THE INHERITANCE OF NUMBER OF SEEDS PER POD AND LEAFLET SHAPE IN THE SOYBEAN

BY

WAYNE ELWIN DOMINGO

B. S., University of Nebraska, 1938
M. S., Utah State Agricultural College, 1940

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE SCHOOL OF THE UNIVERSITY
OF ILLINOIS, 1942

URBANA, ILLINOIS

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

March 31, 1942

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Wayne Elwin Domingo

ENTITLED The Inheritance of Number of Seeds Per Pod and Leaflet Shape in the Soybean

BE ACCEPTED* AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Doctor of Philosophy

C. M. Woodworth
In Charge of Thesis

W L Burlison
Head of Department

Recommendation concurred in†

E. Roberts
John T. Buchholz
Geo H Dungan

Committee on Final Examination†

*Subject to successful final examination in the case of the doctorate.
†Required for doctor's degree but not for master's.

1000—9-41—22037-S

TABLE OF CONTENTS

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation for the helpful advice and suggestions of Dr. C. M. Woodworth during the course of these investigations and the writing of the thesis.

THE INHERITANCE OF NUMBER OF SEEDS PER POD AND LEAFLET SHAPE IN THE SOYBEAN

I. INTRODUCTION

The character "number of seeds per pod" has been shown by Woodworth (7)[1/] to be one of the several obvious characters which contribute to yield in the soybean, Soja max (L.) Piper. A clear understanding of the inheritance of these characters, as well as of the relations between them, is necessary in order to ascertain more accurately the possibility of obtaining all of them in the highest degree in one variety. This paper reports a study of the inheritance of number of seeds per pod and leaflet shape. The latter character was included because of certain evidences of linkage between it and number of seeds per pod.

Soybean pods contain from one to five seeds. The plants of a given strain have either a majority of one-, two-, three-, or four-seeded pods or large percentages of any two consecutive classes from one to four. There is little variation in seeds-per-pod values of plants within a variety.

The terminal leaflet of most soybean varieties is ovate in shape; a few varieties have lanceolate leaflets and one variety is known with oval leaflets, Figure 1. The lateral leaflets, although of the same general shape as the terminal leaflets, are somewhat asymetrical and therefore have not been considered in this study.

1/ Numbers in parentheses refer to "Literature Cited," page 44.

Figure 1. Terminal leaflets of soybean plants; ovate or normal; lanceolate or narrow of Types 114, 173, and 174; and oval of Type 122.

II. REVIEW OF LITERATURE

Nagai (1) reported a cross between the Kaimame variety, which had a majority of three-seeded pods, and the Akatsuka variety, which had a majority of two-seeded pods. Approximately 70 percent of the pods in the F_1 were two-seeded, and approximately 70 percent of the F_2 segregates resembled the parent with the lower seeds-per-pod value.

Data through the F_4 generation are presented by Takahashi (4) on a cross between Wearuoong, a variety with normal leaflets and a majority of two-seeded pods, and Yanta, a variety with narrow leaflets and a majority of three- and four-seeded pods. A good fit to a 3:1 ratio for number of seeds per pod was obtained when he divided the F_2 plants into two classes according to whether less than 10 percent or more than 10 percent, respectively, of the pods from a given plant were four-seeded. He assumed that the parents differed by a single gene and assigned to that allelomorphic pair the symbols F and f. The choice of 10 percent as a basis for separation was somewhat arbitrary; 10 percent was the upper limit of percent of four-seeded pods found among plants of the two-seeded variety as well as the upper limit of percent of four-seeded pods among plants of the normal leaflet class of the F_2 population of his cross. The choice of either 6 percent or 16 percent as the basis of separation would have resulted in deviations from a 3:1 ratio greater than would be expected by chance one time in twenty. The F_2 plants segregated in a 3:1 ratio of normal-leaflet plants to narrow-leaflet plants. The work of Takahashi and Fukuyama (5) and of Woodworth (7) indicated this same relationship and Woodworth (7) assigned the symbols Na and na to the allelomorphic genes involved. Linkage relations between narrow leaflet and high seeds-per-pod value were apparent in F_3 and later generations and the ratios obtained could be explained on the basis of 10 percent crossing over.

III. MATERIALS AND METHODS

The mean seeds-per-pod values of the parental types available for crosses ranged from 1.05 ± 0.01 for T 122 to 3.59 ± 0.03 for T 114.[1/] Of the several crosses made, 16, including 3 reciprocals, were carried through the F_2 generation, with seeds-per-pod values and leaflet-shape classifications obtained on individual plants of the parental, F_1, and F_2 generations. The crosses were made in the summer of 1940; the F_1 plants were grown in the greenhouse in the winter of 1940-41; and the parental types and the F_2 generations, along with a few F_1 plants, were grown in the field in the summer of 1941. The seeds-per-pod values of the F_1 plants grown in the greenhouse are not comparable with the parental and F_2 generations grown in the field because of the dissimilarity of environmental conditions. The few F_1 plants grown in the field the same season as the parental and F_2 generations are used for such comparison.

All of the seeds available for each F_2 generation, along with its reciprocal, were spaced at 4-inch intervals in consecutive rod rows spaced 2 feet apart bordered on one side by one row (50 seeds) of one parent and on the other side by one row of the other parent. After harvest, the pods were pulled from the plants and the number of one-, two-, three-, four-, and five-seeded pods recorded for each plant. Aborted seeds and tiny organs which were probably unfertilized or aborted ovules were included since they were considered potential seeds. The number of potential seeds for each plant was

1/ In accordance with Illinois Agricultural Experiment Station procedure, the strains used as parents have each been given a "type" number (abbreviated T) and the crosses have each been given a cross number.

obtained by summating the number of one-seeded pods multiplied by one, the number of two-seeded pods multiplied by two, etc. A seeds-per-pod value for each plant was calculated by dividing the total number of potential seeds by the total number of pods. All data were taken by the same individual.

Leaflet-shape classifications of all populations were made by observation when the plants had reached approximately their maximum height. Difficulty was encountered in classifying some of the F_2 segregates. In a few crosses several leaflet measurements were made of dimensional relations in which the parents were believed to differ in anticipation of segregation for leaflet indices which would be more precise than segregation for general shape. Classification of difficult cases would thereby be facilitated. The measurements were made on 5 different terminal leaflets of each plant of the population at approximately equal intervals from the base of the plant to the top. The indices obtained on parental types and their F_2 generations segregating for leaflet shape were (a) the width of the leaflet at its widest point divided by its length, (b) the distance from the base of the leaflet to its widest point divided by its total length, and (c) the size of the angle formed by the two margins of the basal portion of the leaflet. The five values obtained on one plant for one index were averaged to give one index for the plant.

Additional data were obtained from earlier crosses made at the Experiment Station by the Department of Agronomy of the University of Illinois in cooperation with the Division of Forage

Crops and Diseases of the United States Department of Agriculture. All of the data on crosses numbered 114, 144, 159-160 (reciprocals), 163, 173, 177-178, 179, and 180-181 reported in this paper were collected prior to the writer's arrival at the Station in 1940. Only normally filled and aborted seeds were counted in these classifications. The F_2 generation of cross 480 was grown in the summer of 1940. It had been classified by Experiment Station workers according to leaflet shape and the writer took data on number of seeds per pod. Twenty-five seeds from each of 25 plants selected at random from the F_2 generation of cross 480 were planted at 4-inch intervals in rows 2 feet apart in the 1941 plots. Seeds-per-pod and leaflet-shape classification were made on these populations, and correlation coefficients were calculated between seeds-per-pod values of F_2 plants and their respective F_3 means and coefficients of variability. Station workers made leaflet-shape classifications on plants of the F_2 generation of station cross 655 in the summer of 1941.

In Table 1 are presented the parents of each cross, the mean seeds-per-pod value and leaflet shape of most of the parental types and of the field-grown F_1 plants, and the mean seeds-per-pod values and coefficients of skewness for most of the F_2 populations.

In order to obtain uniformity of area under the F_2 histograms the number in each class is expressed in percent of the total rather than in actual numbers; this should be considered in studying the graphs, especially those with a low number of plants. Data from which each of the graphs were made are presented in the appendix.

Table 1.—The Crosses Reported, the Mean Seeds-Per-Pod Values, and Leaflet Shapes of Most of the Parental Types and of the Field-Grown F_1 Plants, and the Mean Seeds-Per-Pod Values and Coefficients of Skewness of Most of the F_2 Populations

Cross number	P_1 Type	P_1 Seeds per pod	P_1 Leaflet shape	P_2 Type	P_2 Seeds per pod	P_2 Leaflet shape	Field-grown F_1 Seeds per pod	Field-grown F_1 Leaflet shape	F_2 N	F_2 Seeds per pod	F_2 Skewness
497	122	1.06 ± 0.01	oval	6	2.42 ± 0.01	normal			109	1.92 ± 0.03	-0.588
498	122		oval	48		normal			64		
500	122	1.09 ± 0.01	oval	10	2.93 ± 0.01	normal	2.11(2)[a/]	normal	215	2.04 ± 0.03	-0.354
501	122	1.05 ± 0.01	oval	174	3.37 ± 0.02	narrow			79	2.06 ± 0.05	-0.143
502	6		normal	122		oval			38		
503	6	2.42 ± 0.01	normal	174	3.36 ± 0.02	narrow			90	2.66 ± 0.09	0.214
504	122	1.05 ± 0.01	oval	38	2.08 ± 0.01	normal	1.97(2)	normal	88	1.76 ± 0.04	-0.409
507	38	2.14 ± 0.01	normal	174	3.41 ± 0.02	narrow			168	2.56 ± 0.02	0.531
508	48	2.08 ± 0.01	normal	122	1.06 ± 0.01	oval	1.94(3)	normal	178	1.80 ± 0.02	-0.697
511-523	48	2.08 ± 0.01	normal	114	3.51 ± 0.04	narrow			202	2.49 ± 0.02	0.818
512	111	2.31 ± 0.02	normal	10	2.95 ± 0.01	normal	2.78 (2)	normal	68	2.77 ± 0.02	-0.412
513-519	111	2.31 ± 0.02	normal	34	2.92 ± 0.01	normal	2.88(6)	normal	71	2.76 ± 0.02	-0.571
515	10		normal	122		oval			326		
516-524	10	2.93 ± 0.01	normal	114	3.67 ± 0.02	narrow	2.97(15)	normal	109	3.08 ± 0.02	0.261
520	34	2.92 ± 0.01	normal	174	3.36 ± 0.02	narrow			49	2.92 ± 0.02	-0.063
522	114	3.67 ± 0.02	narrow	122	1.05 ± 0.01	oval			250	2.09 ± 0.02	0.171
525	114	3.51 ± 0.04	narrow	34	3.01 ± 0.02	normal	2.91(2)	normal	57	3.02 ± 0.02	0.000
527	174	3.41 ± 0.02	narrow	48	2.10 ± 0.01	normal	2.78(2)	normal	59	3.01 ± 0.04	0.286
529	174	3.37 ± 0.02	narrow	10	2.95 ± 0.01	normal	2.92(6)	normal	190	3.06 ± 0.01	0.211
Station crosses											
114	8	2.05 ± 0.02		10	2.60 ± 0.02				104	2.29 ± 0.02	-0.816
144	13	2.62 ± 0.02		Fasc.	1.80 ± 0.03				104	1.93 ± 0.03	-0.333
157	10	2.65 ± 0.01		Det.	2.08 ± 0.01				71	2.50 ± 0.02	-0.889
159-160	Korean	1.72 ± 0.02		63	2.47 ± 0.02				294	2.10 ± 0.02	0.093
163	109	2.96 ± 0.04		Det.	1.99 ± 0.02				165	2.32 ± 0.02	1.036
173	113	3.14 ± 0.03		Fasc.	1.59 ± 0.04				60	2.18 ± 0.04	0.484
177-178	109	3.25 ± 0.04		8	2.12 ± 0.02				302	2.58 ± 0.02	0.029
179	10	2.72 ± 0.02		109	3.35 ± 0.02				147	2.78 ± 0.02	0.116
180-181	113	3.19 ± 0.02		8	2.12 ± 0.01				276	2.50 ± 0.04	0.367
480	141			173					227	2.26 ± 0.02	0.583
655	135			122							

a/ Number of plants constituting average.

Since no difference between reciprocal crosses could be detected in any case the data are combined for analysis and the crosses are identified as one, e.g., cross 516-524.

IV. INHERITANCE OF NUMBER OF SEEDS PER POD

The relative constancy of seeds-per-pod values within a variety suggests that the character is governed largely by genic action. Weatherspoon and Wentz (6) counted seeds in 5 pods from each of 2 plants from 10 replications of 237 varieties. From the amount of variance due to replications they concluded that "number of seeds per pod . . . (was) very little influenced by soil differences." Certain of the data obtained in the current study indicate that the character is not wholly uninfluenced by environmental factors. The planting of parental varieties in close proximity to their F_2 populations necessitated planting 9 of the 11 varieties at more than one location in the field. Types 34, 38, 48, 114, 141, and 173 occurred twice in the field, T 10 occurred 3 times, and types 122 and 174 each occurred 4 times. The "t" test was applied to all possible comparisons between seeds-per-pod means of the different entries of each variety; Table 2. Of the 21 such comparisons 6 mean differences were significant. The significant differences were between the means of the two entries of types 34, 38, and 114, and between entry number 3 of T 122 and the other three entries of T 122.

Intermediate x Low

The six F2 populations derived from crosses between T 122, whose pods were predominately one-seeded, and strains with intermediate seeds-per-pod values were strikingly similar. Figure 2 shows the parental and F_2 distributions of crosses 500 and 504, representing this type of cross. The following characteristics

Table 2.--Comparison of Mean Seeds-Per-Pod Values of Different Entries of the Same Strain Planted at Different Locations in the Field. An Asterisk Beside the "t" Value Indicates Significance of the Mean Difference

Parental type	Entry	$\bar{x}$	N	Entry	$\bar{x}$	N	Mean difference	σ Mean difference	t
T10	T10-1	2.93 ± 0.01	42	T10-2	2.95 ± 0.01	47	0.02	0.01	2.00
	T10-1	2.93 ± 0.01	42	T10-3	2.93 ± 0.01	36	0.00	0.01	0.00
	T10-2	2.95 ± 0.01	47	T10-3	2.93 ± 0.01	36	0.02	0.01	2.00
T34	T34-1	3.01 ± 0.01	35	T34-2	2.92 ± 0.01	35	0.09	0.01	9.00*
T38	T38-1	3.08 ± 0.01	42	T38-2	3.14 ± 0.01	41	0.06	0.01	6.00*
T48	T48-1	2.08 ± 0.01	35	T48-2	2.10 ± 0.01	44	0.02	0.01	2.00
T114	T114-1	3.67 ± 0.02	32	T114-2	3.51 ± 0.04	34	0.16	0.04	4.00*
T122	T122-1	1.05 ± 0.01	36	T122-2	1.06 ± 0.01	38	0.01	0.01	1.00
	T122-1	1.05 ± 0.01	36	T122-3	1.09 ± 0.01	30	0.04	0.01	4.00*
	T122-1	1.05 ± 0.01	36	T122-4	1.05 ± 0.01	30	0.00	0.01	0.00
	T122-2	1.06 ± 0.01	38	T122-3	1.09 ± 0.01	30	0.03	0.01	3.00*
	T122-2	1.06 ± 0.01	38	T122-4	1.05 ± 0.01	30	0.01	0.01	1.00
	T122-3	1.09 ± 0.01	30	T122-4	1.05 ± 0.01	30	0.04	0.01	4.00*
T141	T141-1	2.15 ± 0.01	19	T141-2	2.19 ± 0.03	22	0.04	0.03	1.33
T173	T173-1	2.31 ± 0.05	13	T173-2	2.21 ± 0.03	14	0.10	0.06	1.67
T174	T174-1	3.37 ± 0.02	36	T174-2	3.37 ± 0.02	41	0.00	0.03	0.00
	T174-1	3.37 ± 0.02	36	T174-3	3.36 ± 0.02	43	0.01	0.03	0.33
	T174-1	3.37 ± 0.02	36	T174-4	3.41 ± 0.02	46	0.04	0.03	1.33
	T174-2	3.37 ± 0.02	41	T174-3	3.36 ± 0.02	43	0.01	0.03	0.33
	T174-2	3.37 ± 0.02	41	T174-4	3.41 ± 0.02	46	0.04	0.03	1.33
	T174-3	3.36 ± 0.02	43	T174-4	3.41 ± 0.02	46	0.05	0.03	1.67

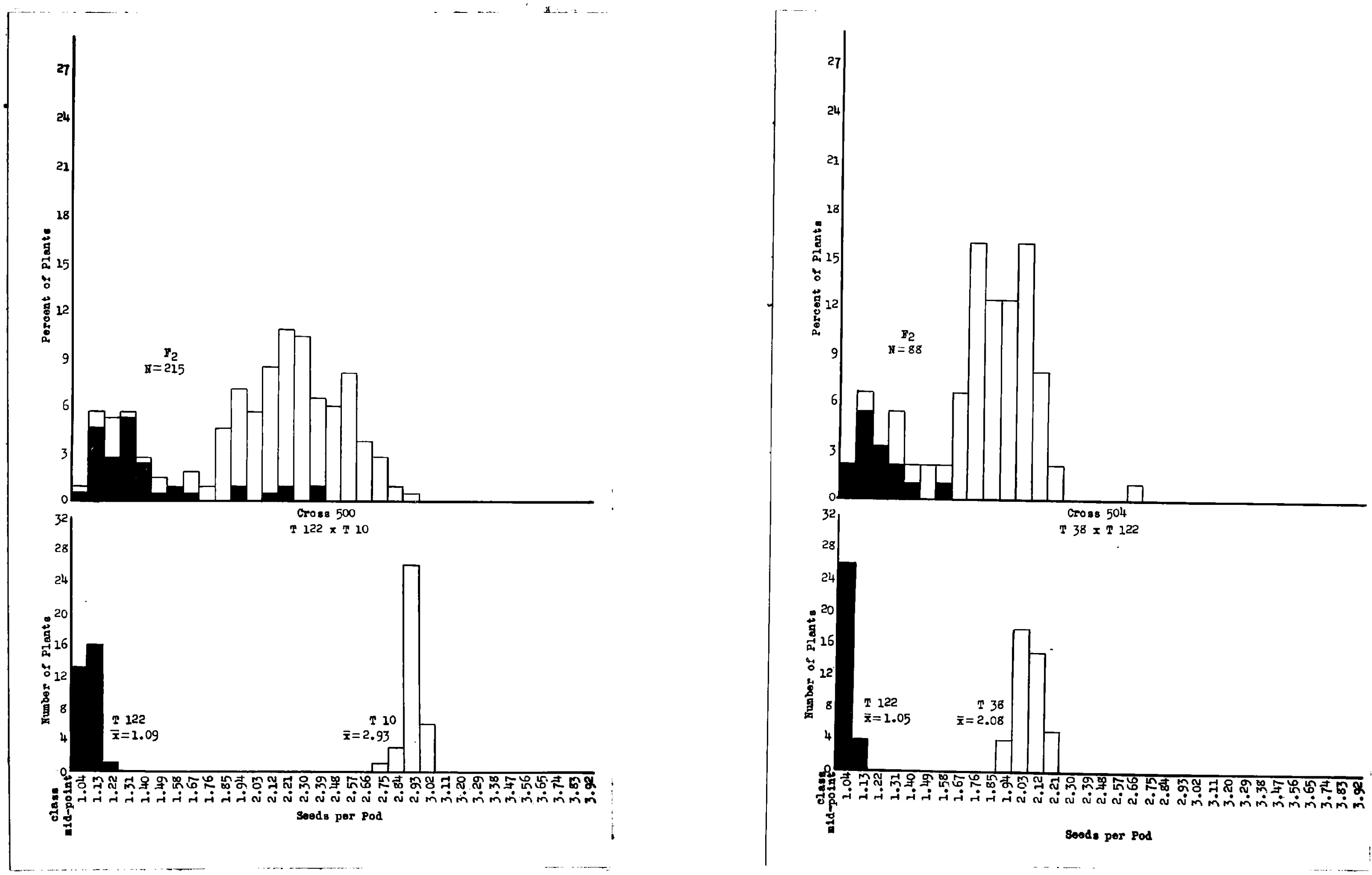


Figure 2. Histograms of parental and F_2 seeds-per-pod distributions of two crosses involving T 122. Shaded areas indicate the number of plants within each class which were classified as oval-leaflet type by observation.

were common to most of the F_2 distributions: (a) with as low as 88 in one F_2 population certain segregates of each cross had seeds-per-pod values equal to the mean values of both of their respective parents, (b) no suggestion of transgressive segregation was apparent, (c) distinct bimodality was exhibited, with the larger portion of the curve composed of plants with the higher seeds-per-pod values, (d) the seeds-per-pod value of the modal class of the larger portion of the curve was lower than the mean of the higher parent, and the seeds-per-pod value of the modal class of the smaller portion of the curve was higher than the mean value of the lower parent. All F_2 populations showed a good fit to the 3:1 ratio when the range of possible division of N into approximate 3:1 portions at the 5 percent level of probability was compared with the low point dividing the two portions of that curve.

Intermediate x High

Of the eight F_2 populations derived from crosses between types with appreciable percentages of four-seeded pods (T 114 and T 174) and types with intermediate seeds-per-pod values, four crosses (507, 511-523, 516-524, and 529) each had over 100 plants in their F_2 distributions. Their histograms are presented in Figure 3. Certain F_2 segregates of each cross had seeds-per-pod values equal to the means of both of their respective parents except in cross 511-523 where no F_2 plant had a seeds-per-pod value as high as the mean of the higher parent. The difference between the parents of this cross was the greatest of the 8 crosses, and over 10 percent of the F_2 segregates fell within the range of the

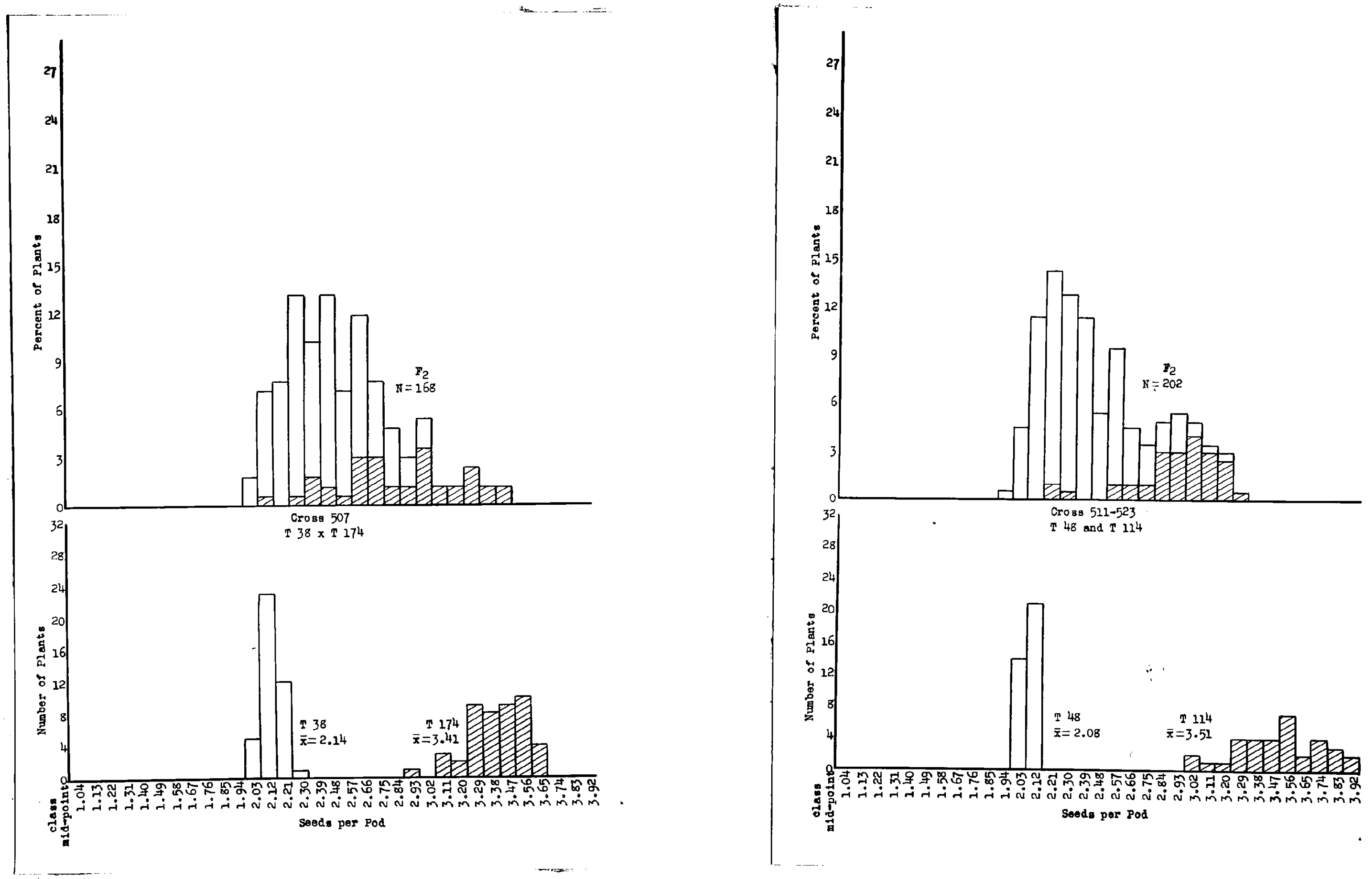
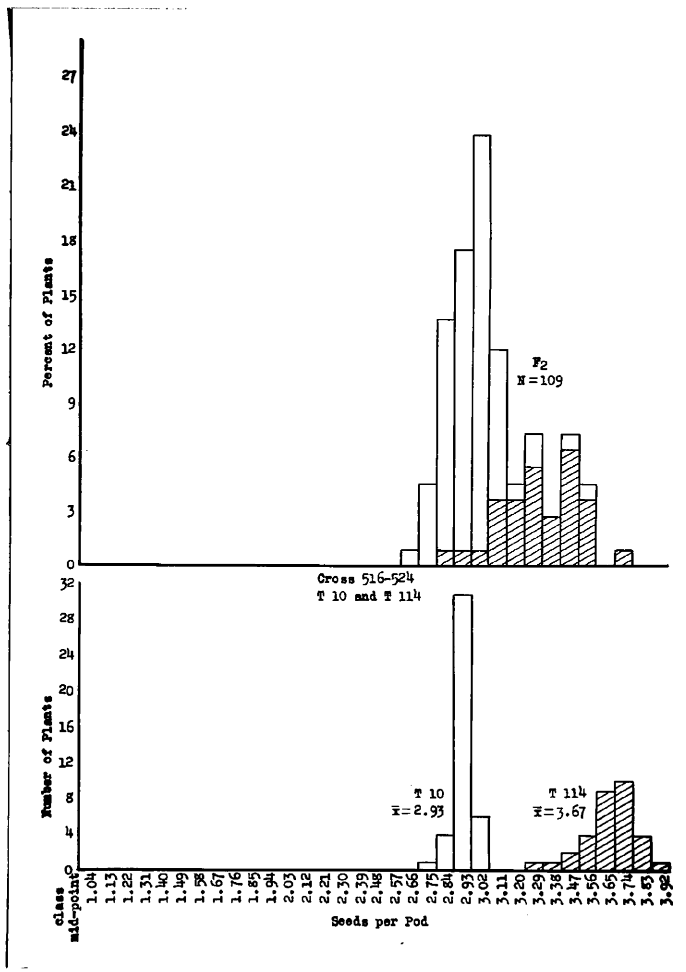


Figure 3. Histograms of parental and F_2 seeds-per-pod distributions of four crosses involving T 114 or T 174. Cross-hatched areas indicate the number of plants within each class which were classified as narrow-leaflet type by observation. (continued)



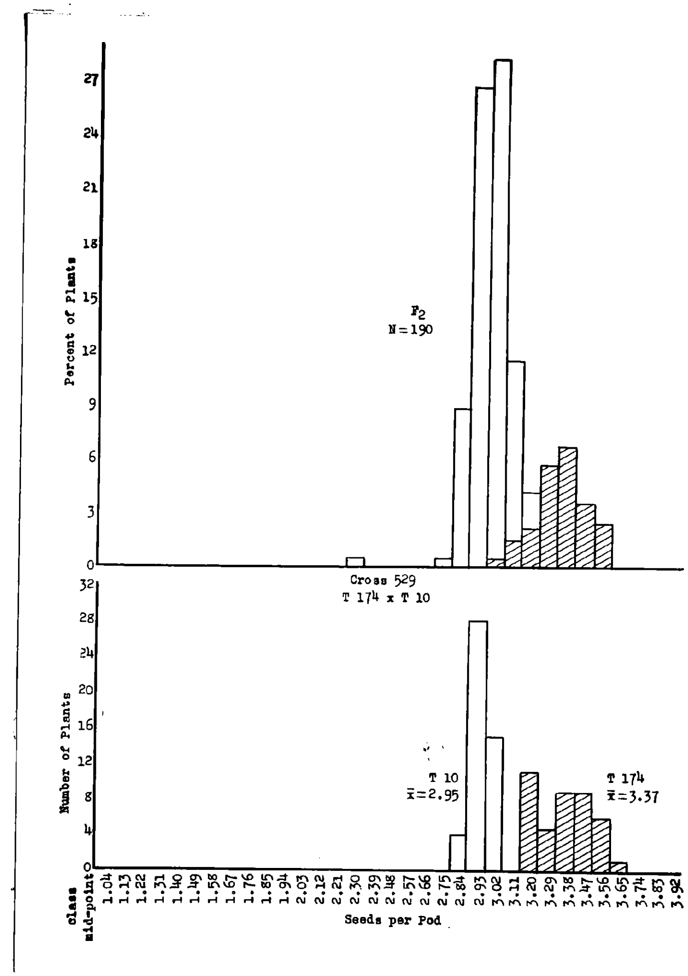


Figure 3. Concluded. Histograms of parental and F_2 seeds-per-pod distributions of four crosses involving T 114 or T 174. Cross-hatched areas indicate the number of plants within each class which were classified as narrow-leaflet type by observation.

higher parent. In all of the crosses the seeds-per-pod value of the modal class of the F_2 distribution was only slightly higher than the mean of the lower parent and was very nearly the same as the mean of the remnant F_1 plants grown in the field in the same season.

Station crosses 173, 177-178, 179, and 180-181 each had one parent with seeds-per-pod values comparable to those of T 114 and T 174. Their F_2 distributions were similar to those of crosses 507 and 516-524, Figure 3, in general shape and relation to parental means.

The F_2 distributions of crosses 527, 529, and 511-523 exhibited a bimodal tendency with plants with high values constituting the smaller portion of the curve. These F_2 populations showed a good fit to a 3:1 ratio when the range of possible division of N into approximately 3:1 portions at the 5 percent level of probability was compared with the low point dividing the two portions of the curve.

The 12 crosses that had one parent with seeds-per-pod means over 3.00 produced F_2 populations with skewness coefficients ranging from 0.0 to +0.848, none of which are significant by the measure of their magnitude in relation to the standard deviation of the sample.

Low x High

The lines with the lowest and the highest seeds-per-pod values were used in crosses 501 and 522. Since the F_2 distributions were very similar, only that of the cross with the largest F_2 population, cross 522 with 250 individuals, is presented:

Figure 4. In both crosses (a) no F_2 segregate had a seeds-per-pod value equal to the mean of either parent, (b) the value of the modal class of the F_2 distribution was slightly below the average of the two parents, and (c) both of the F_2 distributions showed a bimodal tendency, with approximately 13 percent of the segregates with the lower seeds-per-pod values constituting the smaller portion of the curve.

Intermediate x Intermediate

F_2 histograms of crosses 512 and 159-160 are presented in Figure 5 as representing those 11 crosses between types with intermediate seeds-per-pod values. Even though the parents of these 11 crosses are classed as "intermediate" their seeds-per-pod means differed significantly. No general statement can be made concerning the size of their F_2 means in relation to the parental means. In 7 of the crosses (114, 157, 159-160, 163, 173, 177-178, and 180-181) the F_2 means were intermediate between the parental means; in 2 of the crosses (512 and 513-519) the F_2 means approached the mean of the higher parent; and in 2 crosses (144 and 179) the F_2 means approached the mean of the lower parent. Of the several crosses studied cross 159-160 produced the most normal distribution. Tendency toward skewness or bimodality might have been obscured, however, by the relative closeness of the parental values. It is noteworthy that no hint of transgressive segregation was evident in this cross even with 294 F_2 individuals from parents whose seeds-per-pod values were relatively close.

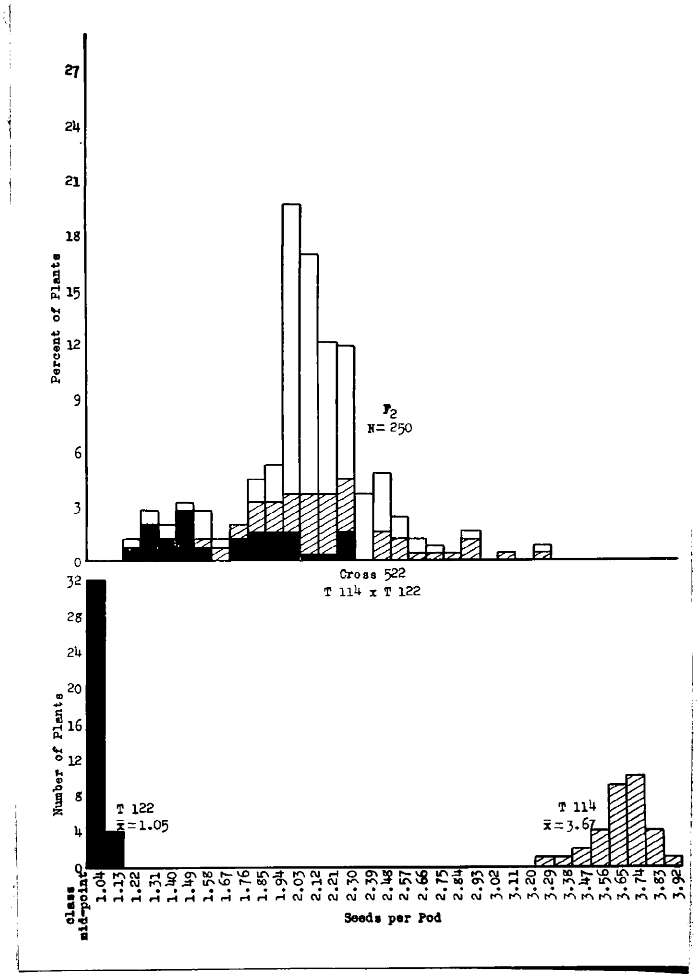


Figure 4. Histograms of parental and F_2 seeds-per-pod distributions of cross 522. Shaded areas and cross-hatched areas indicate the number of plants within each class which were classified as oval-leaflet and narrow-leaflet types, respectively, by observation.

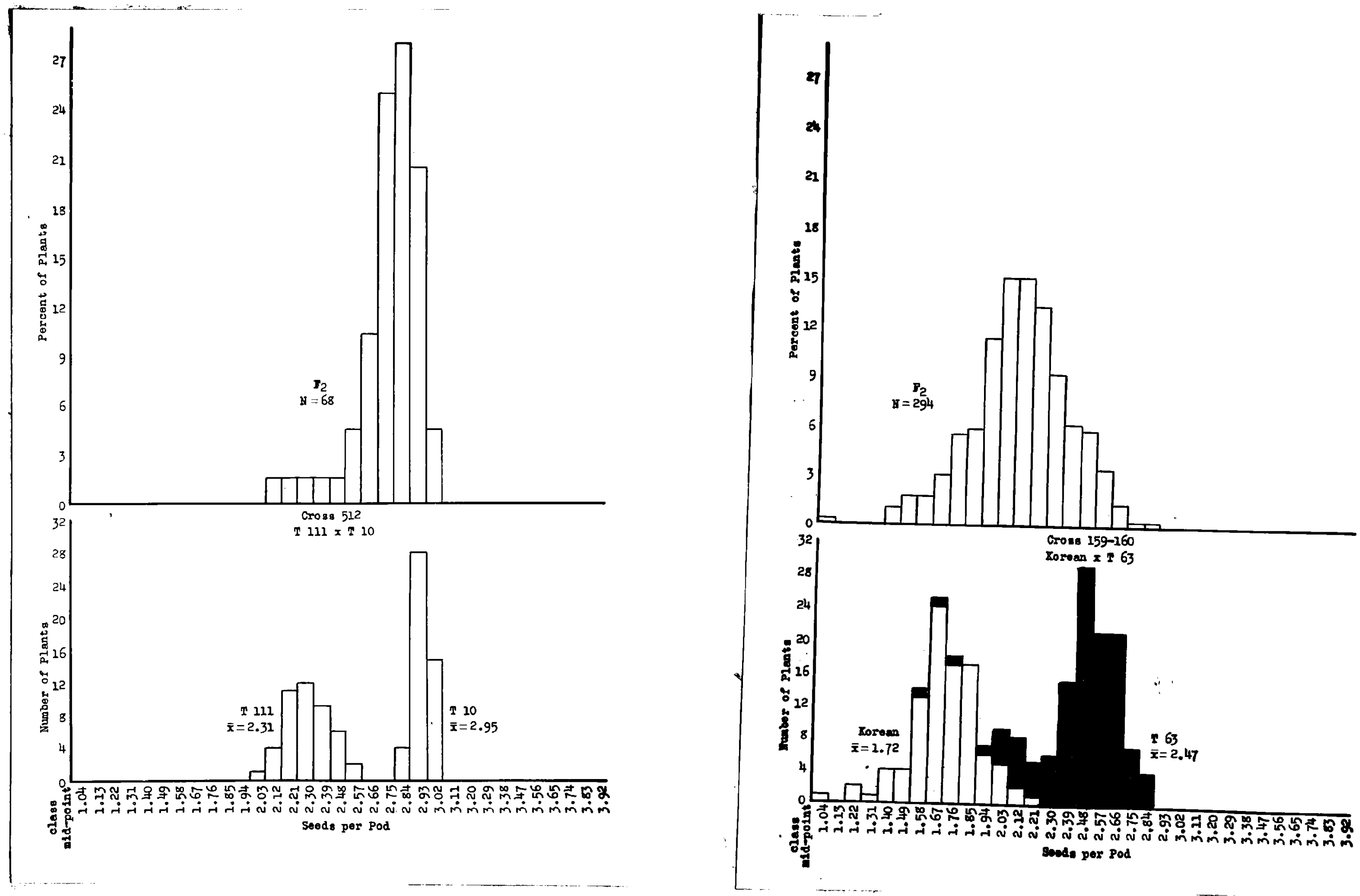


Figure 5. Histograms of parental and F_2 seeds-per-pod distributions of crosses 159-160 and 512. Parent T 63 is shaded to distinguish its distribution from that of Korean which it overlaps.

Significant positive correlations were obtained when F_2 seeds-per-pod values were correlated with the mean seeds-per-pod values of their respective F_3 progenies; cross 114, + 0.65; cross 144, +0.52; cross 163, +0.68; and cross 480, +0.70.

A negative, but not significant, correlation coefficient of -0.36 was obtained when 22 F_2 seeds-per-pod values of cross 480 were correlated with the coefficients of variability of their respective F_3 progenies. At the 5 percent level of probability a value of 0.42 would have been significant. A significant negative correlation between F_2 seeds-per-pod values and F_3 coefficients of variability would be considered evidence that F_2 plants with high seeds-per-pod values were more nearly homozygous for seeds-per-pod genes than those with low seeds-per-pod values.

V. INHERITANCE OF LEAFLET SHAPE

Normal x Normal

The F_1 and F_2 populations derived from crosses between parents with normal leaflets consisted only of plants with normal leaflets.

Normal x Narrow

From 11 crosses between normal-leaflet and lanceolate- or narrow-leaflet parents 29 populations were grown and classified by observation with respect to leaflet shape. Only normal and narrow leaflet types were observed in the progenies, although a few types which were classified as normal appeared to be somewhat intermediate. The ratios of normal to narrow plants obtained was, in each case, a good fit to a 3:1 ratio, Table 3. Of the 22 F_2 plants selected at random from cross 480, 6 had narrow leaflets and bred true for narrow leaflets. Of the 16 that had normal leaflets in F_2, 6 bred true for normal in F_3 and 10 segregated into approximately 3:1 ratios of normal to narrow; Table 4.

Normal x Oval

Eight crosses between normal- and oval-leaflet types produced 21 F_2 populations which segregated for normal and oval. When the ratios were tested to fit a 3 normal : 1 oval ratio the total χ^2 value exceeded that which would be expected at even the 1 percent level of probability, Table 5. Of the 21 populations, however, 16 populations, representing all of the progenies from 6 of the 8 crosses, had P values above 5 percent. The P value of the group as a whole was lowered by the large χ^2 values of 5 populations representing all of the progenies from 2 of the 8 crosses. It will be noted that each of the 2 crosses whose progenies do not fit the 3:1

Table 3.--F_2 Segregates of Normal x Narrow Crosses, Showing Segregation in a 3:1 Ratio of Normal- to Narrow-Leaflet Plants

F_1 plant number	Leaflet shape Normal	Leaflet shape Narrow	Total	χ^2
503A	6	3	9	0.333
503B	8	4	12	0.444
503C	40	17	57	0.708
503D	8	4	12	0.444
503E	37	9	46	0.725
507A	128	40	168	0.127
507B	4	2	6	0.222
507C	7	1	8	0.667
507D	9	4	13	0.231
511A	30	10	40	0.000
511B	91	21	112	2.333
511C	55	17	72	0.074
523A	56	14	70	0.933
523B	7	1	8	0.667
523C	3	3	6	2.000
523D	70	20	90	0.371
523E	10	1	11	1.485
523F	44	9	53	1.818
527	42	17	59	0.457
528	12	4	16	0.000
516	38	17	55	1.024
524A	2	2	4	1.333
524B	37	13	50	0.027
520A	24	7	31	0.097
520B	15	3	18	0.667
529A	14	3	17	0.491
529B	3	0	3	1.000
529C	129	41	170	0.071
525	42	15	57	0.052
			Total	18.801
				P = 50-90%

Table 4.--Segregates of 10 F_3 Populations from a Normal x Narrow Cross, Showing Segregation in a 3:1 Ratio of Normal- to Narrow-Leaflet Plants

F_3 plant number	Leaflet shape		Total	χ^2
	Normal	Narrow		
480A 4	14	4	18	0.075
480C 1	7	2	9	0.037
480C 4	15	6	21	0.143
480C 5	18	5	23	0.131
480C 6	13	3	16	0.333
480C 8	18	5	23	0.131
480C 10	16	2	18	1.852
480F 3	16	4	20	0.267
480F 5	17	5	22	0.060
480F 7	18	2	20	2.400
			Total	5.429
			P =	50-90%

Table 5.--F_2 Segregates of Crosses Between Normal-Leaflet and Oval-Leaflet Parents. χ^2 Values Indicate the Goodness of Fit to a 3:1 Ratio of Normal to Oval

F1 plant number	Leaflet shape Normal	Oval	Total	χ^2	
497	86	23	109	0.884	
498	47	17	64	0.083	
500A	57	10	67	3.627	
500B	9	0	9	3.000	
500C	73	21	94	0.355	
500D	4	3	7	1.191	
500E	21	6	27	0.111	
500F	1	2	3	2.777	
500G	6	2	8	0.000	
655A	247	67	314	2.246	
655B	198	60	258	0.419	
655C	123	34	157	0.936	
502	28	10	38	0.035	
504A	49	9	58	2.781	
504B	8	0	8	2.667	
504C	17	5	22	0.060	
			Sub-Total		21.172 P = 10-20%
508A	145	33	178	3.963	
508B	64	7	71	8.681	
(Reciprocal of 498)					
515A	75	11	86	6.837	
515B	94	13	107	9.424	
515C	115	18	133	9.326	
(Reciprocal of 500; same as 655, see text)					
			Sub-Total		38.231 P = <1%
			Grand Total		59.403 P = <1%

hypothesis have reciprocals among the 5 crosses whose progenies fit the 3:1 hypothesis; T 122 was the staminate parent in both of these crosses. Cross 515, whose F_2 did not fit the hypothesis, and cross 655, whose F_2 fit the hypothesis, are probably the same as regards leaflet-shape genes since T 135 used in cross 655 was a chlorophyll-deficient mutation from T 10 used in cross 515.

Narrow x Oval

The six F_1 plants from 2 crosses between narrow-leaflet and oval-leaflet parents had normal leaflets. The F_2 progenies from these 6 plants contained plants that were classified as normal, narrow, and oval leaflet types. Data presented in Table 6 show χ^2 values obtained when the ratios were tested with a theoretical ratio of 9 normal, 3 oval, and 4 narrow. The P value lies between 50 and 90 percent.

Leaflet Indices

A discussion of leaflet indices will be facilitated by designating each of the three indices by a letter, as follows: index "a", the width of the leaflet at its widest point divided by its total length; index "b", the distance from the base of the leaflet to its widest point divided by its total length; and index "c", the size of the angle formed by the two margins of the basal portion of the leaflet.

The narrow-leaflet type differed significantly from the normal-leaflet type in index "a". Only a few of the F_2 segregates from narrow x normal crosses were difficult to classify by observation. Since the difference was fairly precise, a clearly bimodal,

Table 6.--F_2 Segregates of Narrow x Oval Crosses Showing Segregation in a 9:3:4 Ratio of Normal- to Oval- to Narrow-Leaflet Plants

F_1 plant number	Leaflet shape: Normal	Oval	Narrow	Total	χ^2
501A	41	17	14	72	1.802
501B	5	1	1	7	0.679
522A	32	8	14	54	0.553
522B	76	25	29	130	0.506
522C	33	6	11	50	2.241
522D	5	0	0	5	3.897
522E	8	1	2	11	1.279
				Total	10.957
					P = 50-70%

and in fact discontinuous, F_2 distribution of the "a" index was anticipated with plants having low "a" values consituting the smaller portion of the curve. The parental and F_2 distributions of the "a" index of cross 516-524 are shown in Figure 6. While the F_2 distribution was bimodal, with approximately one-fourth of the segregates constituting the smaller portion of the curve, yet it was continuous, and this fact indicates the unadaptability of index "a" in the classification of questionable plants.

The oval-leaflet type differed significantly from the normal type in indices "a", "b", and "c", but a few F_2 segregates were difficult to classify. Indices "a" and "b" were obtained on crosses 500 and 504, and index "c" was obtained on cross 500. No hint of bimodality or discontinuous variation was evident in the F_2 distributions of index "a". Figure 7 presents the parental and F_2 distributions of index "b" of cross 504. It will be noted that those plants classified as oval by observation tended to have high "b" values. The F_2 distribution, however, lacked the discontinuity necessary for the index to be of value in classification of difficult cases. Figure 8 presents the parental and F_2 distributions of index "c" for cross 500. Those plants classified as oval by observation tended to have low "c" values, but the F_2 distribution was continuous. Index "c" also appears to have little value in classification of normal x oval segregates.

Certain of the segregates from the narrow x oval crosses were especially difficult to classify. The narrow- and oval-leaflet types differed significantly in indices "a" and "b", both of which

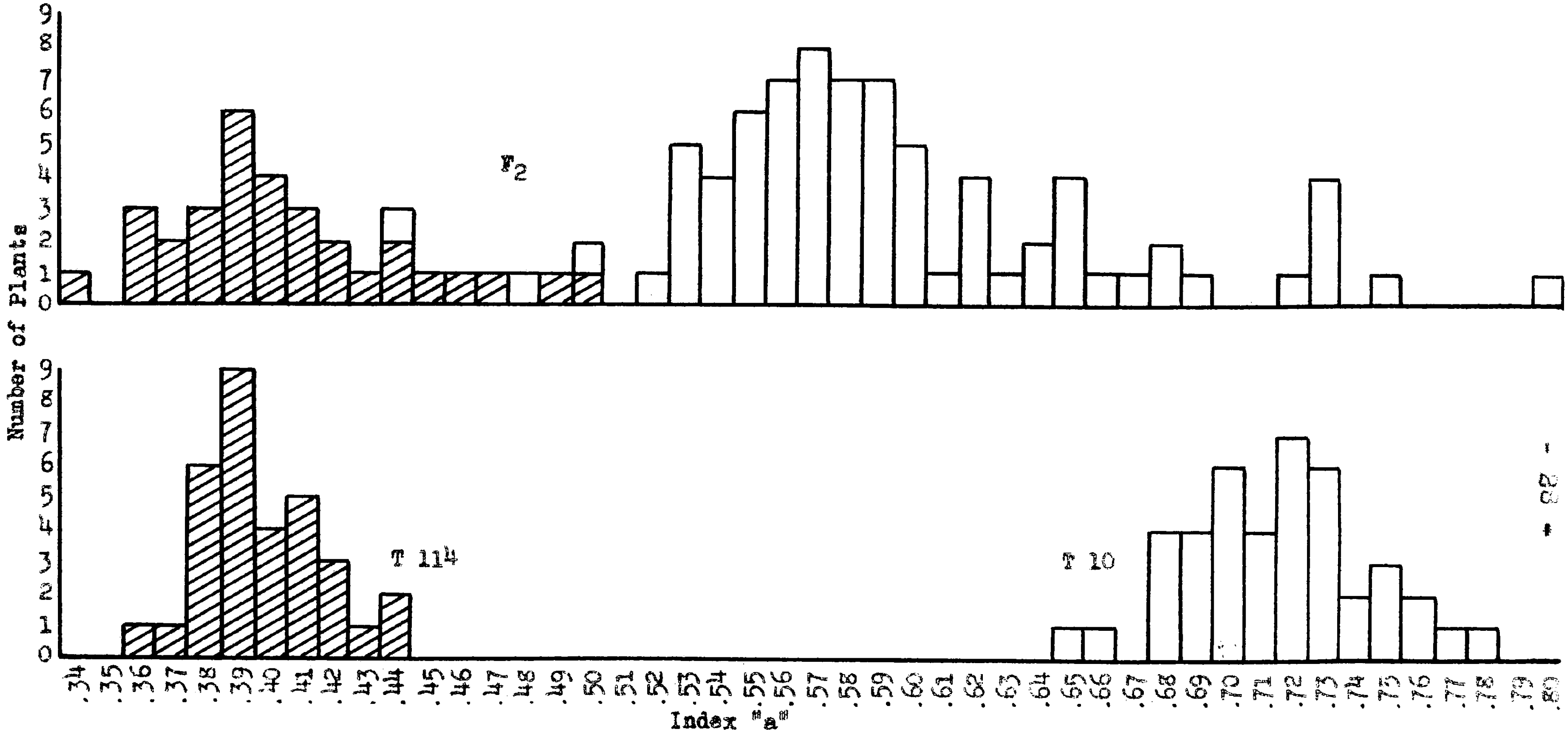


Figure 6. Parental and F_2 frequency distributions of index "a" (width of leaflet at its widest point divided by its total length) of cross 516-524. Cross-hatched areas indicate the number of plants within each class which were classified as "narrow" by observation.

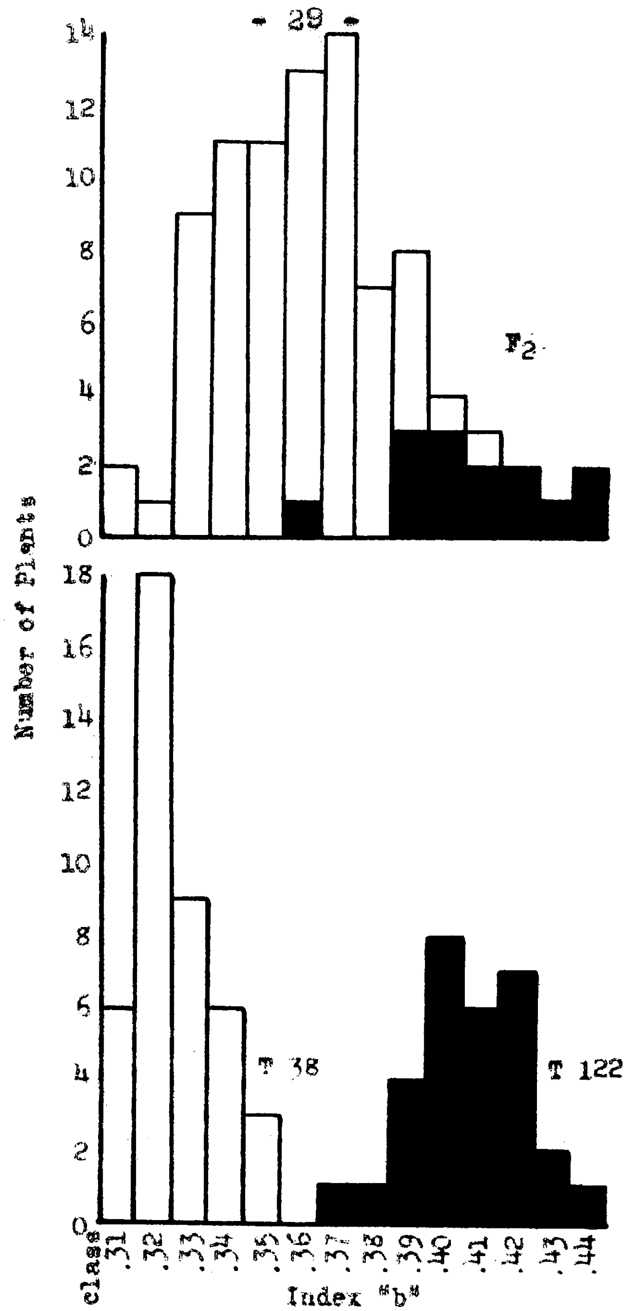


Figure 7. Parental and F_2 frequency distributions of index "b" (the distance from the base of the leaflet to its widest point divided by its total length) of cross 504. Shaded areas indicate the number of plants within each class which were classified as "oval" by observation.

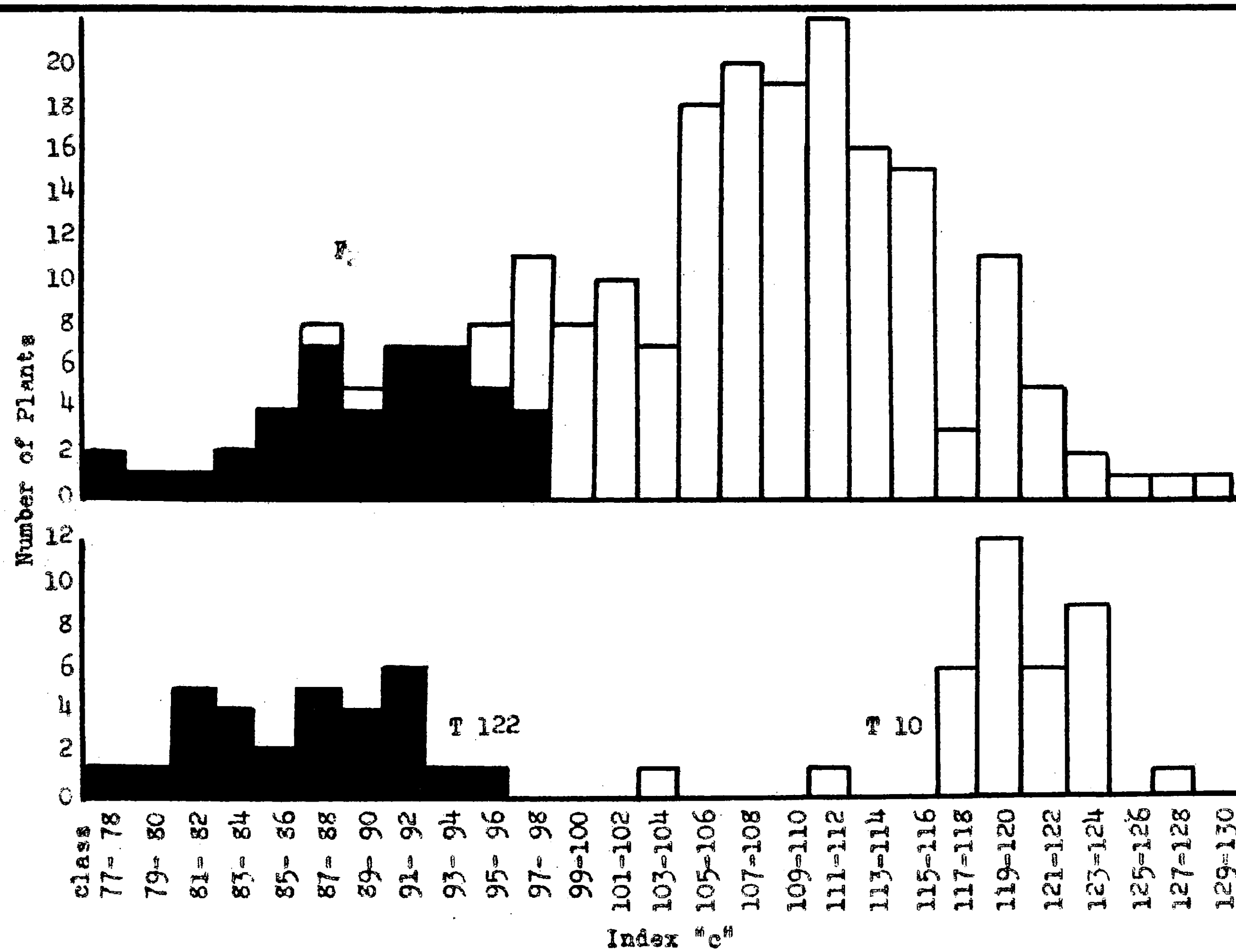


Figure 8. Parental and F_2 frequency distributions of index "c" (angle formed by the two margins of the basal portion of the leaflet) of cross 500. Shaded areas indicate the number of plants of each class which were classified as "oval" by observation.

were obtained on crosses 510 and 522. The "a" F_2 distributions showed that the plants classified as either "narrow" or "oval" tended to have low "a" indices. Even though the "narrow" plants in general had lower indices than the "oval" plants, many narrow and oval plants had the same "a" value. Index "a", therefore, seems to be of little value in classifying narrow x oval segregates. The parental and F_2 distributions of index "b" of cross 522 are presented in Figure 9. They indicate that narrow-leaflet plants have low "b" values, normal-leaflet plants have intermediate "b" values, and oval-leaflet plants have high "b" values. The F_2 distribution, however, lacks both the trimodality and the discontinuity necessary for this index to be of value in classifying questionable plants.

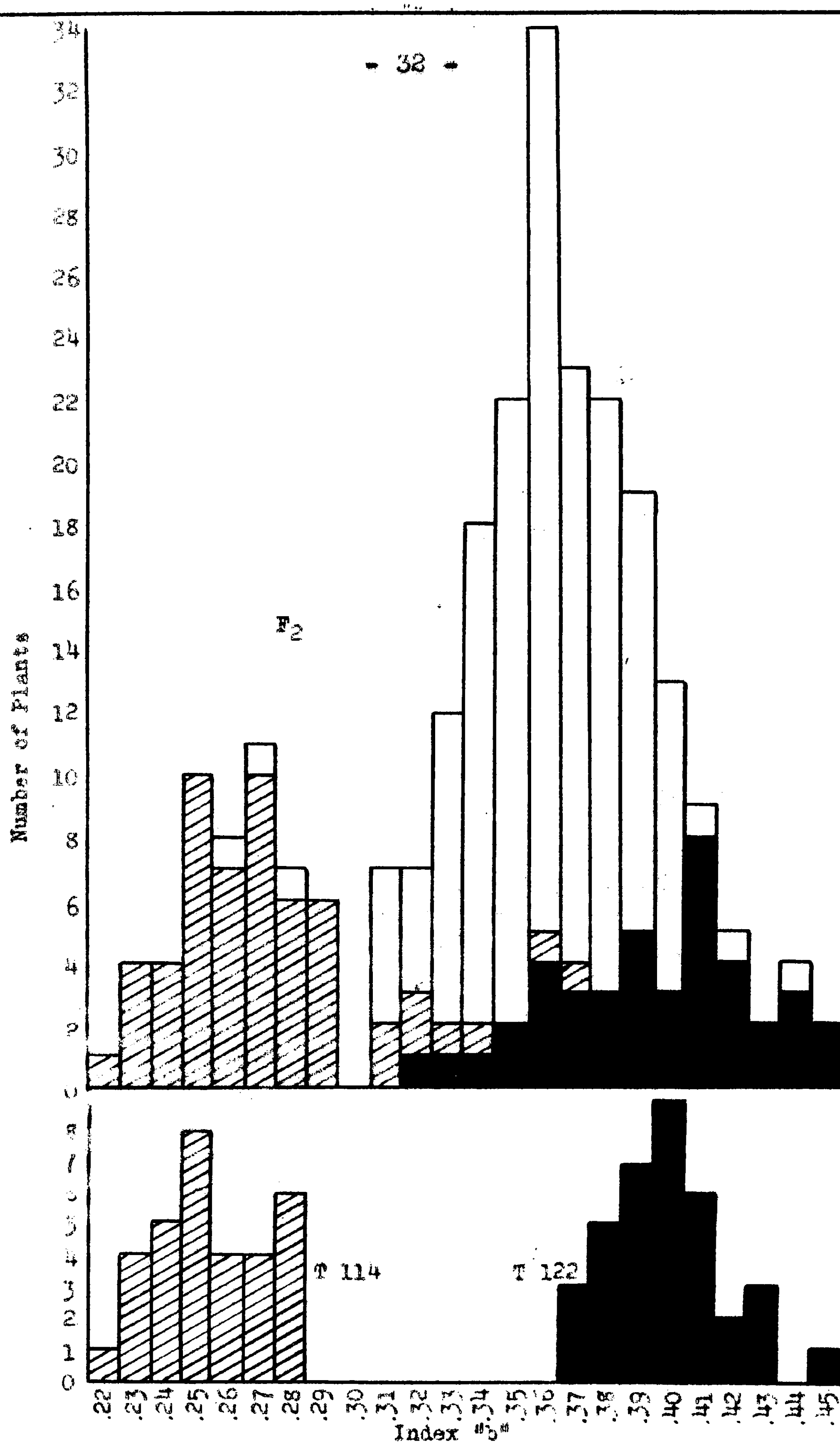


Figure 9. Parental and F_2 frequency distributions of index "b" (the distance from the base of the leaflet to its widest point divided by its total length) of cross 522. Shaded areas and cross-hatched areas indicate the number of plants within each class which were classified as "oval" and "narrow", respectively, by observation.

VI. LINKAGE OF GENES FOR LEAFLET SHAPE AND SEEDS-PER-POD

In the absence of linkage of genes for number of seeds per pod with genes for leaflet shape it would be expected that each seeds-per-pod class of F_2 generations segregating in a 3:1 ratio for leaflet shape would consist of normal-leaflet plants and recessive plants in approximately a 3:1 ratio. That such is not the case is shown by histograms in Figures 2 and 3.

The tendency, shown in Figure 2, for oval-leaflet segregates from crosses involving T 122 (oval leaflets and low seeds-per-pod value) to have a low seeds-per-pod value is true of all the crosses involving that parent. Such a tendency suggests linkage of the recessive gene for oval leaflet shape with a recessive major gene for the low seeds-per-pod character, on the assumption that the seeds-per-pod character is governed by the combined action of a few major genes and several modifying genes. An indication of linkage intensities was obtained by disregarding the action of the modifying genes and dividing the F_2 seeds-per-pod distribution into 2 groups at the low point of a smooth curve fitted to the data. All normal-leaflet plants having the "low" seeds-per-pod value and all oval leaflet plants having a "high" seeds-per-pod value were then considered as cross-over types. By this method cross-over percentages of 6, 6, 8, and 9 percent were obtained for crosses 497, 508, 504, and 500, respectively, or 7 percent when the calculations were based on the totals from the 4 crosses.

All of the F_2 distributions from the crosses involving T 114 or T 174 (narrow leaflets and high seeds-per-pod values) show a tendency for narrow-leaflet segregates to have high seeds-per-pod values, as is shown in Figure 3. Such a tendency suggests linkage of the recessive gene for narrow leaflet shape with a major gene for the high seeds-per-pod character. Since not all of these F_2 distributions produce a bimodal F_2 histogram an estimate of this linkage intensity is not possible for all of them in the manner described above. However, when the method above was applied to those crosses which did show the bimodal tendency, 529, 511-523, and 527, crossover percentages of 4, 12, and 12 percent, respectively, were obtained, or 9 percent when applied to totals from the three crosses.

VII. LINKAGE OF GENES FOR LEAFLET SHAPE AND OTHER QUALITATIVE CHARACTERS

Narrow Leaflet and Fasciation

The character "fasciation" is recessive and governed by the single gene difference Ff, Takagi (3). Six of the F_3 populations from cross 480 that were segregating for leaflet shape were also segregating for normal and fasciated stems. That the two characters are not linked is shown in Table 7 by the low X^2 value 3.482 (P = 30 - 50 percent) obtained when the F_2 ratios were tested against the independence ratio of 9:3:3:1.

Narrow Leaflet and Pubescence Color

The gene for tawny pubescence (T) is dominant to that for gray, Piper and Morse (2). That their locus is not linked with that of Nana is shown by the X^2 values of 6.495 (P = 5 - 10 percent) and 4.808 (P = 10 - 20 percent) for crosses 516 and 520, respectively, when their F_2 ratios were tested against the independence ratio of 9:3:3:1, Table 7.

Oval Leaflet and Pubescence Color

When the F_2 segregates of cross 497 were tested to a ratio of 9 normal leaflet, tawny pubescence: 3 normal, gray: 3 oval, tawny: 1 oval, gray, a X^2 value of 2.090 (P = 50 - 70 percent) was obtained, indicating independence of those two loci, Table 7.

Further evidence of the independence of genes for leaflet shape and pubescence color was obtained from cross 523 whose F_2 generation was segregating for tawny and gray pubescence as well as for normal, narrow, and oval leaflets. When the 250 segregates

Table 7.--F_2 Segregates of Several Crosses Between Parents Differing in Leaflet Shape and Other Qualitative Characters, Showing Independence of the Genes Involved by the 9:3:3:1 Segregation

Characters	Cross	XY	Xy	xY	xy	X^2	P
Narrow leaflet Na vs fasciation F	480	61	22	16	4	3.482	.30-.50
Narrow leaflet Na vs pubescence color T	516	55	22	19	13	6.495	.05-.10
Narrow leaflet Na vs pubescence color T	520	26	13	5	5	4.808	.10-.20
Oval leaflet vs pubescence color T	497	67	18	19	4	2.090	.50-.70

were tested against a theoretical independence ratio of 27 normal leaflet, tawny pubescence: 9 normal, gray: 9 oval, tawny: 3 oval, gray: 12 narrow, tawny: 4 narrow, gray, a χ^2 value of 7.400 (P = 20-30 percent) was obtained.

VIII. DISCUSSION

That the seeds-per-pod character is not entirely uninfluenced by environment is suggested by the fact that the difference between means of one strain planted at different locations in the field was occasionally greater than that expected by chance one time in 20.

Mean seeds-per-pod values of parental types of the early crosses differed considerably from the mean seeds-per-pod values of the same parental types of the recent crosses. This difference is due to the fact that in the later classifications unfertilized or aborted ovules were considered as seeds whereas they were not included in the earlier counts.

The F_2 seeds-per-pod distributions indicate that the character is governed by many genes, all of which do not contribute equally to the expression of the character. The bimodality evident in the low x intermediate crosses and the suggested bimodality in some of the intermediate x high crosses indicate a few major genes for number of seeds per pod. Also, the F_2 distributions of low x intermediate crosses indicate the action of modifying genes since the modal classes of the two sub-curves of these distributions had values higher and lower than the means of the "low" and the "intermediate" parents, respectively.

It is felt that the bimodality of the F_2 seeds-per-pod distributions from all crosses with T 132 justifies the assignment of a symbol to the major gene involved. The symbols Lo and lo are suggested for this allelomorphic pair. LoLo and Lolo are responsible for "intermediate" seeds-per-pod values and lolo for "low" seeds-per-pod values.

The F_2 data from crosses 527, 529, and 511-523 agree with N. Takahashi's hypothesis that plants with high seeds-per-pod values differ from those with intermediate values by only a single recessive gene. Takahashi assigned symbols to the allelomorphic pair. It is not known whether the genes involved in the present study are the same as Takahashi's. Neither his symbols nor new symbols are used here since not all of the crosses between normal and narrow parents exhibited the bimodal F_2 seeds-per-pod distributions. The nearly significant negative correlation coefficient obtained when F_2 seeds-per-pod values from cross 480 were correlated with their respective F_3 coefficients of variability suggests that the F_2 plants with the higher seeds-per-pod values were more nearly homozygous with respect to seeds-per-pod genes than those with lower seeds-per-pod values. If a single major gene pair is involved, aa F_2 genotypes would produce high F_2 values and little variability in F_3, AA and Aa F_2 genotypes would both produce lower F_2 values than aa but in F_3 AA would produce little variability and Aa would produce much variability. The negative correlation mentioned above might have been ~~higher~~ greater if the pure-breeding, low seeds-per-pod F_2-genotypes AA and their respective slightly variable F_3's could have been omitted in the correlation.

Data from crosses 527, 529, and 511-523 on linkage intensity between high seeds-per-pod and narrow leaflet indicate approximately 9 percent crossing over as compared with 10 percent obtained by Takahashi (4).

It does not seem likely that the major seeds-per-pod genes form a multiple allelomorphic series. That is, the "intermediate" gene which is allelomorphic to lo is probably not the same "intermediate" gene which is allelomorphic to the recessive high seeds-per-pod gene. The o locus and the na locus are linked with an "intermediate" locus with 7 and 9 percent crossing over, respectively. If the two "intermediate" genes were the same gene, o and na would then be linked with either 2 or 16 percent crossing over, approximately, depending on the order of the loci on the chromosome. The χ^2 test was applied to F_2 ratios from the narrow x oval crosses testing their fit to both a theoretical linkage ratio with 16 percent crossing over and the independence ratio. The "p" values obtained were 5-10 percent for the linkage ratio and 50-95 percent for the independence ratio; the "P" value for linkage with 2 percent crossing over would be extremely small. It appears, therefore, that na and o are not linked and that the dominant "intermediate" genes that are allelomorphic to both lo and the high seeds-per-pod gene are not one and the same gene.

Only data from cross 508 and 515 are at variance with the hypothesis that the oval-leaflet plants differ from the normal-leaflet plants by the single gene o. It is felt that these are chance deviations. Each cross had a reciprocal whose F_2 segregates fit the 3:1 hypothesis. Also, cross 655, whose segregates fit the hypothesis, is thought to be the same as cross 515, as regards this character, since their parents differed only in that the pistillate parent of cross 655 is a chlorophyll-deficient mutation from the pistillate parent of cross 515.

Data from the narrow x oval crosses indicate that the genotypes associated with particular phenotypes are NaO normal, Nao oval, naO and nao narrow. The production of the narrow character by the double recessive nao indicates that na is epistatic to o and that it should be possible to isolate two genetically different narrow-leaflet strains.

None of the leaflet indices used seemed to be of value in making leaflet-shape classifications of questionable plants. Even the width/length index for narrow x normal segregates has little value in classification because some F_2 segregates, probably the same ones that would cause difficulty in classification by observation, fall between the two well-defined portions of the F_2 distribution. The most difficult classification was between oval and normal segregates. It is felt that the most dependable criterion in making this classification is the degree of similarity of the outlines of the basal and distal halves of the leaflet. The leaflet may be folded once in the middle so that the basal and distal tips are together. In "oval" leaflets the margins of the basal half of the leaflet are quite parallel to the margins of the distal half while such is not the case in the normal leaflets.

IX. SUMMARY

1. Data on the inheritance of number of seeds per pod and leaflet shape in the soybean were obtained from 30 crosses between parents whose mean seeds-per-pod values ranged from 1.05 ± 0.01 to 3.67 ± 0.02 and whose terminal leaflet shapes were either ovate (normal), lanceolate (narrow), or oval. One parental variety had oval leaflets and a very low mean seeds-per-pod value. Two varieties had narrow leaflets and very high mean seeds-per-pod values. The remaining parental types had somewhat intermediate mean seeds-per-pod values, most of which differed significantly.

2. The data indicate that number of seeds per pod, while somewhat influenced by environmental conditions, is largely governed by a few major and several minor genes. The symbols Lo and lo are suggested for one allelomorphic pair of major genes. Lo exhibits considerable dominance over lo and produces an "intermediate" seeds-per-pod value; lo produces a "low" seeds-per-pod value. Certain of the data suggest a major recessive gene which produces a "high" seeds-per-pod value as contrasted with an "intermediate" value produced by its dominant allelomorph.

3. Plants with oval-shaped terminal leaflets differ from plants with normal leaflets by one leaflet-shape gene. The symbols O and o are suggested for this allelomorphic pair. OO and Oo produce normal leaflets and oo produces oval leaflets.

Data from the normal- x narrow-leaflet crosses substantiated earlier reports that a single gene difference is involved. NaNa and Nana produce normal leaflets and nana produces narrow leaflets.

The F_1 plants of crosses between narrow-leaflet plants and oval-leaflet plants had normal leaflets and the F_2 segregates fit a 9 normal: 3 oval: 4 narrow ratio. Oval-leaflet genes are apparently not linked with narrow-leaflet genes.

4. The oval-leaflet gene o is linked with the gene lo for low number of seeds-per-pod with approximately 7 percent crossing over, but is not linked with the pubescence color gene t.

The narrow leaflet-shape gene na is closely linked with the gene or genes for high number of seeds per pod but is not linked with the gene for pubescence color t or with the gene for fasciation f.

X. LITERATURE CITED

1. Nagai, I. On the heredity of the soybean. Separate Mag. Noggo and Engei Vol. 1, Nos. 1 and 2. 1926. (In Japanese)

2. Piper, C. V., and Morse, W. J. The soybean; history, varieties, and field studies. U. S. Dept. Agr., Bur. Plant Indus. Bull. 197. 1910.

3. Takagi, F. On the inheritance of some characters in Glycine soja, Bentham (soybean). Tohoku Imp. Univ. Sci. Rept., 4th ser., Biol. 4:577-589. 1929.

4. Takahashi, N. Linkage relation between the genes for the forms of leaves and the number of seeds per pod of soybeans. Japan. Jour. Genetics 9:208-225. 1934. (In Japanese. English summary, p. 225.)

5. Takahashi, Y., and Fukuyama, J. Morphological and genetical studies of the soybean. Hokkaido Imp. Agr. Exp. Sta. Rept. 10. (In Japanese.) 1919.

6. Weatherspoon, J. H., and Wentz, J. B. A statistical analysis of yield factors in soybeans. Jour. Amer. Soc. Agron. 26: 524-531. 1934.

7. Woodworth, C. M. Genetics and breeding in the improvement of the soybean. Ill. Agr. Exp. Sta. Bull. 384. 1932.

Table 8.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 500

	T 10	T 122	F_2		
	Leaflet shape	Leaflet shape	Leaflet shape		
Range	Normal	Oval	Normal	Oval	F_2 Total
1.00-1.08		13	1	1	2
1.09-1.17		16	2	10	12
1.18-1.26		1	5	6	11
1.27-1.35			1	11	12
1.36-1.44			1	5	6
1.45-1.53			2	1	3
1.54-1.62				2	2
1.63-1.71			3	1	4
1.72-1.80			2		2
1.81-1.89			10		10
1.90-1.98			13	2	15
1.99-2.07			12		12
2.08-2.16			17	1	18
2.17-2.25			21	2	23
2.26-2.34			22		22
2.35-2.43			12	2	14
2.44-2.52			13		13
2.53-2.61			17		17
2.62-2.70			8		8
2.71-2.79	1		6		6
2.80-2.88	3		2		2
2.89-2.97	26		1		1
2.98-3.06	6				
3.07-3.15					

Table 9.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 504

Range	T 38 Leaflet shape	T 132 Leaflet shape	F_2 Leaflet shape		F_2 Total
	Normal	Oval	Normal	Oval	
1.00-1.08		26		2	2
1.09-1.17		4	1	5	6
1.18-1.26				3	3
1.27-1.35			3	2	5
1.36-1.44			1	1	2
1.45-1.53			2		2
1.54-1.62			1	1	2
1.63-1.71			6		6
1.72-1.80			14		14
1.81-1.89			11		11
1.90-1.98	4		11		11
1.99-2.07	18		14		14
2.08-2.16	15		7		7
2.17-2.25	5		2		2
2.26-2.34					
2.35-2.43					
2.44-2.52					
2.53-2.61					
2.62-2.70					1
2.71-2.79					

Table 10.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 529

Range	T 10 Leaflet shape Normal	T174 Leaflet shape Narrow	F_2 Leaflet shape Normal	F_2 Leaflet shape Narrow	F_2 Total
2.17-2.25					
2.26-2.34			1		1
2.35-2.43					
2.44-2.52					
2.53-2.61					
2.62-2.70					
2.71-2.79			1		1
2.80-2.88	4		17		17
2.89-2.97	28		51		51
2.98-3.06	15		53	1	54
3.07-3.15			19	3	22
3.16-3.24		11	4	4	8
3.25-3.33		5		11	11
3.34-3.42		9		13	13
3.43-3.51		9		7	7
3.52-3.60		6		5	5
3.61-3.69		1			
3.70-3.78					

Table 11.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 511-523

Range	T 48 Leaflet shape	T 114 Leaflet shape	F_2 Leaflet shape		F_2 Total
	Normal	Narrow	Normal	Narrow	
1.90-1.98			1		1
1.99-2.07	14		9		9
2.08-2.16	21		23		23
2.17-2.25			27	2	29
2.26-2.34			25	1	26
2.35-2.43			23		23
2.44-2.52			11		11
2.53-2.61			17	2	19
2.62-2.70			7	2	9
2.71-2.79			5	2	7
2.80-2.88			4	6	10
2.89-2.97			5	6	11
2.98-3.06		2	2	8	10
3.07-3.15		1	1	6	7
3.16-3.24		1	1	5	6
3.25-3.33		4		1	1
3.34-3.42		4			
3.43-3.51		4			
3.52-3.60		7			
3.61-3.69		2			
3.70-3.78		4			
3.79-3.87		3			
3.88-3.96		2			

Table 12.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 507

Range	T 38 Leaflet shape Normal	T 174 Leaflet shape Narrow	F_2 Leaflet shape Normal	F_2 Leaflet shape Narrow	F_2 Total
1.99-2.07	5		3		3
2.08-2.16	23		11	1	12
2.17-2.25	12		13		13
2.26-2.34	1		21	1	22
2.35-2.43			14	3	17
2.44-2.52			20	2	22
2.53-2.61			11	1	12
2.62-2.70			15	5	20
2.71-2.79			8	5	13
2.80-2.88			6	2	8
2.89-2.97			3	2	5
2.98-3.06			3	6	9
3.07-3.15		5		2	2
3.16-3.24		5		2	2
3.25-3.33		10		4	4
3.34-3.42		7		2	2
3.43-3.51		10		2	2
3.52-3.60		3			
3.61-3.69		2			
3.70-3.78					
3.79-3.87		1			
3.88-3.96					

Table 13.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_2 Generation of Cross 516-524

Range	T 10 Leaflet shape Normal	T 114 Leaflet shape Narrow	F_2 Leaflet shape Normal	F_2 Leaflet shape Narrow	F_2 Total
2.53-2.61					
2.62-2.70			1		1
2.71-2.79	1		5		5
2.80-2.88	4		14	1	15
2.89-2.97	31		18	1	19
2.98-3.06	6		25	1	26
3.07-3.15			9	4	13
3.16-3.24			1	4	5
3.25-3.33		1	2	6	8
3.34-3.42		1		3	3
3.43-3.51		2	1	7	8
3.52-3.60		4	1	4	5
3.61-3.69		9			
3.70-3.78		10		1	1
3.79-3.87		4			
3.88-3.96		1			

Table 14.--Seeds-Per-Pod Distributions and Leaflet Shapes of the Parental Types and the F_3 Generation of Cross 522

Range	T 122 Leaflet shape	T 114 Leaflet shape	F_2 Leaflet shape			F_2 Total
	Oval	Narrow	Normal	Oval	Narrow	
1.00-1.08	32					
1.09-1.17	4					
1.18-1.26			1	2		3
1.27-1.35			2	5		7
1.36-1.44			2	3		5
1.45-1.53			1	7		8
1.54-1.62			4	2	1	7
1.63-1.71			1		2	3
1.72-1.80				3	2	5
1.81-1.89			3	4	4	11
1.90-1.98			5	4	4	13
1.99-2.07			40	4	5	49
2.08-2.16			33	1	8	42
2.17-2.25			21	1	8	30
2.26-2.34			16	4	7	27
2.35-2.43			9			9
2.44-2.52			8		4	12
2.53-2.61			3		3	6
2.62-2.70			2		1	3
2.71-2.79			1		1	2
2.80-2.88					1	1
2.89-2.97			1		3	4
2.98-3.06						
3.07-3.15					1	1
3.16-3.24						
3.25-3.33		1	1		1	2
3.34-3.42		1				
3.43-3.51		2				
3.52-3.60		4				
3.61-3.69		9				
3.70-3.78		10				
3.79-3.87		4				
3.88-3.96		1				

Table 15.--Seeds-Per-Pod Distributions of the Parental Types and the F_2 Generation of Cross 159-160 (All Plants Had Normal-Shaped Leaflets)

Range	Korean	T 63	F_2
1.00-1.08	1		1
1.09-1.17			
1.18-1.26	2		
1.27-1.35	1		
1.36-1.44	4		3
1.45-1.53	4		5
1.54-1.62	13	1	5
1.63-1.71	24	1	9
1.72-1.80	17	1	16
1.81-1.89	17		17
1.90-1.98	6	1	33
1.99-2.07	5	4	44
2.08-2.16	2	6	44
2.17-2.25	1	4	39
2.26-2.34		6	27
2.35-2.43		15	18
2.44-2.52		29	17
2.53-2.61		21	10
2.62-2.70		21	4
2.71-2.79		7	1
2.80-2.88		4	1
2.89-2.97			

Table 16.--Seeds-Per-Pod Distributions of the Parental Types and the F_2 Generation of Cross 512 (All Plants Had Normal-Shaped Leaflets)

Range	T 10	T 111	F_2
1.90-1.98			
1.99-2.07		1	
2.08-2.16		4	1
2.17-2.25		11	1
2.26-2.34		12	1
2.35-2.43		9	1
2.44-2.52		6	1
2.53-2.61		2	3
2.62-2.70			7
2.71-2.79			17
2.80-2.88	4		19
2.89-2.97	28		14
2.98-3.06	15		3
3.07-3.15			

Table 17.--Parental and F_2 Frequency Distributions of Index "a" (Width of Leaflet at Its Widest Point Divided by Its Total Length) of Cross 516-534. Plants Were Classed as "Normal" or "Narrow" by Observation

Class	T 10 Leaflet shape Normal	T 114 Leaflet shape Narrow	F_2 Leaflet shape Normal	F_2 Leaflet shape Narrow	F_2 Total
34				1	1
35					
36		1		3	3
37		1		2	2
38		6		3	3
39		9		6	6
40		4		4	4
41		5		3	3
42		3		2	2
43		1		1	1
44		2	1	2	3
45				1	1
46				1	1
47				1	1
48			1		1
49				1	1
50			1	1	2
51					
52			1		1
53			5		5
54			4		4
55			6		6
56			7		7
57			8		8
58			7		7
59			7		7
60			5		5
61			1		1
62			4		4
63			1		1
64			2		2
65	1		4		4
66	1		1		1
67			1		1
68	4		2		2
69	4		1		1
70	6				
71	4				
72	7		1		1
73	6		2		2
74	2				
75	3		1		1
76	2				
77	1				
78	1				
79					
80			1		1

Table 18.--Parental and F_2 Frequency Distributions of Index "b" (the Distance from the Base of the Leaflet to Its Widest Point Divided by Its Total Length) of Cross 504. Plants Were Classed As "Normal" or "Oval" by Observation

Class	T 38 Leaflet shape Normal	T 122 Leaflet shape Oval	F_2 Leaflet shape Normal	F_2 Leaflet shape Oval	F_2 Total
31	6		2		2
32	18		1		1
33	9		9		9
34	6		11		11
35	3		11		11
36			12	1	13
37		1	14		14
38		1	7		7
39		4	5	3	8
40		8	1	3	4
41		6	1	2	3
42		7		2	2
43		2		1	1
44		1		2	2

Table 19.--Parental and F_2 Frequency Distributions of Index "c" (the Angle Formed by the Two Margins of the Basal Portion of the Leaflet) of Cross 500. Plants Were Classed as "Normal" or "Oval" by Observation

Class	T 10 Leaflet shape Normal	T 122 Leaflet shape Oval	F_2 Leaflet shape Normal	F_2 Leaflet shape Oval	F_2 Total
77-78		1		2	2
79-80		1		1	1
81-82		5		1	1
83-84		4		2	2
85-86		2		4	4
87-88		5	1	7	8
89-90		4	1	4	5
91-92		6		7	7
93-94		1		7	7
95-96		1	3	5	8
97-98			7	4	11
99-100			8		8
101-102			10		10
103-104	1		7		7
105-106			18		18
107-108			20		20
109-110			19		19
111-112	1		22		22
113-114			16		16
115-116			15		15
117-118	6		3		3
119-120	13		11		11
121-122	6		5		5
123-124	9		2		2
125-126			1		1
127-128	1		1		1
129-130			1		1

Table 20.--Parental and F_2 Frequency Distributions of Index "b" (the Distance from the Base of a Leaflet to Its Widest Point Divided by Its Total Length) of Cross 522. Plants Were Classed as "Normal," "Narrow," or "Oval" by Observation

Class	T 114 Leaflet shape Narrow	T 122 Leaflet shape Oval	F_2 Leaflet shape Normal	F_2 Leaflet shape Oval	F_2 Leaflet shape Narrow	F_2 Total
22	1				1	1
23	4				4	4
24	5				4	4
25	8				10	10
26	4		1		7	8
27	4		1		10	11
28	6		1		6	7
29					6	6
30						
31			5		2	7
32			4	1	2	7
33			10	1	1	12
34			16	1	1	18
35			20	2		22
36			29	4	1	34
37		3	19	3	1	23
38		5	19	3		22
39		7	14	5		19
40		9	10	3		13
41		6	1	8		9
42		2	1	4		5
43		3	1	1		2
44			1	3		4
45		1	1	1		2

VITA

The author was born near Weeping Water, Nebraska, on June 30, 1916. He graduated from Weeping Water High School in 1933. He attended the University of Nebraska from 1934 to 1938, receiving the degree of Bachelor of Science in Agronomy and Vocational Education. For the academic years 1938-39 and 1939-40 he was appointed research fellow in Agronomy at the Utah State Agricultural College from which institution he received the Master of Science degree. For the academic years 1940-41 and 1941-42 he was appointed fellow in Agronomy at the University of Illinois.

He is the author of one paper; "Bulk emasculation and pollination of smooth bromegrass, *Bromus inermis*." Jour. Amer. Soc. Agron. 33:993-1002. 1941.

He is a member of the American Society of Agronomy, Alpha Zeta, Gamma Sigma Delta, Phi Kappa Phi, and an associate member of Sigma Xi.