A STUDY OF THE INHERITANCE OF COLOR IN FLOWERS, ANTHERS AND SEEDS IN THE FLAX CROSS, CRYSTAL x PACIFIC

by

KENNETH WILLIAM BUCHANNON, B.S.A.

A Thesis

Submitted to the Committee on Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree of

MASTER OF SCIENCE

THE UNIVERSITY OF MANITOBA

April 1952

TABLE OF CONTENTS

INTRODUCTION

This study was undertaken primarily to determine the inheritance of color in flowers, anthers and seeds, and the association between these characters, in a cross of an oil-seed variety with a fiber variety of flax. The varieties Crystal and Pacific were chosen because they are being used in the breeding program at the Dominion Laboratory of Cereal Breeding, Winnipeg, and it was felt that any information concerning the genetics of these two varieties would be of value.

While this experiment was not designed to study the inheritance of plant height, observations were made which give some indication as to the inheritance of this character.

REVIEW OF LITERATURE

PETAL COLOR

Tammes (8) has determined 8 hereditary factors A1, B1, B2, C', D, E, F and K which influence the color and its distribution in the petals. According to her investigations B1, B2 and C' are basic color factors all of which must be present in the dominant condition for the production of color. If any one of them is recessive the petals are white. Factors D and F determine the tint of the petals. If only the three basic factors are present in the dominant condition the color is pink; if F is present the color is also pink but of a deeper shade; if D is present the color is lilac. D and F together with the basic factors produce blue petals. The intensity of blue, lilac and pink colors is dependent upon the intensifiers A and E; E has more effect than A but E and A together have more effect than E alone. The factor K is responsible for the distribution of color in the petals; when K is present the entire petal is colored but is slightly paler toward the base; when K is lacking the color is restricted to the upper edge of the petal although the outline is indefinite.

Initially Tammes (8) had determined the presence of only 2 basic factors B' and C' but Kappert, as reported by Tammes (8), demonstrated that B' consisted of two factors B1 and B2. This designation was accepted by Tammes (8).

Tammes (8) found that when a white, crimped-petal variety (....b1b1B2B2C'C'....) with yellow anthers and green seeds was crossed with common blue flax there was a deficiency of white-flowered segregates in F_2 and later generations. She attributed this deficiency to the factor C'; this factor having a semi-lethal effect in the absence of B1.

Kappert, as cited by Tammes (8) and Myers (5), gave a different explanation for the deficiency of white-flowered segregates. He concluded that there was a different degree of gamete competition resulting in the formation of more female gametes of the genotype Bl B2 C' than of the genotype bl B2 C'. He observed that a white-flowered variety when crossed with a certain blue-flowered variety gave a deficiency of white-flowered segregates, but when crossed with another blue-flowered variety no deficiency was observed. These observations led to the conclusion that the deficiency was dependent upon the genetic constitution of the blue-flowered parent.

Shaw et al. (7) determined the following seven hereditary factors for petal color: B, C, D, E, F, K and N. Their theory as to the inheritance of petal color differed only slightly from that of Tammes (8). They considered Tammes' factor A was unnecessary and found no evidence in support of dividing factor B into Bl and B2. The factor N was assumed by Shaw et al. (7) to act as a reduction factor, resulting in a lighter shade of petal color when present.

Mohammad and Khan (6) in studying crosses between white-flowered and blue-flowered varieties, obtained segregations in F_2 of 3 blue to 1 white. They explained petal color inheritance on the basis of the 7 hereditary factors suggested by Shaw et al. (7).

Myers (5) studied the cross Redwing x Ottawa 770 B and came to the conclusion that these two varieties differed by a single factor pair with respect to petal color. However, his ratios in F_2 and in the F_3 segregating lines showed a marked deficiency of white-flowered plants. He found that in the F_3 families the homozygous white lines produced only 78.1 percent as many flowering plants as did the homozygous blue lines, and only 77.0 percent as many as the segregating lines.

These calculations, however, accounted for only 21.9 percent to 23 percent of the deficiency of white-flowered plants whereas the actual deficiency was 33.8 percent. In comparing the mean number of plants in the check rows Myers (5) found that the white-flowered variety, Ottawa 770 B, produced 23.6 percent less flowering plants than Redwing. Three possible explanations were offered for the deficiency of white-flowered segregates: (a) a semi-lethal action of the recessive petal color gene, (b) a semi-lethal gene or genes carried by both parents and acting only in the presence of the recessive petal color condition or (c) a semi-lethal gene or genes closely linked to the recessive petal color gene.

McGregor (4) in studying the crosses Cyprus x Ottawa 770 B and Buda x Ottawa 770 B found the recessive class to be smaller than the theoretical in each case. However, the results obtained were well within the deviations expected on the basis of random sampling.

El-Kilany (2) obtained two mutations from G.O.F. (Giza oil flax). One of these had white flowers and yellow anthers and the other had blue flowers and blue anthers. In a cross between these two mutations he observed a segregation of 3 blue to 1 white.

ANTHER COLOR

Tammes (8) after studying various crosses, determined that a factor H in the presence of Bl, B2 and D was necessary to produce blue anthers. In the absence of any one of these 4 factors the anther color was yellow. This was later confirmed by Shaw et al.(7).

Mohammad and Khan (6) observed complete linkage between white flowers and yellow anthers, and between blue flowers and blue anthers in the crosses which they studied.

El-Kilany (2) in a cross between a blue-flowered variety with blue anthers and white-flowered variety with yellow anthers obtained the following F_2 segregates: blue flowers with blue anthers, blue flowers with yellow anthers and white flowers with yellow anthers. He did not obtain any plants with white flowers and blue anthers.

SEED COLOR

Tammes (8) determined that seed color depended upon the interaction of two of the petal color factors, Bl and D, together with a basic factor G and two or more polymeric factors. According to her investigations, when G is recessive the seed is yellow because the yellow cotyledons are visible through the colorless seed coat. If G is dominant the seed may still be yellow providing the polymeric factors are not present. Bl, D and G in the dominant condition form a series of seed colors varying from light yellow to blackish-brown but usually reddish-brown in tone. When Bl is recessive the seed colors also form a series from light to dark but of a greenish tone. If D or both D and Bl are recessive the seed colors form a series from light yellow to dark brown, but this series has a greenish tone in contrast to the reddish toned series produced by Bl, D and G.

Shaw et al. (7) found that seed color was dependent upon four factors, namely M, G, X and the petal color factor D. Their studies indicated that M in the presence of D converted the fundamental yellow color into fawn, and if G was also present fawn was changed to brown. In the absence of D, M had no action and the seed remained yellow. The factor G in the absence of D caused the seeds to be grey. Factor X converted yellow to dark yellow and fawn to dark fawn.

Mohammad and Khan (6) determined from their studies of several crosses that two factors, G and M, were responsible for seed color.

They found that seed color factor M was linked with petal color factor D with a crossover value of approximately 7 percent and that seed color factor G was inherited independently. They crossed a yellow-seeded type with two brown-seeded varieties and in both cases obtained a ratio of 9 brown: 3 grey: 3 fawn: 1 yellow.

Myers (5) in the cross Redwing x Ottawa 770 B found that all blue-flowered segregates produced brown seeds and that all white-flowered segregates produced yellow seeds.

Blaringhem, as cited by Myers (5), obtained brown-seeded and yellow-seeded individuals in the ratios of 3:1 and 15:1 in different crosses between brown-seeded and yellow-seeded varieties.

McGregor (4) found that in the crosses Cyprus x Ottawa 770 B and Buda x Ottawa 770 B yellow seeds and yellow anthers were always associated with white-flowered segregates.

Dillman (1) reported that the factors determined by Tammes for seed color and petal color have been found to hold true in a great number of crosses made by Brinsmade. The varieties used by Brinsmade were of a different origin to those of Tammes.

PETAL SHAPE

Tammes (8) and McGregor (4) both found that crimped petals were associated only with white-flowered, yellow-anthered, yellow-seeded varieties. Tammes (8) however, points out that there are varieties possessing white flowers, yellow anthers and yellow seeds which do not have crimped petals.

MATERIALS and METHODS

The material used in this study consisted of the parents (Crystal and Pacific), the F_1, F_2 and F_3, and the first generation of the F_1 backcross to both parents. Crystal, a selection from the cross Bison x Ottawa 770B, is an oil-seed variety of medium height with white crimped-petal flowers, yellow anthers and greenish-yellow seeds. The color of the seed is the result of a greenish seed coat and yellow cotyledons. Pacific, a selection from the cross J. W. S. x Cirrus, is a fiber variety with long straw, blue flowers, blue anthers and brown seeds. The brown color of the seeds is confined to the seed coat. The average plant height of Crystal and Pacific is 56.46 centimeters and 68.85 centimeters respectively.

The cross was made in the field in the summer of 1949. The F_1 plants were grown in the greenhouse in the early part of the winter of 1949-50 and at that time backcrosses were made to both parents. Part of the seed from the F_1 plants was grown in the second greenhouse crop of 1949-50. In the spring of 1950 there was seed for F_1 plants, F_2 families, F_3 lines and backcrosses to both parents available for planting.

Part of the land obtained in 1950 for experimental work was formerly used for truck crop production and was heavily infested with cutworms. The material to be studied suffered a high degree of damage as a result of this infestation. Some of the plots were reduced to one or two plants, and the total damage was approximately 76 percent. Observations were made on the segregation for flower color in the F_2 families. The F_3 lines were designated as white-flowered, segregating or blue-flowered. It was considered, however, that the observations on the F_3 lines were without value since there was some doubt as to whether lines with only a very few blue-flowered or white-flowered plants were actually homozygous or segregating.

Additional crosses were made in the field in 1950 and the F_1 and F_2 were grown in the greenhouse in the winter of 1950-51. Additional backcrosses were also made in the greenhouse. In the spring of 1951 seed was available for the following populations which were planted in 10 foot rows:

(a) 12 rows of Pacific
(b) 12 rows of Crystal
(c) 6 rows of F_1 plants
(d) 74 F_2 families (1 row per family)
(e) 202 F_3 lines (1 row per line)
(f) 6 rows of F_1 backcross to Pacific
(g) 8 rows of F_1 backcross to Crystal

Fifty seeds per row were planted for the parents, F_2 and F_3. The number of seeds per row in the other populations depended upon the amount of seed available and in some cases this was less than 50 seeds.

The experiment was not completely randomized but consisted of blocks of F_3 lines separated by plots of F_1, F_2, parents and backcrosses.

At the time of flowering the material was examined as to flower color and anther color. The white-flowered plants in the F_2 families were marked by attaching a small white tag to each one. At the same time observations were made as to the color of the anthers in both the white-flowered and blue-flowered plants. The F_3 lines were recorded as being white, segregating or homozygous blue.

At maturity all of the material was pulled and brought into the Laboratory. During the winter of 1951-52 each plant was examined to determine the seed color. The presence or absence of tags on the

F_2 plants indicated what the flower color had been, and in this way it was possible to determine the association between flower color and seed color. Each plant was also measured to the nearest centimeter in order to obtain some information on the inheritance of plant height and to determine if there was any relationship between height and flower color.

EXPERIMENTAL RESULTS and DISCUSSION

PETAL COLOR

The segregation for petal color in 74 F_2 families is shown in Table 1.

Table 1.

Segregation for blue *vs.* white petal color in F_2 families

Plot No.	Blue	White	% White	X^2*
5	41	4	8.89	6.2296**
6	33	8	19.51	0.6585
7	34	12	26.09	0.0289
8	36	10	21.74	0.2608
9	38	8	17.39	1.4203
10	38	9	19.15	0.8581
11	41	4	8.89	6.2296**
12	37	6	13.95	2.7984
46	33	8	19.51	0.6585
47	34	7	17.07	1.3740
48	34	11	24.44	0.0073
51	29	8	21.62	0.2272
52	35	8	18.60	0.9380
53	27	12	30.77	0.6923
76	27	7	20.59	0.3529
77	24	3	11.11	2.7777
78	31	6	16.22	1.5224
79	32	6	15.79	1.7192
80	37	10	21.28	0.3475
81	35	12	25.53	0.0061
82	34	13	27.66	0.1773
83	32	10	23.81	0.0317
106	27	12	30.77	0.6923
107	33	12	26.67	0.0667
112	30	7	18.92	0.7297
113	30	6	16.67	1.3333
127	36	10	21.74	0.2608
128	35	6	14.63	2.3496
129	39	9	18.75	1.0000
130	39	8	17.02	1.5957
131	36	9	20.00	0.6000
132	35	5	12.50	3.3333
133	28	6	17.65	0.9804
134	32	11	25.58	0.0077
153	33	8	19.51	0.6585
154	30	9	23.08	0.7692
155	34	7	17.07	1.3740
157	34	4	10.53	4.2456**
179	34	6	15.00	2.1333
180	36	8	18.18	1.0908

(Concluded on next page)

Table 1 -- Concluded.

Plot No.	Blue	White	% White	X^2*
181	44	6	12.00	4.5067**
182	38	3	7.32	6.8373**
183	28	8	22.22	0.1481
184	34	5	12.82	3.0855
185	28	8	22.22	0.1481
186	36	4	10.00	4.8000**
201	26	3	10.34	3.3218
202	34	5	12.82	3.0855
206	34	13	27.66	0.1773
207	37	6	13.95	2.7984
208	39	8	17.02	1.5957
221	36	5	12.19	3.5853
224	32	7	17.95	1.0341
227	35	4	10.26	4.5213**
228	38	4	9.52	5.3651**
265	27	9	25.00	0.0000
266	34	8	19.05	0.7936
267	37	6	13.95	2.7984
268	41	5	10.87	4.8985**
269	38	7	15.55	2.1407
270	36	3	7.69	6.2308**
271	32	9	21.95	0.2105
272	16	8	33.33	0.8889
291	31	8	20.51	0.4188
292	39	9	18.75	1.0000
297	38	7	15.55	2.1407
298	36	12	25.00	0.0000
320	28	10	26.31	0.0351
321	28	17	37.78	3.9185**
322	35	11	23.91	0.0289
323	41	7	14.58	2.7777
324	43	4	8.51	6.8156**
325	33	12	26.67	0.0667
326	32	13	28.89	0.3629
Total Segregation	2507	579		64.0319

* For 5% level of Significance $X^2 = 3.841$ for 1 degree of freedom (Fisher 3)

** Poor fit for a 3:1 ratio

From Table 1 it will be noted that 62 families fit a 3:1 ratio at or above the 5 percent level of significance. The 12 divergent families exceed the number (approximately 4) expected due to chance when P.05 is taken as the level of significance. A chi-square test for goodness of fit for the total segregation gave a P value below .01.

This poor fit resulted from too few individuals in the recessive class.

The 202 lines studied in F_3 gave a ratio of 67 blue: 92 segregating: 43 white. A chi-square test for fit to a 1:2:1 ratio gave a P value between .02 and .01 indicating that the deviation was greater than would be expected on the basis of chance.

The segregation for petal color in the 92 segregating F_3 lines is shown in Table 2.

Table 2.

Segregation for blue vs. white petal color in 92 F_3 lines

Plot No.	Blue	White	X^2
14	41	4	6.2296*
18	32	14	0.7246
19	40	6	3.5072
20	34	14	0.4444
24	41	8	1.9660
25	27	15	2.5714
26	37	8	1.2519
28	36	7	1.7441
31	28	10	0.0351
32	27	11	0.1026
39	31	17	2.0496
54	29	12	0.3984
57	33	8	0.6585
58	35	11	0.0289
59	37	8	1.2419
63	39	9	1.0000
64	36	8	1.0909
65	33	12	0.5167
68	21	8	0.1035
69	24	6	0.4000
84	33	13	0.2608
85	33	10	0.0697
87	31	10	0.5671
89	38	8	1.4203
90	37	12	0.0058
92	32	12	0.1212
93	31	17	2.7777
94	37	8	1.2519
95	36	14	0.2400
96	40	7	2.5603
98	30	10	0.0000
114	29	11	0.1333
116	29	10	0.0085
118	35	10	0.1852
119	37	3	6.5333*

(Continued on next page)

Table 2 -- Continued.

Plot No.	Blue	White	X^2
122	31	15	1.4202
142	25	12	0.7297
145	42	4	6.6217*
158	31	3	4.7462*
159	15	5	0.0000
160	25	9	0.0392
161	40	7	2.5603
163	34	13	0.1733
164	30	14	1.0909
165	28	7	0.4667
170	29	6	1.1524
171	39	11	0.2400
188	34	9	0.3799
189	35	10	0.1852
190	37	8	1.2519
193	33	12	0.0667
194	29	15	1.9393
196	21	8	0.1035
197	27	14	1.8292
212	34	5	3.0855
216	31	12	0.3899
229	35	10	0.1852
230	32	10	0.0317
233	40	7	2.5603
234	35	11	0.0289
235	23	7	0.0444
238	32	7	1.0341
242	37	7	1.9393
244	36	9	0.6100
248	43	6	3.0000
255	21	5	0.4615
258	42	8	2.2600
274	26	9	0.0095
276	33	7	1.2000
277	38	11	0.1700
279	33	13	0.2608
284	39	7	2.3478
285	32	10	0.0317
287	32	15	1.1885
288	35	6	2.3496
299	29	14	1.3100
302	34	7	1.3740
303	37	9	0.7246
304	34	13	0.1773
306	34	11	0.0073
307	32	5	2.6036
308	32	8	0.5333
312	19	7	0.0513
313	9	4	0.2308
315	26	9	0.0095
316	25	7	0.1667

(Concluded on next page)

Table 2 -- Concluded.

Plot No.	Blue	White	X^2
329	34	9	0.3799
330	36	10	0.2608
335	42	7	3.0050
339	35	5	3.3333
340	31	8	0.4188
341	34	10	0.0413
Total Segregation	2987	858	14.7871

* Poor fit for a 3:1 ratio

An examination of Table 2 shows that all but 4 lines fit a 3:1 ratio. The 4 divergent lines are very close to the number (approximately 5) expected due to chance when P.05 is taken as the level of significance. A chi-square test for the totals of the segregating lines gave a P value below .01. This poor fit was caused by a deficiency in the recessive class as was the case in the total F_2 segregation.

The ratio in the backcross to the recessive parent was 158 blue: 126 white. A chi-square test for a 1:1 ratio gave a P value between .10 and .05 indicating a good fit. The backcross to the dominant parent produced all blue-flowered progeny.

The data from F_2, F_3 and backcrosses to both parents gave no positive indication of more than one factor pair influencing the inheritance of petal color. Also, previous workers (4) (5) (8) have observed a deficiency of white-flowered segregates in crosses involving varieties similar to Crystal. It appears, therefore, that the results obtained in this study may best be explained on the basis of the following assumptions: (a) Crystal and Pacific differ by only one factor pair for petal color and (b) there is a condition associated with white petals which results in lower viability.

Table 1 shows that in all but 13 of the F_2 families the number of white-flowered segregates was less than the theoretical 25 percent. On the basis of chance alone it would be expected that the deviations would vary above and below this theoretical proportion. The poor fit of the 12 divergent families was caused, in every instance but one, by a deficiency of the recessive class. The above observations indicate that an actual deficiency of white-flowered segregates did exist.

The poor fit of the total F_2 segregation to a 3:1 ratio may be explained when it is realized that a slight deficiency in the recessive class of each family would not result in significant deviations, but that when these deviations accumulated over 74 families the effect would be increased in proportion to the number of families studied. The total deficiency as calculated from F_2 was 30.71 percent; i.e. the expected number of white-flowered F_2 plants is 836 instead of the 579 observed. On the basis of a 30.71 percent deficiency the expected ratio in the 202 F_3 lines would be 55.67 blue: 111.34 segregating: 34.99 white. A chi-square test based on the corrected theoretical ratio gave a P value slightly above .02, indicating that this calculated deficiency did not fully account for the divergence from a 1:2:1 ratio. No evidence is available as to the cause of the remaining deviation.

Evidence that a deficiency of white-flowered plants occurred in the material studied is also available in the backcross data and in the percentage survival of the white-flowered parent. The data from the backcross to the recessive parent showed that there were 20 percent too few individuals in the recessive class to give a perfect 1:1 ratio. The average survival of the parents, as determined from the number of plants in the check rows, was 37.46 percent for Crystal and 78.37 percent for Pacific. A germination test in the greenhouse showed 21 percent germination for Crystal and 92 percent for Pacific.

On the basis of an association between white-petal color and lower viability one would expect a difference in the percentage survival of the blue-flowered, segregating and white-flowered F_3 lines. The percentage survival was 82.36 percent for the blue-flowered lines, 83.56 percent for the segregating lines and 80.27 percent for the white-flowered lines. A greenhouse test using reserve seed from F_2 plants, for which the F_3 breeding behavior was known, gave the following results expressed in percentage germination: homozygous blue 97.8, segregating 93.2 and white 80.8. The greenhouse results show the trend that would be expected. No evidence is available to explain the difference in germination between field and greenhouse tests.

That a deficiency of white-flowered segregates did exist in the material studied is quite evident. However, the reason for this deficiency is not easily accounted for since the data did not indicate any specific cause or causes. It would appear that there is a semi-lethal action associated with white petal color. This may be due to a semi-lethal effect of the recessive petal color gene, or of a closely linked gene. The low germination capacity of Crystal is evidence that either of these conditions may exist. Kappert, as cited by Myers (5) and Tammes (8), has reported that white, crimped-petal varieties gave a deficiency of white-flowered segregates when crossed with certain blue-flowered types, but not with others. This would indicate the presence of a factor, or factors, in some blue-flowered varieties that has a semi-lethal effect in the presence of recessive petal color genes. Since the present study consisted of only one cross it is impossible to determine if Pacific contributed a semi-lethal factor. Tammes (8), on the other hand, attributed the deficiency to the factor C' having a semi-lethal effect in the absence of Bl. In view of the low viability of Crystal it would appear that Tammes' explanation could account for the deficiency in the cross studied, assuming of course, that Crystal is genetically similar to Tammes' white, crimped-petal variety with yellow anthers and greenish-yellow seeds.

ANTHER COLOR

In over 3000 F_2 plants studied it was found that yellow anther color was completely linked with white petals, and blue anther color completely linked with blue petals. The same linkage relationship held true in the segregates from the backcross to the recessive parent. On the basis of the large number of plants examined it appears evident that petal color and anther color are controlled by the same gene or by genes so closely linked that no crossovers were observed.

SEED COLOR

An examination of the F_2 plants revealed that white-flowered plants produced only greenish-yellow seeds and blue-flowered plants produced only brown seeds. The same relationship existed in the segregates from the Crystal backcross. The blue-flowered plants from the Pacific backcross produced brown seeds only. Among the F_3 lines it was found that all plants from homozygous blue-flowered lines had brown seeds and all plants from white-flowered lines had greenish-yellow seeds. F_3 lines which segregated for petal color also segregated for seed color.

The brown seed from different plants showed a tendency to vary slightly in the intensity of the brown color. However, since some of the seed bolls were immature at the time of harvest it was impossible to ascertain whether the variations in color were due to genetic factors or to incomplete ripening. In no instance was there any doubt as to whether the seed should be classified as brown or as greenish-yellow.

The results obtained in this cross indicated that the production of color in petals and seeds is controlled by the same gene or by genes so closely linked that no crossovers were observed.

On the basis of the factors proposed by Tammes (8) for flower color, anther color and seed color it would appear that Pacific has the genotype AABlBlB2B2C'C'DDEEFFKK and that Crystal is genetically similar except for being homozygous recessive for Bl.

PLANT HEIGHT

The frequency distribution of plant heights for individual plants of parents, F_1, F_2 and backcrosses, and of mean heights for individual F_3 lines is shown in Table 3.

A comparison of the data for blue-flowered and white-flowered F_2 populations, and for blue-flowered, segregating and white-flowered F_3 lines indicates that there is no association between petal color and plant height. There is no significant difference between the mean heights of the two F_2 populations or between the blue, segregating and white F_3 lines.

The mean heights of F_1 and the backcross to Pacific are essentially the same as the mean height of Pacific, indicating that tall stature is dominant.

Table 3

Frequency Distribution of Plant Heights in Centimeters
of Parents, F_1, F_2, F_3 and Backcrosses

Class Centers	Population									
	Parents		F_1	F_2		F_3			Backcrosses	
	Crystal (Plants)	Pacific (Plants)	(Plants)	Blue-flowered (Plants)	White-flowered (Plants)	Blue-flowered (Lines)	Seg. (Lines)	Blue-flowered (Lines)	F_1 x Crystal (Plants)	F_1 x Pacific (Plants)
39				1					1	
40	1			1					1	
41					1				1	
42	3			3					1	
43	1		1	1	3				1	
44	4			5	3				2	
45	4		1	5	3		1		1	
46	2			6	3				1	
47	4			9	1				1	
48	10			21	6				3	
49	4		3	21	7					
50	7		1	27	3	1	2		6	2
51	6		3	24	5		2		1	
52	8	1	3	32	9	1			1	
53	12		2	41	15	1			13	
54	12	4	4	52	8	1	1		9	1
55	14	3	2	44	14	1	2	1	15	1
56	14	2	2	83	7	4	2		11	
57	9	3	5	97	16	2	7	3	9	2
58	12	4	4	92	22	2	6	4	12	
59	5	7	4	92	19	3	5	3	11	1
60	9	10	4	115	24	6	5	2	12	5
61	13	8	7	99	28	2	7	1	17	3
62	7	15	10	105	28	4	7	2	17	5
63	7	29	11	113	36	6	5	2	18	7
64	10	26	14	150	23	6	6	8	15	11
65	3	22	10	108	30	4	6	4	9	9
66	10	27	12	125	18	7	3	3	11	14
67	3	25	9	106	23	2	3	1	13	13
68	2	25	14	108	20	2	5	2	9	15
69	3	23	9	102	29	2	3		6	19
70	4	38	20	118	27	1	4	1	13	16
71		31	15	84	20	3	3	2	8	10
72		27	9	98	23	3		1	9	16
73		29	10	69	19		1		6	13
74		16	18	76	14		1		4	9
75		13	15	72	17	2	3	2	3	9
76		8	10	27	9	1	1		3	6
77		13	10	42	7				1	9
78		9	4	36	13				3	5
79		8	6	26	7					4
80		7	7	26	2				1	7
81		8	3	15	6					3
82			3	12					3	1
83		3	2	8	5				1	1
84		2	2	4	1					
85		1	2	2	1					
86				3	2					1
87					1					
88					1					1
89				1						
Totals	203	447	271	2507	579	67	92	42	283	219
Mean Ht.	56.46	68.85	68.46	64.70	64.79	63.31	62.83	63.64	62.18	69.87
S.E.	± .47	± .28	± .48	± .16	± .35	± .69	± .65	± .77	± .47	± .42
S.D.	6.73	5.98	7.96	7.86	8.38	5.65	6.25	4.98	7.90	6.22
S.E.	± .33	± .20	± .34	± .11	± .25	± .49	± .46	± .54	± .33	± .30

SUMMARY and CONCLUSIONS

The purpose of this study was to determine the mode of inheritance of flower color, anther color and seed color in the cross Crystal x Pacific. Observations were also made with the object of obtaining some information on the inheritance of plant height and to determine if there was an association between height and petal color.

The results obtained indicated that petal color was controlled by a single factor pair and that there was a condition associated with white petals which resulted in lower viability. The cause of the deficiency was not clear but it appeared that the gene C' had a semi-lethal effect in the absence of Bl. Evidence from the F_2, the backcross to the recessive parent and the recessive parent itself indicated that an actual deficiency did exist.

Further research is planned concerning the deficiency of white-flowered segregates in crosses between white and blue-flowered varieties. This research will consist of studying crosses between Crystal and Pacific and some of Tammes' varieties of known genetic constitution.

In the cross studied it was found that yellow anthers and greenish-yellow seeds were always associated with white flowers, and that the same relationship existed between blue anthers, brown seeds and blue flowers. These observations indicated that anther color, seed color and flower color were all controlled by the same basic gene, or by genes so closely linked that no crossovers were observed.

Data on the heights of plants indicated that tall stature was dominant and that there was no association between flower color and plant height.

ACKNOWLEDGMENTS

Grateful acknowledgments are made to Dr. R. F. Peterson, Officer in Charge, Dominion Laboratory of Cereal Breeding, Winnipeg, for providing facilities and materials, and for helpful criticism and advice in interpreting results; to Dr. P. J. Olson, Professor of Plant Science, University of Manitoba and Dr. A. Love, Associate Professor of Botany, University of Manitoba, for suggestions and criticisms concerning the manuscript.

LITERATURE CITED

1. DILLMAN, A.G. Improvement in flax. U. S. Dept. Agr. Yearbook. 745-784. 1936.

2. EL-KILANY, M.A. Flax in Egypt. Part III. Flower and anther color inheritance. Bull. Minist. Agric. Egypt. 205 : 5-7. 1939.

3. FISHER, R.A. Statistical Methods for Research Workers. Edinburgh : Oliver and Boyd. 5th Ed. 1934.

4. McGREGOR, W.G. Inheritance of quality and quantity of oil in flax in relation to other plant characters. Can. J. Res. 15 : 362-379. 1937.

5. MYERS, W.M. A correlated study of the inheritance of seed size and botanical characters in the flax cross, Redwing x Ottawa 770B. J. Am. Soc. Agron. 28 : 623-635. 1936.

6. MOHAMMAD, A. and A. R. KHAN. Some breeding investigations on linseed (Linum usitatissimum L.) in the Punjab. Indian J. Agric. Sci. 11 : 432-435. 1941.

7. SHAW, F.J.F., K. S. A. R. KHAN and M. ALAM. Studies in Indian oil seeds. V. The inheritance of characters in Indian linseed. Indian J. Agric. Sci. 1 : 1-57. 1931.

8. TAMMES, Tine. The genetics of the genus Linum. Bibliographia Genetica. 4 : 1-36. 1928.