0102	5.25 ± .791	.0666 ± .0062	33.63 ± 5.57
60804	.7585 ± .0127	6.07 ± .915	.0750 ± .0066	31.86 ± 5.17
		F_1 Ac 366 1200-1 x Robust		
62401	.7750 ± .0136	9.44 ± 1.43	.0450 ± .0027	28.44 ± 4.65
62402	.7500 ± .0109	6.82 ± 1.02	.0640 ± .0056	41.40 ± 7.17
62501	.7917 ± .1089	8.67 ± 1.30	.0625 ± .0039	23.04 ± 3.64
62502	.7166 ± .0252	13.14 ± 2.03	.0750 ± .0103	50.00 ± 9.22

W-- Width of terminal leaflet in m m

L-Length of terminal leaflet in m m

F-- Length of petiole in m m

Table 7 is a comparison of Robust, 1200-1, and the F_1 of this cross grown in the green house. The means of the ratios $\frac{W}{L}$ of Robust have a spread of .1150, of 1200-1, .0835 and of the F_1, .0751 showing just a slight difference in spread while the means themselves fall pretty closely in the same range. In the ratios $\frac{W}{LxF}$ the spread for Robust is .0160, for 1200-1, .0259 and for the F_1 .0300. The spread here is in the reverse order of the



means $\frac{W}{L}$, the F_1 having the greatest and Robust the least. Again there are means in all strains practically the same. At the same time there is no significant difference in variation of the three strains.

Table 8.

A comparison of biometric constants calculated from varieties and F_1 plans grown in the green house in the spring of 1926.

Plant #	M $\frac{W}{L}$	CV	M $\frac{W}{L \times P}$	CV
	Early Prolific			
60402	.7700 ± .0128	7.79 ± 1.17	.0900 ± .0245	61.11 ± 12.98
60403	.7950 ± .0152	8.98 ± 1.35	.0850 ± .0157	87.05 ± 21.00
60404	.7250 ± .0098	6.37 ± .960	.0697 ± .0067	45.48 ± 8.08
	Hunter			
60601	.7450 ± .0404	25.46 ± 4.02	.0900 ± .0096	50.00 ± 9.22
60602	.8000 ± .0185	10.87 ± 1.60	.0900 ± .0107	55.50 ± 10.53
60603	.8000 ± .0195	10.75 ± 1.59	.0900 ± .0125	64.44 ± 13.01
	Early Wonder			
61101	.7125 ± .0166	9.75 ± 1.44	.0718 ± .0016	9.33 ± 1.40
61102	.7200 ± .0074	4.86 ± .732	.0360 ± .0026	15.10 ± 2.34
	F_1 Ac 369 Bingham x Robust			
61901	.7900 ± .0195	11.57 ± 1.37	.0825 ± .0046	26.30 ± 4.30
	F_1 Ac 363 Darling x Robust			
62301	.7500 ± .0134	8.36 ± 1.26	.0825 ± .0141	87.87 ± 21.05
62302	.7916 ± .0152	6.97 ± 1.04	.0916 ± .0200	79.14 ± 17.77

W--Width of terminal leaflet in m m

L--Length of terminal leaflet in m m

P--Length of petiole in m m

Table 8 is a list of biometrical constants for three varieties and F_1s of crosses of different varieties x Robust. The mother parents of these F_1s were not measured on account of the small number of leaves present and the F_1s of the parent varieties given here were measured for the same reason. This table is given to show how easily F_1s or mother varieties may be confused with each other unless properly labled and kept separate.

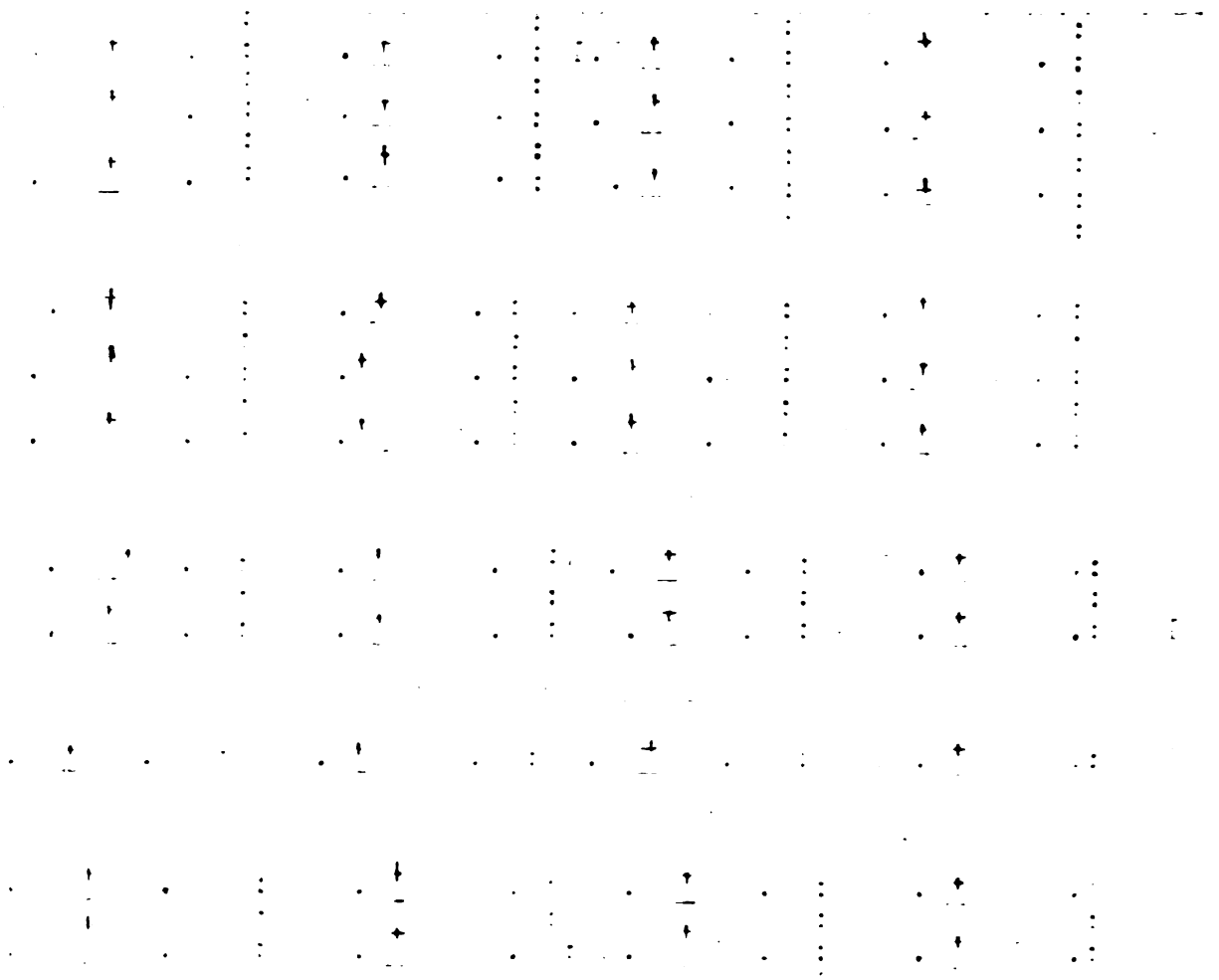


Table 9.

Biometric constants computed from terminal leaflets and petioles of Robust plants measured at different times in the green house.

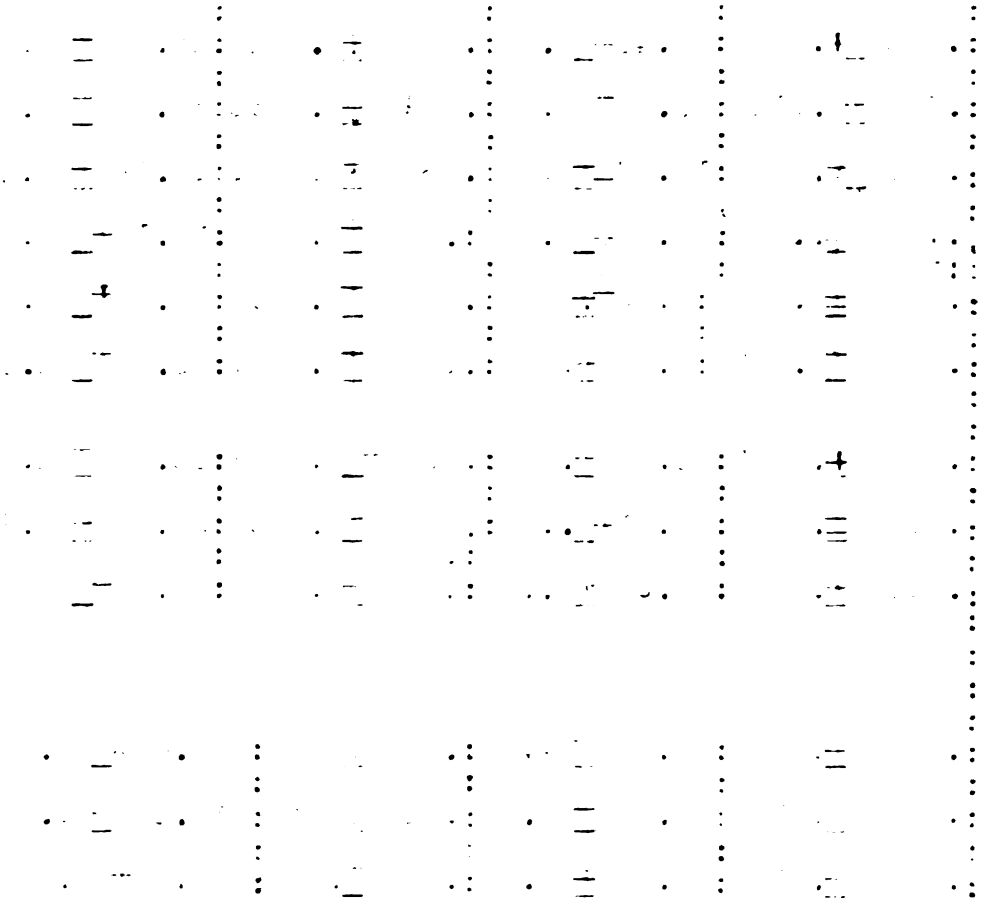
Plant #	Date	M $\frac{W}{L}$	CV	M $\frac{W}{L \times P}$	CV
M 1	April 19	.7400 ± .0117	7.45 ± 1.12	.0500 ± .0040	40.00 ± 6.54
M 2	19	.7000 ± .0140	9.55 ± 1.44	.0440 ± .0030	34.09 ± 5.75
M 3	19	.6250 ± .0230	17.87 ± 2.75	.0600 ± .0030	29.16 ± 4.82
M 1	May 6	.7400 ± .0140	9.45 ± 1.42	.033 ± .0010	18.19 ± 2.84
M_2	6	.7250 ± .0080	5.33 ± .803	.0440 ± .0030	35.45 ± 5.97
M_3	6	.7250 ± .0070	4.55 ± .686	.0440 ± .0027	29.09 ± 4.81
M_1	May 19	.7950 ± .0097	5.76 ± .868	.0675 ± .0057	39.55 ± 6.79
M_2	19	.7300 ± .0128	8.21 ± 1.23	.0475 ± .0035	34.75 ± 5.77
M_3	19	.7250 ± .0067	4.35 ± .655	.0390 ± .0027	32.82 ± 5.30
M_1	June 2	.7450 ± .0057	3.59 ± .541	.0460 ± .0030	30.86 ± 5.02
M_2	2	.7500 ± .0190	11.92 ± 1.37	.0440 ± .0015	15.90 ± 2.82
M_3	2	.7800 ± .0128	7.69 ± 1.16	.0400 ± .0028	33.50 ± 5.90

W--Width of terminal leaflet in m m

L--Length of terminal leaflet in m m

P--Length of terminal petiole in m m

Table 9 deals with biometric constants computed from measurements of Robust leaflets and petioles on different dates to determine the influence of the state of growth on the characters considered. All of the plants were measured on the dates indicated. The plant m_1 has the same mean ratio $\frac{W}{L}$ on April 19, May 6, and June 2 but has a different mean on May 19.



The mean of the ratio $\frac{W}{LxF}$ was constantly changing and not always in the same direction. The ratio $\frac{W}{L}$ of plant M_2 showed a gradual increase during the entire period while the ratio $\frac{W}{LxF}$ remained practically constant. The plant M_3 increased in the ratio $\frac{W}{L}$ but decreased in the ratio $\frac{W}{LxF}$ till may 19, then remained constant for the ratio $\frac{W}{LxF}$ while the ratio $\frac{W}{L}$ increased to be significantly different during the period from May 19 to June 2.

In comparing plants for the same dates we find that there is a significant difference in the ratios $\frac{W}{L}$ for plants M_1 and M_3 on April 19 but no significant difference for the ratio $\frac{W}{LxF}$. On May 6, these plants were not significantly different for the ratio $\frac{W}{L}$ while on May 19 they were significantly different for both ratios.

Table 10.

Robust, Darling and the F_1 grown in the field in 1926.

Robust

Plant #	$\frac{W}{M\ L}$	CV	$\frac{W}{M\ LxP}$	CV
67101	.8250 ± .0399	22.66 ± 3.54	.0830 ± .0102	56.47 ± 10.75
67102	.6950 ± .0239	16.14 ± 2.48	.0750 ± .0071	44.66 ± 7.80
67103	.8100 ± .0224	13.96 ± 1.98	.0675 ± .0062	42.96 ± 7.50
67104	.7600 ± .0172	10.61 ± 1.60	.0800 ± .0136	80.00 ± 18.20
67105	.7750 ± .0320	19.48 ± 3.04	.0575 ± .0046	37.91 ± 6.40

Darling

613301	.7300 ± .0128	8.21 ± 1.24	.0650 ± .0050	36.15 ± 6.09
613302	.7400 ± .0177	11.21 ± 1.73	.0750 ± .0071	44.66 ± 7.80
613303	.7800 ± .0201	12.30 ± 1.90	.0575 ± .0056	46.43 ± 8.73
613304	.7500 ± .0165	10.32 ± 1.56	.0575 ± .0052	42.43 ± 7.50
613305	.7400 ± .0234	9.41 ± 1.42	.0575 ± .0086	70.08 ± 14.87

F_1 376 Darling X Robust.

617806	.7600 ± .0114	7.07 ± 1.07	.0625 ± .0041	30.88 ± 5.13
617807	.7300 ± .0128	8.21 ± 1.24	.0530 ± .0020	18.30 ± 2.84
617808	.7500 ± .0134	8.41 ± 1.27	.0800 ± .0070	41.37 ± 7.21
617809	.7300 ± .0085	5.47 ± .824	.0540 ± .0017	14.81 ± 2.58
617810	.7300 ± .0159	10.24 ± 1.54	.0500 ± .0028	26.80 ± 4.30

W-- Width of terminal leaflet, in m m

L-- Length of terminal leaflet, in m m

P-- Length of petiole, in m m

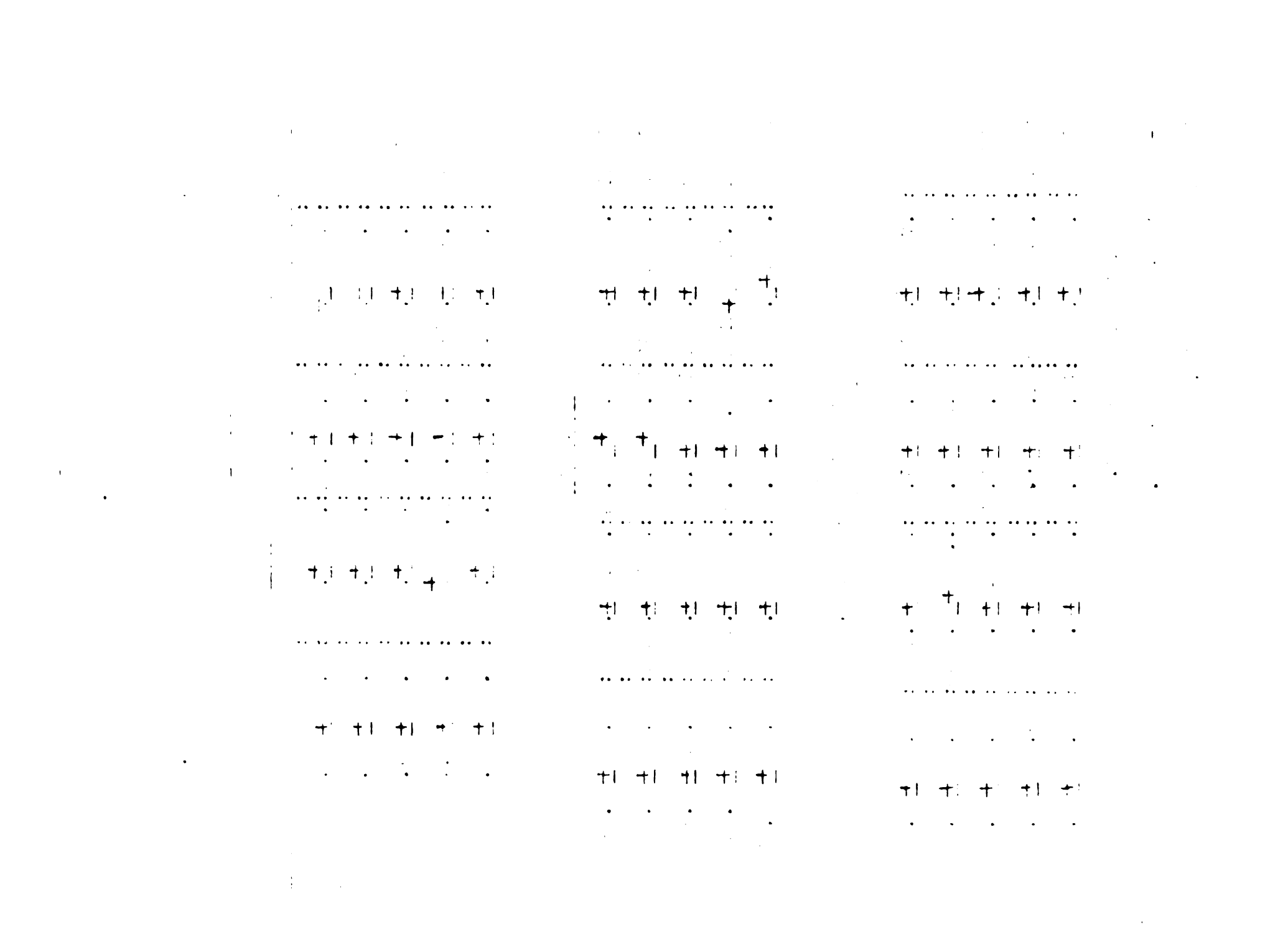


Table 10 gives Robust, Darling and the F_1 of this cross raised in the field of 1926. Robust has a range of .8250 $\pm$ .0299 to .6950 $\pm$ .0239 for the ratio $\frac{W}{L}$ and of .0850 $\pm$ .0102 to .0575 $\pm$ .0046 for the ratios $\frac{W}{LXP}$. Darling has a range of .7800 $\pm$ .0201 to .7300 $\pm$ .0120 for the ratio $\frac{W}{L}$ and .0750 $\pm$.0071 to .0575 $\pm$ .0052 for the ratio $\frac{W}{LXP}$. The F_1 has a range from .7600 $\pm$ .0104 to .7300 $\pm$ .0085 for the ratio $\frac{W}{L}$ and .0800 $\pm$ .0070 to .0500 $\pm$ .0028 for the ratio $\frac{W}{LXP}$. This shows that F_1 would fit into either parent group as far as the means are concerned. However from the coefficients of variation it is seen that the F_1 is more uniform than either parent group but not significantly different from them on the basis of probable error. The F_1 plant 617809 is a very uniform plant and just from casual observation appears in a class by itself however there is no significant difference between this plant and 613301 in the Darling group.

Table 11.

A comparison or Robust, Mexican Tree and the F1 of this cross grown in the field 1926.

Plant #	M W/L	CV	M W/LxP	CV
Robust				
67101	.8250 ± .0299	22.66 ± 3.54	.0850 ± .0102	56.47 ± 10.75
67102	.6950 ± .0239	12.96 ± 1.98	.0750 ± .0071	44.66 ± 7.80
67103	.8100 ± .0224	12.96 ± 1.98	.0675 ± .0062	42.96 ± 7.50
67104	.7600 ± .0173	10.61 ± 1.60	.0800 ± .0136	80.00 ± 18.20
67105	.7700 ± .0320	19.48 ± 3.04	.0575 ± .0046	37.91 ± 6.40
Mexican Tree				
619101	.7100 ± .0141	9.33 ± 1.41	.0335 ± .0019	25.35 ± 4.01
619102	.7650 ± .0250	15.68 ± 2.35	.0385 ± .0017	18.96 ± 2.85
619103	.7200 ± .0097	6.36 ± .959	.0440 ± .0014	15.90 ± 2.37
619104	.7400 ± .0170	10.81 ± 1.63	.0380 ± .0018	12.89 ± 1.97
F_1 Ac 280 Mexican Tree x Robust				
619001	.7100 ± .0104	6.88 ± 1.04	.0450 ± .0034	35.55 ± 5.94
619002	.7300 ± .0128	8.21 ± 1.24	.0425 ± .0032	35.29 ± 5.92
619003	.7400 ± .0114	7.27 ± 1.10	.0500 ± .0049	46.00 ± 8.22
619004	.7800 ± .0201	12.30 ± 1.96	.0450 ± .0034	35.55 ± 5.93
619005	.7200 ± .0136	8.88 ± 1.34	.0475 ± .0035	34.73 ± 5.78

W--Width of terminal leaflet in m m

L--Length of terminal leaflet in m m

P--Length of petiole in m m

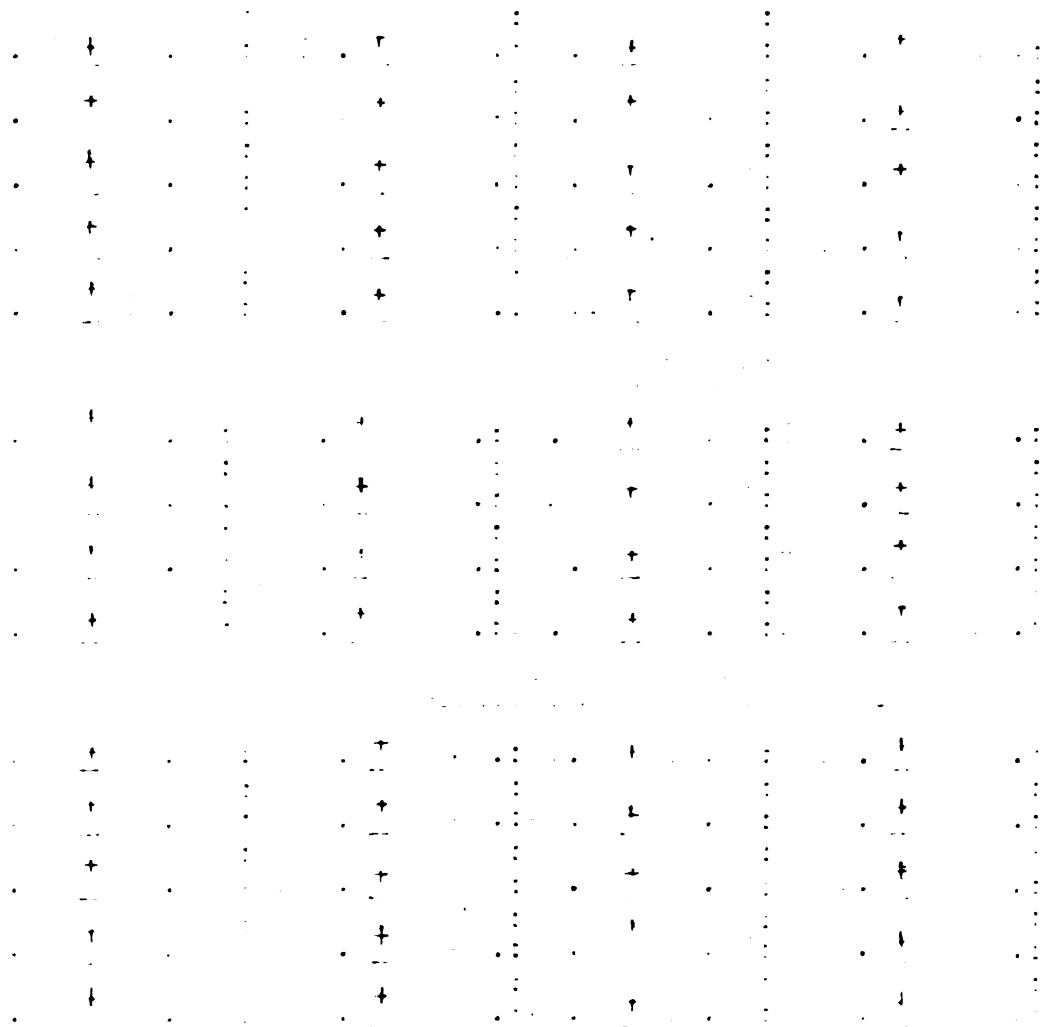


Table 11 is a comparison of Robust, Mexican Tree and the F_1 of this cross. Robust has a spread of .8250 ± .0399 to .6950 ± .0239 for the ratio of $\frac{W}{L}$ and .0850 ± .0102 to .0575 ± .0046 for the ratio $\frac{W}{LxF}$. Mexican Tree has a spread of .7650 ± .0250 to .7100 ± .0141 for the ratio $\frac{W}{L}$ and .0440 ± .0014 to .0335 ± .0019 for the ratio $\frac{W}{LxF}$. The F_1 has a spread of .7800 ± .0201 to .7100 ± .0104 for the ratio $\frac{W}{L}$ and .0500 ± .0049 to .0425 ± .0032 for the ratio $\frac{W}{L}$ xP. Here again the means of the F_1 could be classed with either parent group. The coefficients of variation show, however, that for the ratio $\frac{W}{LxP}$ there is greater variation in the F_1 than in the mother parent indicating that the Robust parent may have affected the F_1. Putting them on the basis of probable error there is no significant difference between the F_1 and the mother parent.

Table 12.

Comparing Robust, Crawford and the F_1 of this cross grown in the field 1926.

ROBUST

Plant #	$\frac{W}{L}$ M	CV	$\frac{W}{L \times P}$ M	CV
67101	.8250 ± .0299	22.66 ± 3.54	.0850 ± .0102	56.47 ± 10.75
67102	.6950 ± .0239	16.14 ± 2.48	.0750 ± .0071	44.66 ± 7.80
67103	.8100 ± .0224	12.96 ± 1.98	.0675 ± .0062	42.96 ± 7.50
67104	.7600 ± .0172	10.61 ± 1.60	.0800 ± .0136	80.00 ± 18.20
67105	.7700 ± .0320	19.48 ± 2.04	.0575 ± .0046	37.91 ± 6.90

CRAWFORD

612401	.7750 ± .0373	22.59 ± 3.54	.0800 ± .0136	80.00 ± 18.20
612402	.8050 ± .0278	16.22 ± 2.50	.0675 ± .0046	32.14 ± 5.28
612403	.7250 ± .0170	11.03 ± 1.71	.0786 ± .0111	66.15 ± 13.55
612404	.7350 ± .0212	13.52 ± 3.04	.0650 ± .0060	42.53 ± 7.67
612405	.7800 ± .0201	12.30 ± 1.96	.0750 ± .0042	26.80 ± 4.30

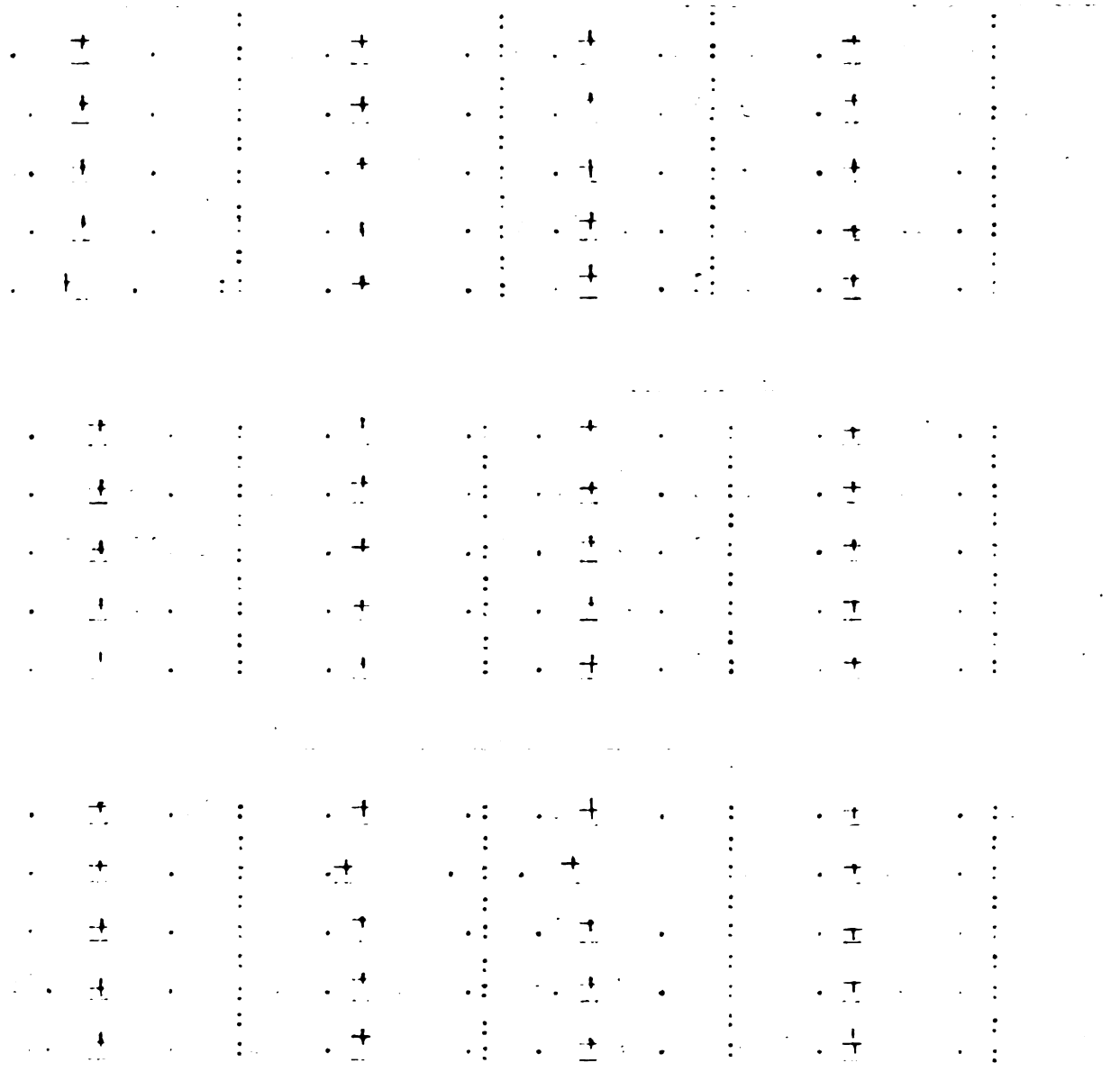
F_1 Ac 378 Crawford X Robust

618401	.7700 ± .0159	9.66 ± 1.46	.0570 ± .0015	12.98 ± 1.99
618402	.7500 ± .0214	13.40 ± 2.04	.0675 ± .0039	27.70 ± 4.51
618403	.7300 ± .0128	8.21 ± 1.24	.0650 ± .0096	69.33 ± 14.99
618404	.7500 ± .0095	5.96 ± .898	.0525 ± .0036	31.42 ± 5.15
618405	.7000 ± .0106	7.14 ± 1.08	.0475 ± .0026	25.68 ± 4.01

W--Width of terminal leaflet in m m

L--Length of terminal leaflet in m m

P--Length of petiole. in m m



In Table 12 is shown Robust, Crawford, and the F_1 of this cross. Robust has a range in means $\frac{W}{L}$ of .8250 ± .0399 to .6950 ± .0209 and for $\frac{W}{LxF}$ from .0850 ± .0102 to .0575 ± .0046. Crawford has a range from .8050 ± .0278 to .7250 ± .0170 for the mean ratio $\frac{W}{L}$ and from .0800 ± .0136 to .0650 ± .0060 for the means of $\frac{W}{LxF}$. The F_1 has a range from .7700 ± .0159 to .7000 ± .0106 for the means of $\frac{W}{L}$ and from .0675 ± .0039 to .0475 ± .0026 for the means of $\frac{W}{LxF}$. In this table the three groups may be considered identical when based upon variation and upon probable error as the means fall so nearly within the same range.

Table 13.

A comparison of Robust, Early Prolific, and the F_1 grown in the field 1926.

Plant #	M $\frac{W}{L}$	CV	M $\frac{W}{LxP}$	CV
Robust				
67101	.8250 ± .0399	22.66 ± 3.54	.0850 ± .0102	56.47 ± 10.75
67102	.6950 ± .0239	16.14 ± 2.48	.0750 ± .0071	44.66 ± 7.80
67103	.8100 ± .0224	12.96 ± 1.98	.0675 ± .0062	42.96 ± 7.50
67104	.7600 ± .0172	10.61 ± 1.60	.0800 ± .0136	80.00 ± 18.20
67105	.7750 ± .0320	19.48 ± 3.04	.0575 ± .0046	37.91 ± 6.40
Early Prolific				
617601	.6700 ± .0159	11.16 ± 1.72	.0370 ± .0014	18.37 ± 2.82
617602	.7400 ± .0149	9.45 ± 1.43	.0950 ± .0034	35.55 ± 5.92
617603	.7900 ± .0170	10.12 ± 1.85	.0600 ± .0028	22.33 ± 3.57
617604	.7500 ± .0165	10.32 ± 1.53	.0450 ± .0024	22.46 ± 3.70
617605	.7600 ± .0064	3.49 ± .594	.0430 ± .0014	15.81 ± 2.36
F_1 Ac 375 Early Prolific x Robust				
617511	.6500 ± .0095	6.87 ± 1.04	.0410 ± .0017	19.51 ± 3.04
617512	.7300 ± .0085	5.47 ± .824	.0450 ± .0016	17.11 ± 2.70
617513	.7300 ± .0185	11.93 ± 1.74	.0550 ± .0034	29.09 ± 4.82
617514	.6600 ± .0114	8.15 ± 1.23	.0480 ± .0024	24.16 ± 3.83
617515	.7800 ± .0128	7.69 ± 1.16	.0475 ± .0026	25.68 ± 4.01

W--Width of terminal leaflet in m m

L--Length of terminal leaflet in m m

P--Length of petioles in m m

Table 13 gives Robust, Early Prolific and the F_1 grown in the field 1926. Robust has a spread of .8250 $\pm$ .0399 to .6950 $\pm$ .0209 for the means of $\frac{W}{L}$ and of .0850 $\pm$ .0102 to .0575 $\pm$ .0046 for the means of $\frac{W}{LxF}$. The Early Prolific has a spread of .7900 $\pm$ .0170 to .6700 $\pm$ .0159 for the means $\frac{W}{L}$ and of .0950 $\pm$ .0034 to .0370 $\pm$ .0014 for the means of $\frac{W}{LxF}$. The F_1 has a spread of .7800 $\pm$ .0128 to .6500 $\pm$ .0095 for the means $\frac{W}{L}$ and of .0550 $\pm$ .0024 to .0410 $\pm$ .0017 for the means $\frac{W}{L \times P}$. As indicated by this table the means of all three groups fall so nearly in the same range that individual F_1 plants may fit into either parent group. On the basis of variation, there is no significant difference between the F_1 and the other plants.

CONCLUSIONS

1. Seed measurements cannot be used as a criterion of identification of
   (a) F_1 seed from the parent.
   (b) Early Prolific from Robust seed.
   Since a single bean may fall within the range of either parent or in the case of Early Prolific and Robust, single beans from either variety cannot be identified.
2. Coefficients of correlation of length to width of beans cannot be used as a criterion of identification.
   (a) As indicated in Table 6, the range in these values obtained from Robust is great enough to include all varieties tested.
3. F_1 plants of crosses between similar strains of white beans cannot be identified by leaflet and petiole measurements as taken and computed in this experiment.
   (a) Examination of Tables 7-13 shows that whether plants are grown in the green house or in the field, the means of all varieties tested are the same when based upon probable error.
   (b) There may be plants in the same variety which are significantly different from each other.
   (c) There are plants in each variety tested identical or nearly so with plants in each of the other varieties.

4. On the basis of the coefficients of variability there is no significant difference in F_1 plants and the parent varieties.
   (a) In Table 10 the F_1 of the Darling x Robust cross appears more uniform than either parent while in Table 11 the F_1 of the Mexican Tree x Robust is apparently more variable than the mother parent. Placing these two F_1 progenies on the basis of probable error there is no significant difference in either case from the mother parent.
5. Bean plants are constantly changing in the ratios $\frac{W}{L}$ and $\frac{W}{LxF}$ as indicated by Table 9.
   (a) A plant may remain constant for one ratio for several weeks while the other ratio changes or both ratios may change as to be significantly different in a period of two weeks.
   (b) One ratio may become wider as the other becomes narrower showing that the ratios change independently of each other.
   (3) A plant may remain constant for both ratios for six weeks which was the duration of this part of the experiment.

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