THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report
of
Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Fred Griffee final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

May 29 1920

H. K. Hayes
Chairman

M. J. Dorsey

E C Stakman

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Fred Griffee for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

H. K. Hayes
Chairman

M J Dorsey

E C Stakman

May 29 1920

HETEROSIS IN WHEAT CROSSES

A THESIS

Presented to the Faculty of the Graduate
School of the University of Minnesota in
Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

By

Fred Griffee

JUNE
1920

CONTENTS

ACKNOWLEDGEMENTS

The writer desires to express his appreciation to Professor H.K. Hayes, Head of the Section of Plant Breeding, for suggestions and criticisms given during the progress of this study, to Professor Andrew Boss, Chief of the Division of Agronomy and Farm Management, for suggestions and material support and to Assistant Professor R.J. Garber for kindly suggestions. The writer also desires to express his appreciation to Mr. Lee Alexander for assistance in the work of planting in the field and greenhouse and to Mr. T.J. Horton for photographic services.

INTRODUCTION

It is well known that an increase in vigor often occurs in many plants (animals as well) as a result of crossing different strains, varieties or species. Numerous data have been published in relation to this phenomenon. This increase is usually more pronounced in the first generation following the cross and obtains in both normally self- and cross-pollinated plants. It is generally believed that within a species the more widely diverse the types of the parents entering the cross, the greater will be the increase in vigor. Only recently has an adequate explanation of the phenomenon been evolved. The more commonly accepted view is that size character inheritance may be explained by the interaction of inherited growth factors. The linkage of factors, presumably located in the same chromosome, explains why a greater growth stimulus may be obtained in the heterozygous than in the homozygous condition. This theory is now being applied successfully in the breeding of a few important crop plants. It is the purpose of this study to review the theory in its application to wheat crosses and to wheat breeding. Does an increase in vigor occur in the first generation following a cross between varieties or species of wheat? Should such an increase occur, of what significance is it to the plant breeder? Can the vigor of heterosis be utilized by the commercial grower?

Hybridization experiments have been so numerous that to canvass the entire field would be a laborious task. Therefore, the literature cited has been reviewed with the purpose of giving a comprehensive rather than an exhaustive summary of data. Since the subject has been reviewed quite recently, the earlier writers will be mentioned briefly, the greater emphasis being placed on the more recent experiments.

REVIEW OF LITERATURE

ANIMAL KINGDOM

Inbreeding: A belief is commonly held by civilized people that incest in human stock produces deleterious results, that the offspring of consanguineous matings are subject to malformation and predisposed to all manner of malfunctions and ills incident thereto. Huth (50), in an extensive study of this subject, cites the Spartans, the Persians, the ruling classes of the Egyptians and Polynesians, the Jews, the aborigines of Central America and many others to show that consanguineous marriage in human stock has seldom resulted in the disastrous effects commonly expected; that races do not undergo a marked deterioration from close intermarriage. Huth quotes Ovid as having had a great horror of incestuous marriage but as being at a loss to understand why such marriages should be prohibited. Ovid cited the case of animals to show that such is not forbidden by nature since incest is constantly practiced by animals and habitually by those that are polygamous, such as deer, cattle, sheep, antelope, gorilla and several species of baboon, a large number of birds, etc.

Ritzema Bos (77), however, by continuously mating rats closely related secured a reduction in fertility and after many generations a reduction in body weight. He is, however, one of the first to attribute the appearance of malformations and predisposition to ills to the probable fact that the factors for such, contained by the parents, accumulate in their offspring.

A review of Miss King's work (60) shows that after 22 generations of inbreeding, the rats with which she worked were larger and more vigorous than the stock rats from which they were descended.

They grew more rapidly and showed no more defects or abnormalities than did the rats that were not inbred. Fabre-Dominique (29) reports his inbreeding of pigeons as accompanied by a decrease of fertility, a decrease in size and a lack of vigor. Castle and his coworkers (15) bred Drosophila for 59 generations of continuous brother and sister matings without apparently reducing the fertility below that shown by the original stock. Moenkhaus (70), working with Drosophila, concluded that inbreeding is not necessarily accompanied by deterioration. All of Shull's (84, 85) measurements in Hydatina Senta pointed to a decrease in size of family in some lines after long continued parthenogenesis. The Chillingham cattle are cited by Kraemer (65) as an example of inbreeding unaccompanied by deterioration.

Cross Breeding: An example of cross breeding in human stock is given by Fischer (30) in a study of the offspring of Boer and Hottentot hybrids. He found the mongrel had a stature average (168.4 centimeters) considerably greater than that of Hottentots (157.9 centimeters) and slightly above that of present day Hollanders (167.5 centimeters) or of South Germans (167-168 centimeters). Crampe (21) in a study with rats found that the family crosses gave animals more easily nourishable and with larger and heavier bodies than intrafamily matings.

Castle and Carpenter (15) crossbred Drosophila with an accompanying increase in productiveness in some crosses and in others neither an increase nor a decrease. A cross between Series "A", having an average production of 95 young, and Series "D", having an average production of 228, gave an F_1 (A x D) with an average production of 356 young. The reciprocal cross (D x A) had an average production of 252 young. Hyde (51) crossed strains of Drosophila with fresh stock and obtained two combinations equalling and four combinations exceeding the most fertile parents. Jennings (52,53) found in Paramecium that if the animals were vigorous before conjugation, some lines were produced that were less vigorous than the originals. If the animals were weak, the tendency of conjugation was to produce more vigorous lines. Whether the strain deteriorated or not following conjugation depended on the selection of vigorous or nonvigorous individuals. The split pairs produced about 25 per cent more individuals on an average for four weeks than the pairs allowed to complete conjugation. He points out that conjugation is accompanied by an increased variation, giving rise to heritable differences; and that mortality is usually higher and abnormalities more common among descendants of conjugants than among non-conjugants.

Whitney (92) reports a very pronounced increase in reproductive rate from crossing sister races of Hydatina Senta which were weakened by parthenogenetic reproduction. An example of a hybrid exceeding either parent in size is furnished by Gerschler (37) in fish crosses. A male of Xiphophorus, the larger parent, measured 43.0 mm. long; the hybrid male 54.0 mm. and the hybrid female 57.5 mm.

Numerous other examples could be cited from the animal kingdom but those given suffice for illustrative purposes. It is generally admitted among geneticists that inbreeding in itself has no deleterious effects. Inbreeding tends to isolate homozygous types. The genetic constitution of the material used determines the possibilities of inbreeding but the selection supplementing the operation determines largely the results. Cross breeding tends to produce heterozygosis and consequent variation. Here again the genetic constitution of the material used limits the possibilities.

PLANT KINGDOM

Some Early Workers: The works of a few early writers are so generally known that they will be mentioned only briefly. The hybrids of Koelreuter[1] (64) give some of the most excellent examples of heterosis. Gärtner[2] (36) mentions a marked increase in size of flower, the general luxuriance of all parts and a heightened fruiting capacity as being some of the characters of plant hybrids. Darwin's (22) work contains abundant evidence bearing on heterosis. The well known studies of Mendel (69) supply an excellent example of heterosis. Wichura (93) gives an illustration of plant hybrids in his willow crosses. He states that a large part of the artificially produced hybrids are distinguished by their vigorous growth.

Immediate Effect of Pollination: Due to double fertilization there is sometimes an increase in endosperm weight as an immediate result of cross-pollination. Focke (32) first proposed the term Xenia to describe the apparent effect of the action of pollen upon the maternal tissue of the seed plant. Since the discovery of double fertilization and the fact that the endosperm is part of the filial generation, the term Xenia has been used to describe the immediate visible effect of double fertilization.

Lewis and Vincent (66) compared the weight of seeds produced by self-pollinations with seeds produced by cross-pollinations. Self-fertilized seed of Newtown weighed on the average .05 gram. When Newtown was crossed with Bellflower, Spitzenberg, Jonathan, or Grimes Golden, the average seed weights were .40, .66, .65 and .60 grams respectively.

---

[1] From Jones (56).

[2] From Roberts (80).

These are examples of striking increases in size as a result of varietal crosses. Collins (16) observed open-pollinated ears of Chinese maize in which the size of seed was influenced by the nature of the pollen. Seeds which showed by their color and texture the effect of foreign pollen were in nearly every case distinctly larger than those showing pure Chinese characteristics. Carrier (14), also working with corn, employed two varieties. He grew strains of Leaming from Virginia, Illinois, Indiana and Nebraska, and Boone County White from Virginia, Kentucky, Indiana and Illinois. In comparison with these he grew mixtures of each four strains. Two years experiments show a strikingly increased yield for the mixture over any of the strains. Collins and Kempton (21) compared the results of pollinations from the same variety and from a different variety. The average results of the latter exceeded those of the former by 8.8 per cent. Wolfe (95) made thirty-one varietal crosses of corn of which 23 yielded more and 8 less than the yield of intra varietal pollinations. Jones (56) compared selfed strains and crosses between them. He made two tests, both of which gave an increase of the crossed over the selfed, the average increase being 19.2 per cent.

<u>Crossing Naturally Self-Pollinated Plants</u>: Continued self-fertilization tends to isolate types in a homozygous condition. Pure line methods of breeding give comparatively certain assurance that self-pollinated plants are homozygous by virtue of the fact that thqy are self-pollinated naturally.

Crossing these crops, however, is theoretically diametrically opposed to selfing. Beal (6,7,8,9) realized the probable value of "infusing fresh blood" into crops grown locally. He advocated securing seeds from different sources to make mixtures for seeding

The principle was tested with beans. In random selections of 50 seeds from 6 different lots the crossed averaged 269 grams and incrossed 213 grams. Card and Adams (13) crossed varieties of Lima beans and secured increased yield in F_1. Belling (10) crossed Velvet Bean and Lyon Bean and secured the following results:

Number beans per pod	- Velvet Bean	4.8	(average 135 pods)
	- Lyon Bean	4.48	(average 134 pods)
	- Hybrid	4.44	(average 250 pods)
Weight of beans	- Velvet Bean	0.73 grams	(average 652)
	- Lyon Bean	0.99 grams	(average 543)
	- Hybrid	1.24 grams	(average 578)

In the F_2 generation there were some plants with pods and beans much larger than those of the Lyon and other plants whose pods and beans were much smaller than those of the Velvet.

Mell (68) produced a hybrid between Gossypium maritimum and G. hirsutum which was earlier in maturity and was more prolific than the parents. Balls (4) crossed Sultani and King varieties of cotton and compared the height of the central axis at maturity. The height of Sultani was 185 cm., that of King 70 cm. and the F_1 hybrid between the two was 135 cm., which is slightly above the parental average. Knight (61) crossed a dwarf pea with a very large and luxuriant pea. In the succeeding spring the hybrid plants showed "excessive luxuriance". "The smallest variety, whose height rarely exceeded two feet was increased to six feet; whilst the height of the larger and more luxuriant kind was very little diminished." Look (67) made crosses between Satisfaction, a variety of pea with a height of 4.6 feet and an internode length of 1.74 inches, and a native variety, with a height of 2 feet and an internode length of 1.5 inches. The F_1 was 6 feet in height and had an internode length of 2.4 inches.

Bayla (5) crossed varieties of eggplant. The average of the hybrids compared with the parents is as follows (data based on average of 10 fruits):

	Weight in grams	Length in cms.	Diameter in cms.	Number of seeds
New York Imperial	35.1	12.3	10.4	2846.2
New York Imperial x Native	335.1	17.4	8.1	916.4
Native x New York Imperial	340.8	15.2	8.7	1089.5

The F_1 plants showed a more vigorous vegetative growth than either parent.

Kock (69) in hybridizing rice crossed "Karang Serang", a native of Carolina characterized by its earliness and good quality of the grain (heavy and bulky), and "Skrivimankotti", a native of Surinam well known for its high yields. The generations subsequent to the cross were vigorous yielders. After five or more years of selection from hybrid progenies, he succeeded in isolating a type yielding more than "Skrivimankotti" and with a promise of "Karang Serang" quality.

East and Park (25) reported that the F_1 generation of a cross between Nicotiana forgetiana and N. alata consisted of vigorous plants which were 25 per cent taller than the parental average. Houser (48) used Zimmer-Spanish tobacco. Six plants were chosen and each allowed to produce 20 seed pods. Ten of these were selfed and ten crossed. Pollen for crossing any one plant was collected from the other five plants. The F_1 hybrid plants in 1906 were indistinguishable in the field but produced 10 per cent greater yield than the selfed plants. In 1908, the hybrids exceeded the most productive parent. In 1909, some hybrids gave a decrease of 13 per cent when compared with the parental average. Others gave an increase of 57 per cent. Hayes (39) reports hybrids of tobacco that were intermediate but as a rule somewhat larger than the parental average. Selby and Houser (82) made numerous crosses with tobacco. When the F_1 crosses were compared with the better parent, some showed a decrease and others showed a marked increase in yield. The maximum increase was 492 pounds per acre. Hayes, East and Beinhart (43) report crosses of "Havana" and "Summatra" varieties. The first hybrid generation was taller than either parent. In F_2 a type was obtained which had the short habit of growth and the large leaves of the "Havana" parent combined with the high number of leaves of the "Summatra" parent. By further selection a type was isolated which bred true for these characters. From crosses of native and imported varieties of cigar tobacco, Shamel (83) secured progeny showing great improvement in yield over the native types.

Hedrick and Booth (47) crossed tomatoes, using the varieties Livingston Stone and Dwarf Aristocrat. The F_1 hybrids yielded so much more than the parents that in the estimation of the authors it would pay a gardener to grow first generation hybrids. Price and Drinkard (76) found, in a cross between standard and dwarf types, that the F_1 was all standard. Wellington (91) crossed varieties Livingston Stone and Dwarf Aristocrat securing a marked increase in yield in the F_1 generation. Hayes and Jones (45) compared the yield of artificially selfed tomatoes with their first generation crosses. The following is taken from their results and shows the increase of F_1 over the better parent:

	1912	1913	1914	1915	Avg.
The cross Stone x Dwarf Champion	+2.01	+2.02	+3.30	+3.99	+2.83
Per cent increase	+15	+11	+16	+17	+15
The cross Lorillard x Best of All	-1.15	-1.50	+1.01	-0.36	-0.09
Per cent increase or decrease	-7	-8	+4	-1	0

The first cross gave a decided increase but the second indicated a decrease. The decrease is so slight, however, that it no doubt comes within the probable error.

Freeman (33,34) crossed Macaroni wheat with bread wheats. Seed on the F_1 plants was all wrinkled and intermediate in texture between the two parents. Some of his results are as follows:

1914 Algerian Macaroni (No.1) x Sonora (No.35)

Pure No. 1	134 cms. tall
(No.1 x No.35) F_1	147 cms. tall

Algerian Macaroni (No.1) x Algerian Red bread (No.3)

Pure No. 1	134 cms. tall
(No.1 x No.3) F_1	124 cms. tall
Pure No. 3	118 cms. tall
(No.3 x No.35) F_1	142 cms. tall

Freeman also reports the hybrid leaf width to be as great or greater than the mean for the wide leaf parent. The difference, however, is very slight.

Cross-Pollinated Plants -- Inbreeding: Corn lends itself beautifully to an experiment on inbreeding and has been used extensively for inbreeding studies. Shull (86,87), after making a study of corn, came to the conclusion that a field of corn is composed of a series of more or less complex hybrids and that apparently injurious effects accompanying self-fertilization are due to the "unfavorable comparison of pure strains with their hybrids and of less complex hybrids with more complex ones." Webber (90) selfed corn with a resulting marked decrease the first year from selfed seed. Hickory King, the first year subsequent to selfing, yielded (per 100 stalks) 46 ears weighing 9 1/3 pounds. The same strain following a cross yielded (per 100 stalks) 82 ears weighing 27½ pounds. East and Hayes (24) say: (1) "The decrease in vigor due to inbreeding naturally cross-fertilized species and the increase in vigor due to crossing naturally self-fertilized species are manifestations of the same phenomenon", and (2) "Inbreeding is not injurious in itself, but weak types kept in existence in a cross-fertilized species through heterozygosis may be isolated by its means. Weak types appear in self-fertilized species, but are eliminated because they must stand or fall by their own merits." Emerson and East (27) succeeded in isolating and studying several abnormalities of corn. These were all recessive to normal types and when crossed with them the F_1 was perfectly normal. None of these abnormalities are known to increase the yield or improve the quality of the crop. Some have no effect while others cause total destruction of the plants. Jones (54,56) briefly summarizes the case of inbreeding in maize. "Twelve generations of continuous inbreeding confirm previous conclusions" that "reduction in vegetative vigor is rapid at first, but gradually slows down and finally ceases." This reduction is "correlated with the theoretical approach to homozygosity." There is a marked tendency toward uniformity. Accompanying the reduction in variability is an isolation of strains, some having abnormalities. "After continued inbreeding there is an approach to the stability of a naturally inbred race." Hayes (41) compares Minnesota No. 13, pollinated with a mixture of pollen, with 15 first generation self-fertilized lines. The line pollinated with the mixture yielded at the rate of 49.3 bushels per acre and the average of selfed lines was at the rate of 24 bushels per acre.

Olson, Bull, and Hayes (72) give a probable explanation for a reduction in yield from a close selection to type. By close and long continued selection a similarity of type may be obtained.

Such similarity is due to the fact that selection tends toward the production of a variety in which the inheritance for the selected characters approaches the condition obtained in self-fertilized plants. Reduced yields accompanying inbreeding in corn are, according to the best genetic evidence, a direct result of increased genetic purity. Continued selection to type may be expected to tend toward the same reduction in yield although somewhat less rapidly.

Cross-Pollinated Plants -- Crossing Selfed Strains: East (23) grew several crosses of dent varieties of corn some of the varieties had been inbred for three years. The hybrids exceeded either parent in yield. The increase in yield over the parents was most pronounced when the parents had been inbred, as is to be expected. Shull (88) devised a method of corn breeding in which he isolated strains by selfing. These strains, when combined by crossing, yielded slightly above the average of those families which had not been self-fertilized. The three highest yields produced in all his cultures were the result of hybridizing strains previously isolated by selfing. The average yield per acre of all the hybrids was 78.9 bushels and that of the corresponding crossbred varieties was 79.4. Thus the "cumulative 'injurious effects' of five years of self-fertilization may disappear in a single year as the result of crossing." This illustrates the probability that crosses between selfed strains may sometimes be expected to yield more grain than the varieties from which those strains are isolated. Jones (55) carried Shull's method farther and outlined a method involving a double cross. The object of this was to obtain normally developed seed for commercial planting. Selfed strains are isolated and tests made to determine the four biotypes most desirable for parents. Designating these biotypes as 1, 2, 3, and 4, numbers 1 and 2, and 3 and 4 are crossed by growing each pair separately and detasseling one biotype in each. Seed from the detasseled biotypes of each group is then planted in an isolated plat and all of one combination detasseled. Seed for commercial planting is selected from these latter detasseled rows. Such a cross at the Connecticut station yielded 112 bushels per acre. The best dent variety obtained after a careful varietal survey yielded only 92 bushels per acre. The increase of the cross over the best variety was approximately 22 per cent.

Cross-Pollinated Plants -- Crossing Varieties: The F_1 of a cross between an inedible form of *Citrullus vulgaris*, locally known as "Citron", and Eden, a standard market variety of watermelon, "proved itself of wonderful vigor and productiveness"(Orton, 74). Pammel (75) gives examples of an increase in size of cucurbits due to crossing. Hayes and Jones (45) crossed several varieties of cucumbers. The following is an extract from their results:

	Average yield in fruit per plant	Increase above heavier yielding parent	Per cent Increase	Average number fruits per plant
	lbs.	lbs.		
Early Russian	6.2	---	---	32.9
Early Russian x White Spine	11.1	0.2	1.8	39.5
White Spine	10.9	---	---	29.3
White Spine x London Long Green	13.9	2.7	24.1	37.3
London Long Green	11.2	---	---	25.0
London Long Green x Fordhook Famous	11.6	0.4	3.6	26.6
Fordhook Famous	10.1	---	---	22.5
Fordhook Famous x White Spine	15.2	4.3	39.4	35.7
White Spine	10.9	---	---	29.3

The chief manner of increase is in number of fruits per plant.

Again taking corn as an example, East (23) so arranged his breeding plots that part of the ears of each type would be pollinated by the same type and part would be pollinated by a different type. Rows were selected for yield only. In every case but one the rows selected were the ones in which different types had been crossed. Collins (17) lists 16 hybrids between widely different types of corn. Fourteen crosses yielded more than the average of the parents, the other two yielded less. In a different article (18) sweet corn hybrids are compared with their parents. Eight yielded better than the average of the parents and six yielded more than the better parent. The average increase over the parental average was 57 per cent. The most promising of these hybrids yielded 6 per cent higher than its better parent. Emerson (26) crossed Tom Thumb pop corn, which average 90 cm. in height and ripened in 70 days, with Missouri Late Dent, which had an average height of 225 cm. and matured in 120 days. The F_1 was 187 cm. tall and matured in 100 days. This is 24 cm. taller and 5 days earlier in maturity than the average of the parents.

Fisher (31) notes that, "the effect of using Reid's Yellow Dent as a male on Boone County White was to increase the height of the stalk noticeably, while the reciprocal cross showed a sturdier stalk than is usual with either variety." Hayes and East (42) tested three variety corn hybrids, of which two yielded more than either parent. Averaging all three the yield was 1.8 per cent above the better parents. All three of these exceeded the parental average, the average increase being 28 per cent. Belling (11) compared a hybrid of Cuban and Mosby varieties. The weights of shelled corn for rows of 60 stalks each were:

Cuban	309 ounces
Mosby	291 ounces
F_1 Hybrid	444 ounces
F_2 Hybrid	345 ounces

Here the F_2 exceeds the better parent and the F_1 is markedly a better producer than either parent. Hartley et al (38) report 16 variety crosses at Chico, California, of which 13 exceeded the parental average in yield and 4 exceeded the better parent. The average per cent increase over the parental average is 7.7 . . They report 11 crosses from Texas, of which 10 exceeded the parental average. Roberts (79) reports an increased yield of F_1 in a cross between Chinese maize and Pride of Saline. Hayes (40) tested 19 variety crosses in 1912 of which 16 exceeded the parental average in yield and 9 exceeded the better parent. In 1913, 8 were tested of which 5 exceeded the parental average, the average increase being 8.3 per cent. Collins (19) secured hybrids of Egyptian and Voorhies Red varieties of sweet corn. The hybrids exceeded the parental average in height and yield. Audronescu (2) states that there is evidence of an increase in the size of pollen in an F_1 generation. Jones et al (57) tested numerous crosses, of which a large percentage exceeded the parental average.

Hutchinson and Wolfe (49) made six varietal crosses, all of which tasseled earlier than the parental average and five earlier than the earlier parent. From four crosses, of which yields are recorded, one yielded better than either parent, two better than the parental average, and one less than the parental average. Hayes and Olson (46) report the results of tests carried two to four years on duplicate plots and with adapted corn varieties. Out of 11 crosses, 10 exceeded the better parent and 1 gave a decrease from the parental average.

The following table briefly summarizes the results secured with corn crosses. The headings of columns are:

Column (1) citation in bibliography;

(2) The number of crosses tested;

(3) The number of crosses exceeding the better parent;

(4) The number of crosses exceeded by the better parent;

(5) Average per cent increase or decrease from the better parent;

(6) Number of crosses exceeding the parental average;

(7) Number of crosses exceeded by the parental average;

(8) Average per cent increase or decrease from the parental average;

(9) Method of test.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
71	5	3	2	+ 7.0	5	0	+14.0	Adapted varieties, single plot tests.
72	4	2	2	- 1.2	3	1	+ 7.7	Adapted varieties, single plot tests.
17	16	12	4	+16.6	14	2	+53.0	Widely different types, 16 hills.
18	10	7	3	+25.6	8	2	+81.0	Sweet corn, single plots.
24	3	2	1	+ 1.8	3	3	+28.0	Single rows, unadapted varieties.
38[a]	16	4	12	- 2.5	13	3	+ 7.7	Single rows, female parent, unadapted variety.
38[b]	11	4	7	- 0.1	10	1	+ 9.8	Single rows, adapted varieties.
11	1	1	0	+43.7	1	0	+48.0	Single plots, adapted varieties.
40[c]	19	10	9	- 3.5	16	3	+10.1	1 replication single rows adapted varieties.
40[d]	8	5	3	+ 5.3	5	3	+ 8.3	Single plots, adapted varieties.
45[e]	9	6	3	+ 2.3	9	0	8.5	Single plots, adapted varieties.
45[e]	8	3	5	- 3.0	5	3	3.7	Single plots, adapted varieties.
45[f]	12	9	2	+ 4.2	11	1	16.3	Single plots, adapted varieties.
59	10	-	-	-	-	-	- 1.9	Adapted late varieties
59	3	-	-	-	-	-	+ 1.2	Adapted varieties, early and late.
94	7	5	2	+ 0.3	7	6	+ 3.2	Single plots, adapted varieties.
49	4	1	3	-11.2	3	1	+ 4.3	3 replications, adapted varieties.
46	11	10	1	+11.7	10	1	+14.5	Duplicate plots, adapted varieties.

---

a. Chico, California
b. Texas.
c. 1912.
d. 1913.
e. Average Mt. Carmel and Storrs stations.
f. Mt. Carmel only.

Summary: The literature reviewed serves to illustrate the phenomenon of heterosis, which occurs quite generally in both plant and animal kingdoms. Many hybridization experiments could be cited in which heterosis has not been at all evident. As will be shown later, this is in accord with the theory, it not being necessary to assume that an increase always occurs.

Self-pollinated plants are inbred naturally. Hence, artificial inbreeding is barren of results. Cross-pollinated plants, by virtue of their method of pollination, are in a complex genotypic condition. Inbreeding tends to isolate homozygous strains. These are directly comparable to our pure lines of self-pollinated plants.

THE THEORY

The theory accounting for heterosis is the product of a gradual evolution. In its entirety it is but the application of Mendelian principles to the inheritance of quantitative characters.

Bruce (12) assumed that "dominance is positively correlated with vigor" and that by crossing two pure breeds a "mean vigor" was produced greater than the "collective mean vigor of the parent breeds." He admits the lack of "experimental evidence to justify the assumption that dominance is correlated with a 'blending' character like vigor." Keeble and Pellew (58) suggested that "the greater height and vigor which the F_1 generation of hybrids commonly exhibit may be due to the meeting in the zygote of dominant growth factors of more than one allelomorphic pair, one (or more) provided by the gametes of one parent, the other (or others) by the gametes of the other parents." They based their assumption upon experimental evidence obtained from a pea cross. Some objections were raised to this theory. One was that all the growth factors could be combined in a homozygous condition from which no amount of selfing would result in deterioration, which is opposed to the idea that inbreeding in itself causes a loss of vigor. A second objection was given by East and Hayes (24) who pointed out that "such an interpretation would not fitly explain the fact that all maize varieties lose vigor when inbred". They believed the increased vigor was due to an increased heterozygosis. They say, "inbreeding tends to isolate homozygous strains which lack the physiological vigor due to heterozygosity." Shull (89) also believed that heterosis was due "to the presence of heterozygous elements in the hybrids, and that the degree of vigor is correlated with the number of characters in respect to which the hybrids are heterozygous." He assumed further that "the presence of unpaired genes, or the presence of unlike or unequal paired genes, - - - produce the greater functional activity upon which larger size and greater efficiency depend." Emerson and East (28) thought that if the effect of heterosis were due to dominance, asymmetrical distributions would occur in F_2 with respect to characters in which heterosis was shown in F_1.

All of these objections seemed valid. After the development of the theory of linkage, Jones (55) modified the previous theory by assuming the "dominance of linked factors as a means of accounting for heterosis". The theory admirably explains the phenomenon of heterosis. It assumes that the increase in vigor manifested in F_1 is due to the meeting in the zygote of dominant growth factors of more than one allelomorphic pair, one (or more) provided by the gametes of one parent, the other (or others) by the gametes of the other parent. It is quite definitely known that the majority of growth factors exhibit only partial dominance. It is only necessary to assume that each factor pair exhibits more than half the effect in the simplex condition that it exhibits in the duplex. That all the factors can not be combined in a homozygous condition is explained by the theory of linkage. According to these hypotheses, the maximum number of growth factors can only be obtained in the F_1 generation. Subsequent generations are, therefore, less vigorous than the F_1.

Some examples have been cited in naturally self-fertilized crops where strains, which yielded more than either parent, were isolated in the 4th or 5th generation following a cross. This circumstance is quite within the scope of the theory. It is only necessary to assume that selection subsequent to F_1 may isolate, in a homozygous condition, a combination of growth factors exceeding in number and effect that of either parent. When no increase in vigor occurs in the F_1, it is assumed that the growth factors present are common to both parents or that negative ones are brought in sufficie to offset the stimulus of the additional positive factors.

APPLICATION OF THE THEORY

Since the phenomenon of Heterosis is manifested in both naturally self- and cross-pollinated plants, the theory may be applied to methods of breeding in either group. The method of breeding corn as outlined by Jones (55) is an excellent example of the practical application of the theory to a cross-pollinated crop. Such a crop being of a complex genotypic composition,it is only necessary to isolate strains by selfing and eliminate the inferior ones. Once the breeder has four desirable strains he can use these in producing hybrid seed for commercial planting. F_1 seed produced by crossing two selfed strains is commonly smaller than ordinary seed corn. This fact prejudices many growers against the use of such seed. Jones obviates this objection by making the double cross, the seed of which is of good average size. There is also the possibility of synthetically producing an improved variety by crossing selfed strains which are homozygous for certain desirable characters (Hayes and Garber, 44).

In self-fertilized crop plants the problem is more difficult. Anderson (1) suggests the use of the hybrid vigor by making crosses in large numbers. The crossed seed would be multiplied as rapidly as possible in the hope to make available to the breeder ~~of~~ an increase of vigor in about the third generation from the cross. Anderson states: "The success of such an experiment would involve (1) the selection of suitable strains of like habit, which, when crossed, show greatly increased productiveness; (2) a mastery of technique by a considerable staff of workers; (3) a high number of crossings; (4) careful classification of the produce in the 2nd and 3rd generations; (5) the withdrawal of the variety after a few years; (6) the annual repetition of the cross in quantity to keep up the supply." Producing seed wheat by artificial pollinations is at the outset a laborious task but entirely within the realms of possibility. It is, however, possible to produce several acres of one crop in the second generation of a cross from the results of several hours operations of a skilled worker. This is only a theory and has not been supported by definite experiments. It is not known to what extent the increase in vigor will carry out to the third generation. It would be necessary for a crop produced in this way to produce sufficient increase in yield over the best variety in a locality to warrant the necessary expenditures of extra labor in securing seed. Under systems of intensive farming, where maximum yield is the limiting factor, such a method may suggest an avenue of profitable endeavor.

INFLUENCE OF SIZE OF SEED PLANTED UPON VIGOR AND YIELD

The influence of size of seed planted upon the vigor of the resultant plant has been the subject of numerous experiments. [illegible] Arny and Garber (3) have so recently studied this subject that it will be considered here only briefly. They worked with wheat and secured the following relations:

Coefficient of correlation between weight in milligrams of individual seed planted and height in centimeters at six weeks was 0.356±0.040 in 1914; 0.445±0.022 in 1915; 0.649±0.015 in 1916; and 0.712±0.015 in 1917.

Coefficient of correlation between weight in milligrams of individual seed planted and yield in decigrams of kernels per plant was in 1914, 0.143±0.038; in 1915, 0.088±0.028; in 1916, 0.445±0.020; and in 1917, 0.478±0.023.

Coefficient of correlation between weight of seed planted and average height at maturity was 0.093±0.38 in 1914; -0.099±0.028 in 1915; 0.192±0.024 in 1916; and 0.118±0.030 in 1917.

Under favorable growing conditions the correlation is not high in any instance except for weight of seed planted and height in centimeters at six weeks. The difference in size or yield at maturity that can be attributed to a difference in size of seed planted is very small. Arny and Garber, however, used only plump seeds in their studies. In the present study it is not thought that size of seed planted will seriously affect the validity of the results. It is, nevertheless, a factor which must be considered in an examination of the experimental data.

EXPERIMENTAL MATERIAL

The material chosen for the experiment included eight varieties from Triticum vulgare, one from T. durum, one from T. compactum, and one from T. dicoccum. The varieties with their culture numbers and description are as follows:

Triticum vulgare:

Culture No. H2, Marquis, N.S.N. I-15-174, tip awned, white chaff, smooth chaff, red seed and lax head.

Culture No. H3, Poultofka, N.S.N. I-13-3, tip awned, white chaff, smooth chaff, red seed and lax head.

Culture No. H4, Velvet Chaff, N.S.N. I-15-161, bearded, white chaff, smooth chaff, red seed and lax head.

Culture No. H5, Barletta, N.S.N. I-13-41, tip awned, white chaff, smooth chaff, red seed and lax head.

Culture No. H6, Penny, C.I. 4993, N.S.N. I-18-15, tip awned, white chaff, smooth chaff, white seed and lax head.

Culture No. H7, Haynes Blue Stem, N.S.N. I-16-12, tip awned, white chaff, hairy chaff, red seed and lax head.

Culture No. H8, Haynes Blue Stem, N.S.N. I-16-45, tip awned, white chaff, hairy chaff, red seed and lax head.

Culture No. H9, Bobs, C.I. 4990, N.S.N. I-18-14, awnless, white chaff, smooth chaff, white seed and lax head.

Triticum compactum:

Culture No. H10, Little Club, N.S.N. III-19-5, tip awned, white chaff, smooth chaff, white seed and compact head.

Triticum dicoccum:

Culture No. H11, Spring Emmer, N.S.N. I-13-14, bearded, white chaff, smooth chaff, red seed and dense head.

Triticum durum:

Culture No. H12, Mindum (durum) N.S.N. I-00-52, bearded, light brown chaff, smooth chaff, white seed and dense head. A pure line selection of the variety Arnautka.

METHOD OF PROCEDURE

Planting in Field: In the spring of 1919, 200 seeds of each variety were planted, 50 seeds being planted each week for four consecutive weeks. Plantings were made in rows five feet long and one foot apart. The 50 seeds were so distributed as to plant two rows.

Results of Pollination: From cross-pollinations 1071 seeds were obtained. In addition to the cross-pollinations, plants in each variety were pollinated with pollen from other plants in the same variety. From this operation, 582 seeds were secured, which are termed incrossed seeds.

Planting in Greenhouse: All the seeds obtained by artificial pollinations and in addition 50 seeds of each parent variety (seeds selected at random from samples taken from the rows planted for crossing) were planted November 1, 1919. The soil used had been previously sterilized in order to kill foreign seeds and disease organisms. The rows were spaced three inches apart in the greenhouse bench and the seeds planted two inches apart in the row. To insure planting all seeds at the same depth, they were placed on the surface of the soil and forced to a depth of 3/4 inch by means of a small glass bottle with a rubber band at the 3/4 inch mark. In order to have a check on any differences of environmental conditions due to location in the beds, rows of parent seeds were planted beside rows of hybrid* seed. It was obviously impossible to place all of any parent seed with any one hybrid, therefore, the parent seeds were distributed at intervals. Regardless of care in distribution a slight error enters in, but the distribution overcame the error as far as possible with the space available.

When the seedlings were five weeks old, they were transplanted to seven-inch pots, two plants to each pot and only like plants together. Pots were arranged to group the plants as follows:

First Parent (normal seed)
First Parent (incrossed seed)
Cross
Reciprocal
Second Parent (incrossed seed)
Second Parent (normal seed)

Pots were rotated on the benches from front to back until the plants had reached a height of about 2 feet. A change was made approximately every ten days. The object of this was to correct for any differences that might occur in light and heat.

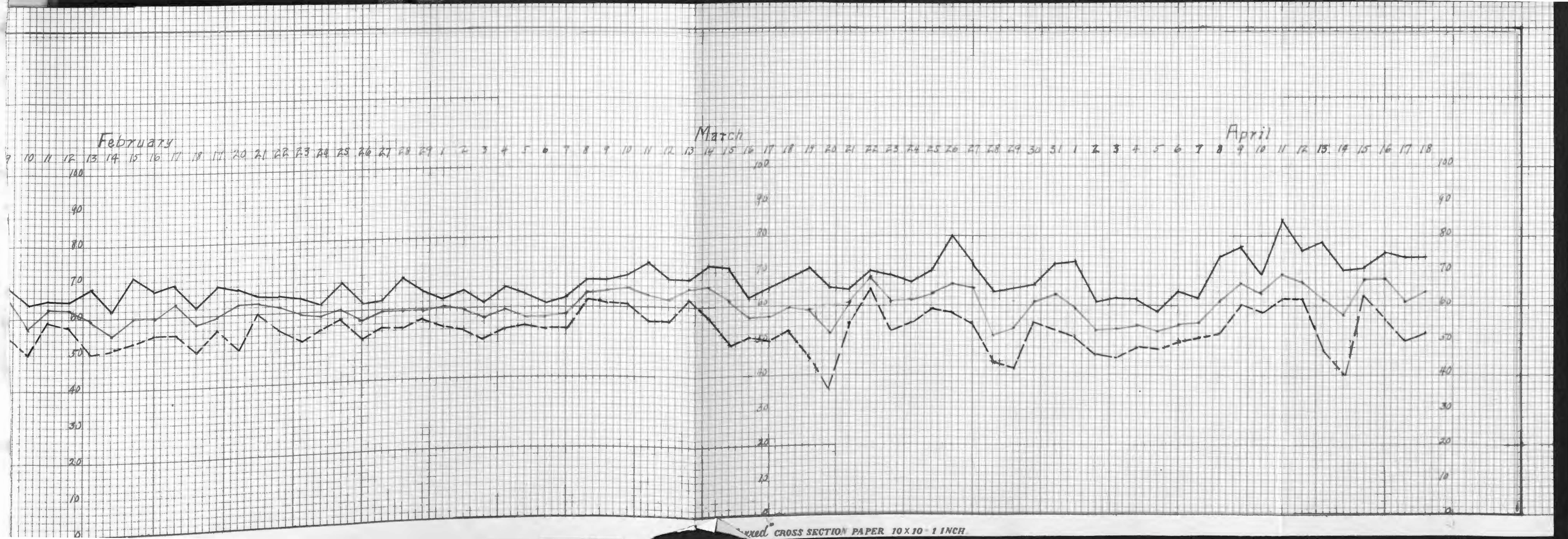
Temperature of Greenhouse: The temperature was kept low during the germination period and early growth period. It was raised somewhat after plants began to head. Plate I shows temperatures as recorded by the thermagraph.

---

*In this discussion the terms "hybrid" and "cross" are used synonomously.

PLATE I


November
December
January
February
Degrees Fahrenheit
100
90
80
70
60
50
40
30
20
10
Maximum
Mean
Minimum


February
March
April
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
100
90
80
70
60
50
40
30
20
10
0
"...xed" CROSS SECTION PAPER 10 X 10 = 1 INCH

IMMEDIATE EFFECT OF POLLINATION

Due to the phenomenon of double fertilization there is the possibility in varietal or interspecific crosses of an immediate visible effect on endosperm development of the mother plant. It seems reasonable to expect a more pronounced effect in the wider crosses. For this reason varietal and interspecific crosses will be discussed separately.

Wrinkling of F1 Seeds: Crosses of T. vulgare with T.durum or T. dicoccum produced strongly wrinkled seeds. (See Plates II and III). Marquis or Velvet Chaff pollinated by Emmer or Mindum gave wrinkled seeds with a somewhat greenish color. The reciprocal crosses of Emmer or Mindum with Marquis or Velvet Chaff resulted in seeds as large or larger than the incrossed seed of the mother parent. These seeds were also markedly wrinkled. On the other hand intercrossing vulgare varieties gave seeds either slightly or not at all wrinkled. (See Plates IV and V). There was a visible wrinkling in some cases, but in no case was it pronounced.

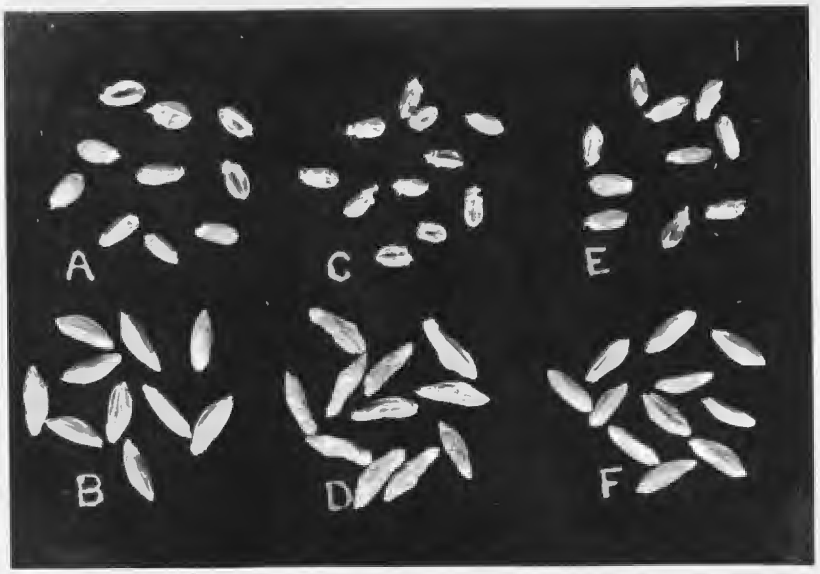


Fig. 1. (A) Marquis (B) Emmer
(C) Marquis x Emmer (D) Emmer x Marquis
(D) Incrossed Marquis (F) Incrossed Emmer

Interspecific cross in which the F_1 seeds are markedly wrinkled.

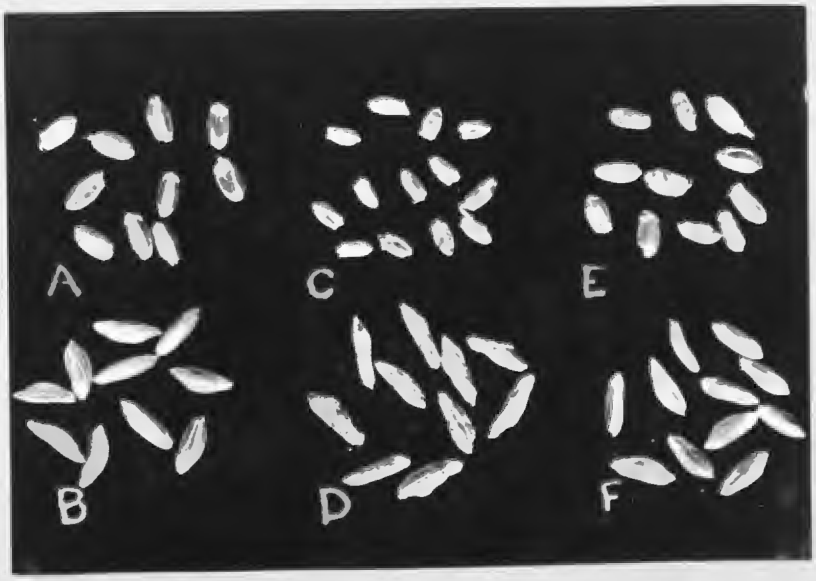


Fig. 2. (A) Velvet Chaff (B) Emmer
(C) Velvet Chaff x Emmer (D) Emmer x Velvet Chaff
(E) Incrossed Velvet Chaff (F) Incrossed Emmer

Interspecific cross which also shows pronounced wrinkling of F_1 seeds.

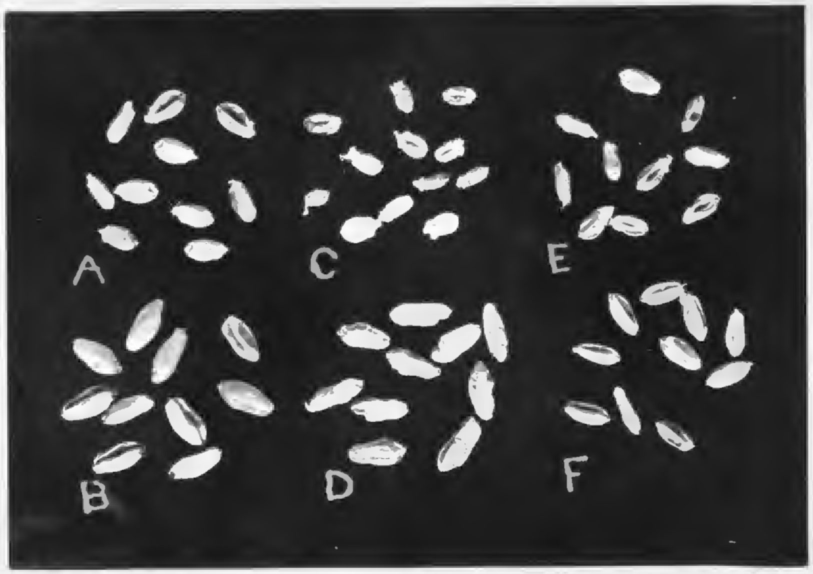


Fig. 3. (A) Marquis (B) Mindum
(C) Marquis x Mindum (D) Mindum x Marquis
(E) Incrossed Marquis (F) Incrossed Mindum

Wrinkling of (C) and (D) pronounced.
An interspecific cross which shows pronounced wrinkling of F_1 seeds.

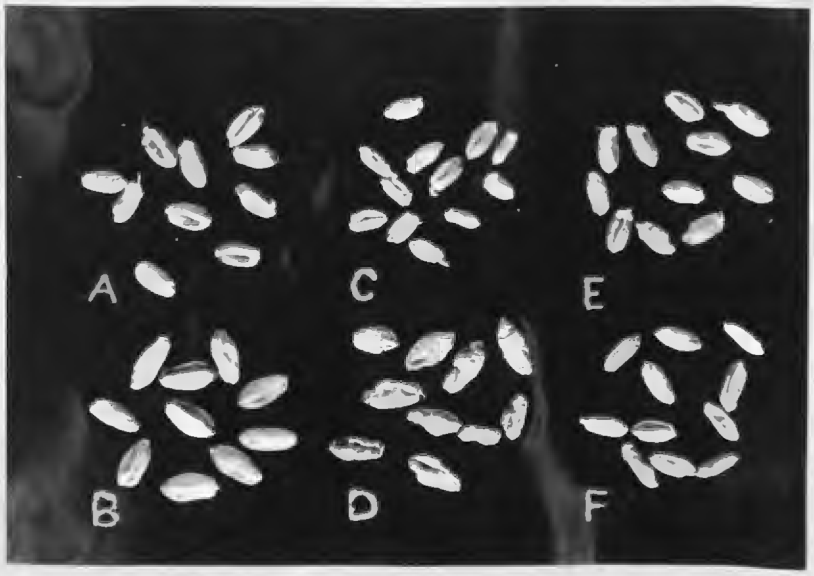


Fig. 4. (A) Velvet Chaff (B) Mindum
(C) Velvet Chaff x Mindum (D) Mindum x Velvet Chaff
(E) Incrossed Velvet Chaff (F) Incrossed Mindum

An interspecific cross which shows pronounced wrinkling of F_1 seeds.

Plate IV

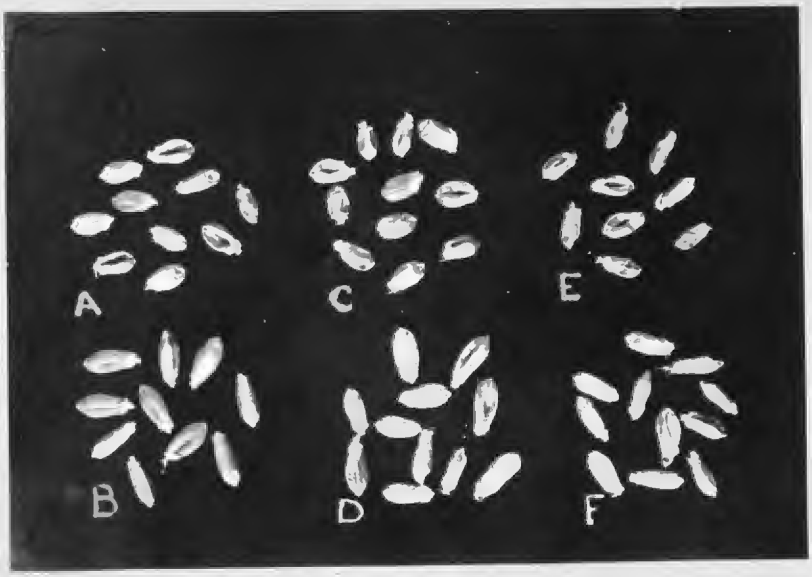


Fig. 5. (A) Marquis (B) Poultofka
(C) Marquis x Poultofka (D) Poultofka x Marquis
(E) Incrossed Marquis (F) Incrossed Poultofka

A varietal cross in which F_1 seeds are only slightly wrinkled.

Fig. 6. (A) Marquis (B) Velvet Chaff
(C) Marquis x Velvet Chaff (D) Velvet Chaff x Marquis
(E) Incrossed Marquis (F) Incrossed Velvet Chaff

A varietal cross in which F_1 seeds are only slightly wrinkled.

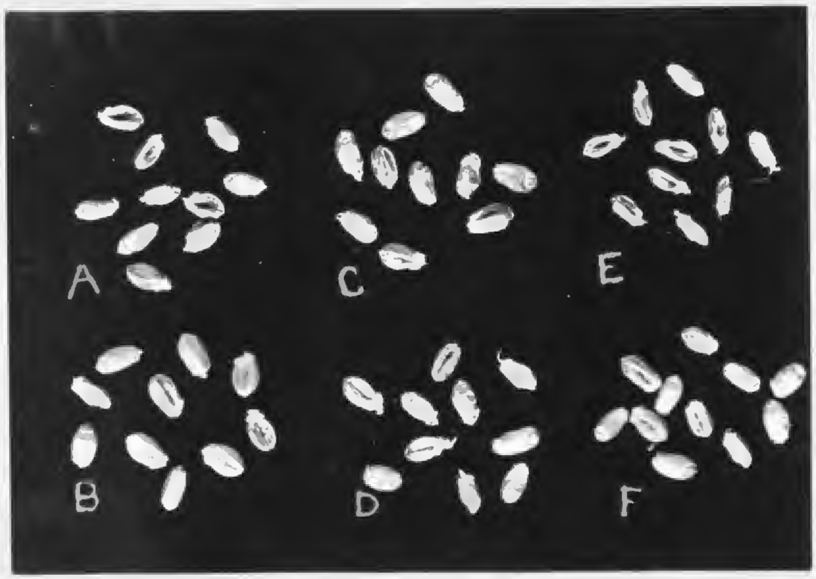


Fig. 7. (A) Marquis (B) Bobs
(C) Marquis x Bobs (D) Bobs x Marquis
(E) Incrossed Marquis (F) Incrossed Bobs

Varietal Cross: (C) and (D) are only slightly wrinkled.

Fig. 8. (A) Velvet Chaff (B) Bobs
(C) Velvet Chaff x Bobs (D) Bobs x Velvet Chaff
(E) Incrossed Velvet Chaff (F) Incrossed Bobs

Varietal Cross: (C) and (D) are wrinkled but not markedly so.

Weight of Seed: For the purpose of determining the effect of emasculation and artificial pollination, the parental varieties were emasculated and then pollinated with pollen produced by other plants of the same variety. The comparison was then made between the seeds which resulted from artificial pollination and those obtained from normal pollination. In every variety, with the exception of Penny, the normal seed was heavier than the incrossed seed. There was no significant difference in the case of Penny. This increase of the normal over the incrossed seed might be attributed to the selection of normal seed from plants in which fertilization was effected earlier than was the case with the incrossed seed of that variety. In most varieties this objection does not hold. The opposite condition held with Marquis since the first heads were used for crossing as fast as they appeared, making obligatory the selection of normal seed from later maturing heads. In this case, in which other conditions except artificial crossing favored the incrossed seed, the weight of the normal and incrossed seed was 15.9±0.45 and 12.6±0.50 milligrams respectively. The difference is 3.3±0.67* milligrams in favor of normal seed which shows that the mechanical operation of crossing causes a reduction in seed size.

VULGARE CROSSES: Crossing Marquis with Poultofka, Barletta, Penny or Bobs resulted in a significant increase in weight of hybrid seed over that of normal Marquis (See Tables I and I A). The largest ~~/~~ average increase was 17.2±0.82 milligrams secured from the

---

* The probable error of a difference was calculated according to the Formula: $E = \sqrt{e_1^2 + e_2^2}$ in which e equals the probable error of the quantities being compared.

cross of Marquis with Bobs. *Marquis x Velvet Chaff showed a slight decrease from the normal seed but a significant increase over the incrossed Marquis. With crosses between Marquis as the pollen parent and the varieties Poultofka, Velvet Chaff, Barletta, and Bobs, there was a decrease in weight of the cross from normal seed of the mother parent in every case. All crosses showed significant increases over the incrossed seed except Barletta x Marquis. Penny crossed with Marquis gave an increase of 9.6±1.00 milligrams over normal seed of Penny and a similar increase over incrossed seed.

Pollinating Velvet Chaff with Barletta, Penny or Bobs gave, in every case, an increase over the incrossed seed of Velvet Chaff. Barletta pollinated with Velvet Chaff gave a marked increase in weight over the normal Barletta. Penny or Bobs pollinated by Velvet Chaff showed no significant variation from either the normal or incrossed seed. Penny crossed with Bobs gave an increase over normal Penny. Bobs x Penny gave an increase over incrossed Bobs.

VULGARE-COMPACTUM CROSSES: Little Club fertilized by Marquis pollen produced about the same seed weight as incrossed or normally pollinated Little Club. The reciprocal cross gave an increase of 16.7±0.71 milligrams over the normal seed of Marquis.

Velvet Chaff pollinated by Little Club showed an increase of 3.3±0.82 milligrams over the incrossed seed and a decrease as compared with normal seed. The reciprocal cross showed a marked increase over normal seed, the difference being 8.9±0.69 milligrams.

VULGARE-DICOCCUM CROSSES: When compared with incrossed seed, F_1 seed of Marquis x Emmer and reciprocal showed no significant difference. Emmer pollinated with Velvet Chaff showed no effect

---

* Thruout this discussion the mother parent will be written first.

on seed size as compared with incrossed seed but the reciprocal gave a decrease of 6.6±0.69 milligrams from incrossed Velvet Chaff.

VULGARE-DURUM CROSSES: Mindum pollinated with Marquis showed a significant increase over incrossed Mindum. The reciprocal cross showed neither increase nor decrease from incrossed Marquis. Pollinating Mindum with Velvet Chaff gave a decided increase over incrossed Mindum. Velvet Chaff pollinated with Mindum showed a decrease from incrossed Velvet Chaff of 4.0±0.83 milligrams.

COMPACTUM-DICOCCUM CROSSES: Intercrosses of Little Club and Emmer showed a slight decrease as compared with incrossed seed of the mother parent.The difference in the case of Little Club x Emmer was 2.4±0.58 milligrams.

COMPACTUM-DURUM CROSSES: Mindum pollinated with Little Club showed no variation from the weight of incrossed Mindum. From several pollinations of Little Club by Mindum only two seeds were secured and these were very small.

Owing to the prevalence of stem rust (Puccinia graminis tritici E. & H.) in the latter part of the growing season, some plants failed to mature plump seeds. Some of these differences in size, therefore, may be due to the fact that the cross was fertilized at an earlier date than the incross. It is believed, however, that such is not the case and it is known not to be the case with some crosses. The following are all of the cases in which the average date of pollination of the incrossed parent was as early or earlier than that of the hybrid:

Cross	Variation from incrossed seed
Marquis x Velvet Chaff	+ 3.0±0.72
Marquis x Penny	+ 7.6±1.15
Haynes Blue Stem x Marquis	+ 6.3±1.02
Little Club x Marquis	- 0.7±0.56
Emmer x Velvet Chaff	+ 0.7±1.48
Velvet Chaff x Mindum	- 4.0±0.83
Emmer x Little Club	- 1.4±1.40

These results show in every varietal cross a significant increase in weight of seed of the hybrid over that of the incrossed mother parent. In the interspecific crosses the only significant variation of hybrid seed from that of the incrossed parent is a decrease in the case of Velvet Chaff x Mindum. The average date of pollination of this cross and that of the incrossed Velvet Chaff were the same. These cases show conclusively that the immediate effect of pollination in some varietal crosses is to produce an increase in seed weight.

Table I

Comparison of Seed Weights of Parents and F_1 Crosses

Name	Average Date Pollination	Weight in Milligrams													Mean	Standard Deviation
		5	10	15	20	25	30	35	40	45	50	55	60	Number		
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H3	7-9			1	8		4	1						14	23.5±1.04	5.8±0.74
H3 x H2	7-8			1	7	5	5	4	4	1	1			28	29.5±1.09	8.6±0.78
H3 x H3	7-9			9	7	18	12	3						49	24.3±0.55	5.8±0.39
H3 (Poultofka)					4	6	13	19	6	2				50	32.3±0.57	6.0±0.40
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H4	7-17	1	17	12	11	7								48	15.6±0.53	5.5±0.38
H4 x H2	7-8		2	5	4	16	4		6					37	25.3±0.90	8.2±0.64
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H5	7-8		1	5	10	3	2	2	2	2				27	24.4±1.23	9.5±0.87
H5 x H2	7-10	4	6	13	2	1		4	2	2	1			35	24.5±1.45	12.7±1.02
H5 x H5	7-11		4	10	5	3	7	2	1	1				33	22.1±1.05	9.0±0.75
H5 (Barletta)				1	4	6	24	10	5					50	30.3±0.52	5.5±0.37
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H6	7-14		1	11	7		2	2	1					24	20.2±1.04	7.6±0.74
H6 x H2	7-10		1	6	10	8	5	4		2				36	24.4±0.91	8.1±0.64
H6 x H6	7-14	4	27	5	7	8		1	2	1				55	15.8±0.82	9.1±0.58
H6 (Penny)		2	13	25	5	5								50	14.8±0.43	4.5±0.30

Table I (continued)

Name	Average Date Pollination	Weight in Milligrams													Mean	Standard Deviation
		5	10	15	20	25	30	35	40	45	50	55	60	Number		
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H9	7-9				3	2	9	12	7	1				34	33.1±0.69	6.0±0.50
H9 x H2	7-6				8	8	15	4						35	27.1±0.54	4.8±0.39
H9 x H9	7-10	6	9	10	6	3	6	2	1	1				44	18.2±1.02	10.1±0.72
H9 (Bobs)			3	3	6	8	14	7	6	3				50	28.7±0.86	9.0±0.61
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H10	7-10				1	2	12	12	4					31	32.6±0.56	4.6±0.39
H10 x H2	7-17	13	31	5	1									50	9.4±0.31	3.2±0.21
H10 x H10	7-16	11	19	7	1	1								39	10.1±0.47	4.3±0.33
H10 (Little Club)		6	28	15	1									50	11.1±0.31	3.3±0.22
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H11	7-10		8	6	4		1							19	14.7±0.80	5.2±0.57
H11 x H2	7-10	1	2	4	12	11	12	3	2	1				48	24.8±0.77	7.9±0.54
H11 x H11	7-10	1	2		9	15	4	12	1					44	26.4±0.76	7.5±0.54
H11 (Little Emmer)				1		3	4	16	12	13			1	50	37.9±0.44	4.6±0.31
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 x H12	7-12	2	7	2	2									13	11.5±0.84	4.5±0.59
H12 x H2	7-14	1	3	6	3	5	5	9	5					37	26.4±1.13	10.2±0.80
H12 x H12	7-18	5	19	22	8			3	1					58	14.7±0.63	7.1±0.44
H12 (Mindum)					7	7	2	3	4	10	9	5	3	50	39.9±1.21	12.7±0.86

Table I (continued)

Name	Average Date Pollination	Weight in Milligrams													Mean	Standard Deviation
		5	10	15	20	25	30	35	40	45	50	55	60	Number		
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H5	7-11		3	4	8	14	4	4						37	23.2±0.74	6.7±0.52
H5 x H4	7-5							1	3					4	38.8±0.71	2.1±0.50
H5 x H5	7-11		4	10	5	3	7	2	1	1				33	22.1±1.05	9.0±0.75
H5 (Barletta)				1	4	6	24	10	5					50	30.3±0.52	5.5±0.37
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H6	7-10		3	4	7	11	7	2						34	23.1±0.76	6.6±0.54
H6 x H4	7-12	2	16	7	11	6	1							43	15.7±0.65	6.4±0.46
H6 x H6	7-14	4	27	5	7	8		1	2	1				55	15.8±0.82	9.0±0.58
H6 (Penny)		2	13	25	5	5								50	14.8±0.43	4.5±0.30
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H9	7-12			13	7	18	22	12	1					73	26.1±0.53	6.7±0.37
H9 x H4	7-9		7	11	18	13	4	1						54	19.9±0.54	5.9±0.38
H9 x H9	7-10	6	9	10	6	3	6	2	1	1				44	18.2±1.02	10.1±0.72
H9 (Bobs)			3	3	6	8	14	7	6	3				50	28.7±0.86	9.0±0.61
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H10	7-8			7	15	17	5	2	1					47	23.2±0.55	5.6±0.39
H10 x H4	7-11			4	10	2	1							17	20.0±0.62	3.8±0.44
H10 x H10	7-16	11	19	7	1	1								39	10.1±0.47	4.4±0.33
H10 (Little Club)		6	28	15	1									50	11.1±0.31	3.3±0.22

Table I (continued)

Name	Average Date Pollination	Weight in Milligrams													Mean	Standard Deviation
		5	10	15	20	25	30	35	40	45	50	55	60	Number		
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H11	7-11		13	18	2									33	13.3±0.32	2.7±0.22
H11 x H4	7-11	1	2	1	2	5	6	4	2	1				24	27.1±1.28	9.3±0.90
H11 x H11	7-10	1	2		9	15	4	12	1					44	26.4±0.76	7.5±0.54
H11 (Emmer)				1		3	4	16	12	13			1	50	37.9±0.44	4.6±0.31
H4 (Velvet Chaff)				1	15	8	1	14	10	1				50	29.6±0.79	8.3±0.56
H4 x H4	7-14		22	42	7	5	10	13	5					104	19.9±0.62	9.4±0.44
H4 x H12	7-14		4	13	4	2								23	15.9±0.56	4.0±0.40
H12 x H4	7-10			1	4	3	1	3	2					14	27.5±1.42	7.9±1.00
H12 x H12	7-18	5	19	22	8			3	1					58	14.7±0,63	7.1±0.44
H12 (Mindum)					7	7	2	3	4	10	9	5	3	50	39.9±1.21	12.7±0.86
H6 (Penny)		2	13	25	5	5								50	14.8±0.43	4.5±0.30
H6 x H6	7-14	4	27	5	7	8		1	2	1				55	15.8±0.82	9.0±0.58
H6 x H9	7-13	1	4	13	12	11	8	3	1					53	21.5±0.69	7.5±0.49
H9 x H6	7-9		1	5	9	4	2		2	1				24	22.9±1.17	8.5±0.83
H9 x H9	7-10	6	9	10	6	3	6	2	1	1				44	18.2±1.03	10.1±0.72
H9 (Bobs)			3	3	6	8	14	7	6	3				50	28.7±0.86	9.0±0.61
H10 (Little Club)		6	28	15	1									50	11.1±0.31	3.3±0.22
H10 x H10	7-16	11	19	7	1	1								39	10.1±0.48	4.4±0.33
H10 x H11	7-11	11	13											24	7.7±0.34	2.5±0.24
H11 x H10	7-11		1	2	1	4	6	1						15	25.0±1.18	6.8±0.84
H11 x H11	7-10	1	2		9	15	4	12	1					44	26.4±0.76	7.5±0.54
H11 (Emmer)				1		3	4	16	12	13				50	37.9±0.44	4.6±0.31

Table I (continued)

Name	Average Date Pollination	Weight in Milligrams													Mean	Standard Deviation
		5	10	15	20	25	30	35	40	45	50	55	60	Number		
H10 (Little Club)		6	28	15	1									50	11.1±0.31	3.3±0.22
H10 x H10	7-16	11	19	7	1	1								39	10.1±0.48	4.4±0.33
H10 x H12	7-18	2												2	(5.0)	....
H12 x H10	7-16		3	5										8	13.1±0.57	2.4±0.40
H12 x H12	7-18		19	22	8			3	1					58	14.7±0.63	7.1±0.44
H12 (Mindum)					7	7	2	3	4	10	9	5	3	50	39.9±1.21	12.7±0.86
H7 (Haynes Blue Stem)				4	8	20	11	6	1					50	26.0±0.54	5.7±0.38
H7 x H7	7-12		13	21	8	1	2	2	1	1				49	17.2±0.77	8.0±0.54
H7 x H2	7-12			3	7	13	2		1					26	23.5±0.67	5.1±0.48
H2 x H2	7-14	6	11	17	3	1								38	12.6±0.50	4.6±0.36
H2 (Marquis)		1	10	24	9	6								50	15.9±0.45	4.7±0.32
H8 (Haynes Blue Stem)			1	8	19	20	1	1						50	21.5±0.43	4.5±0.30
H8 x H8			7	17	11	6	7	13	8					69	24.3±0.80	9.9±0.57

Table I (A)

Summarized Comparison of Seed Weights of Parents and F_1 Crosses

Name	Seed Parent			Cross		Increase or Decrease Of Cross from Seed Parent	
	Normal Seed	Incrossed Seed					
	Weight mgms.	Weight mgms.	Avg. Date Pollination	Weight mgms.	Avg. Date Pollination	Normal Seed	Incrossed Seed
Marquis x Poultofka	15.9±0.45	12.6±0.50	7-14	23.5±1.04	7-9	+ 7.6±1.13	+10.9±1.15
Poultofka x Marquis	32.3±0.57	24.3±0.55	7-9	29.5±1.09	7-8	- 2.8±1.23	+ 5.2±1.22
Marquis x Velvet Chaff	15.9±0.45	12.6±0.50	7-14	15.6±0.53	7-17	- 0.3±0.69	+ 3.0±0.72
Velvet Chaff x Marquis	29.6±0.79	19.9±0.62	7-14	25.3±0.90	7-8	- 4.3±1.19	+ 5.4±1.09
Marquis x Barletta	15.9±0.45	12.6±0.50	7-14	24.4±1.23	7-8	+ 8.5±1.30	+11.8±1.32
Barletta x Marquis	30.3±0.52	22.1±1.05	7-11	24.5±1.45	7-10	- 5.8±1.54	+ 2.4±1.79
Marquis x Penny	15.9±0.45	12.6±0.50	7-14	20.2±1.04	7-14	+ 4.3±1.13	+ 7.6±1.15
Penny x Marquis	14.8±0.43	15.8±0.82	7-14	24.4±0.91	7-10	+ 9.6±1.00	+ 8.6±1.22
Marquis x Bobs	15.9±0.45	12.6±0.50	7-14	33.1±0.69	7-9	+17.2±0.82	+20.5±0.85
Bobs x Marquis	28.7±0.86	18.2±1.02	7-10	27.1±0.54	7-6	- 1.6±1.01	+ 8.9±1.15
Marquis x Little Club	15.9±0.45	12.6±0.50	7-14	32.6±0.56	7-10	+16.7±0.71	+20.0±0.75
Little Club x Marquis	11.1±0.31	10.1±0.47	7-16	9.4±0.31	7-17	- 1.7±0.43	- 0.7±0.56
Marquis x Emmer	15.9±0.45	12.6±0.50	7-14	14.7±0.80	7-10	- 1.2±0.91	+ 2.1±0.94
Emmer x Marquis	37.9±0.44	26.4±0.76	7-10	24.8±0.77	7-10	-13.1±0.88	- 1.6±1.08
Marquis x Mindum	15.9±0.45	12.6±0.50	7-14	11.5±0.84	7-12	- 4.4±0.95	- 1.1±0.97
Mindum x Marquis	39.9±1.21	14.7±0.63	7-18	26.4±1.13	7-14	-13.5±1.65	+11.7±1.29
Velvet Chaff x Barletta	29.6±0.79	19.9±0.62	7-14	23.2±0.74	7-11	- 6.4±1.08	+ 3.3±0.96
Barletta x Velvet Chaff	30.3±0.52	22.1±1.05	7-11	38.8±0.71	7-5	+ 8.5±0.88	+16.7±1.26

Table I (A)(continued)

Name	Seed Parent			Cross		Increase or Decrease of Cross from Seed Parent	
	Normal Seed	Incrossed Seed					
	Weight mgms.	Weight mgms.	Avg. Date Pollination	Weight mgms.	Avg. Date Pollination	Normal Seed	Incrossed Seed
Velvet Chaff x Penny	29.6±0.79	19.9±0.62	7-14	23.1±0.76	7-10	- 6.5±1.09	+ 3.2±0.98
Penny x Velvet Chaff	14.8±0.43	15.8±0.82	7-14	15.7±0.65	7-12	+ 0.9±0.77	- 0.1±1.04
Velvet Chaff x Bobs	29.6±0.79	19.9±0.62	7-14	26.1±0.53	7-12	- 3.5±0.95	+ 6.2±0.81
Bobs x Velvet Chaff	28.7±0.86	18.2±1.02	7-10	19.9±0.54	7-9	- 8.8±1.01	+ 1.7±1.15
Velvet Chaff x Little Club	29.6±0.79	19.9±0.62	7-14	23.2±0.55	7-8	- 6.4±0.96	+ 3.3±0.82
Little Club x Velvet Chaff	11.1±0.31	10.1±0.47	7-16	20.0±0.62	7-11	+ 8.9±0.69	+ 9.9±0.77
Velvet Chaff x Emmer	29.6±0.79	19.9±0.62	7-14	13.3±0.32	7-11	-16.3±0.85	- 6.6±0.69
Emmer x Velvet Chaff	37.9±0.44	26.4±0.76	7-10	27.1±1.28	7-11	-10.8±1.35	+ 0.7±1.48
Velvet Chaff x Mindum	29.6±0.79	19.9±0.62	7-14	15.9±0.56	7-14	-13.7±0.96	- 4.0±0.83
Mindum x Velvet Chaff	39.9±1.21	14.7±0.63	7-18	27.5±1.42	7-10	-12.4±1.86	+12.8±1.55
Penny x Bobs	14.8±0.43	15.8±0.82	7-14	21.5±0.69	7-13	+ 6.7±0.81	+ 5.7±1.07
Bobs x Penny	28.7±0.86	18.2±1.03	7-10	22.9±1.17	7-9	- 5.8±1.45	+ 4.7±1.55
Little Club x Emmer	11.1±0.31	10.1±0.47	7-16	7.7±0.34	7-11	- 3.4±0.46	- 2.4±0.58
Emmer x Little Club	37.9±0.44	26.4±0.76	7-10	25.0±1.18	7-11	-12.9±1.25	- 1.4±1.40
Little Club x Mindum	11.1±0.31	10.1±0.48	7-16	(5.0)	7-18	0.0	0.0
Mindum x Little Club	39.9±1.21	14.7±0.63	7-18	13.1±0.57	7-16	-26.8±1.33	- 1.6±0.84
Haynes Blue Stem x Marquis	26.0±0.54	17.2±0.77	7-12	23.5±0.67	7-12	- 2.5±0.86	+ 6.3±1.02
Average						- 2.8	+ 4.9

GERMINATION OF SEEDS PLANTED

Seeds were planted in the greenhouse November 1. All seeds were planted within a period of 36 hours and at the same depth. Note was then made on the date of emergence.

A comparison of the average number of days required for emergence shows no consistent difference between varietal hybrids and their parents. (See Table II). On the other hand, in some interspecific crosses emergence was delayed one or two days. The normal seed of Little Club emerged in an average of ten days, incrossed Little Club emerged in an average of nine days, and Little Club x Emmer in an average of twelve days. Emmer, normal and incrossed, emerged in nine days from date of planting. Marquis and Emmer emerged in an average of nine days, Marquis x Emmer and reciprocal in an average of ten days.

No consistent difference was shown in the percentage germination between varietal crosses and their parents. Some interspecific crosses, however, showed a marked reduction in percentage germination as compared with their parents. Incrossed Marquis and incrossed Emmer showed a germination of 90 per cent and 71 per cent respectively. Marquis x Emmer showed 84 per cent germination, while only 8 per cent of Emmer x Marquis emerged. Incrossed Mindum showed a germination percentage of 93 while Mindum x Marquis and reciprocal gave a germination of 38 per cent and 39 per cent respectively. Incrossed Velvet Chaff germinated 93 per cent, Velvet Chaff x Emmer 91 per cent while from 24 seeds of Emmer x Velvet Chaff not a single plant emerged. Velvet Chaff x Mindum germinated only 30 per cent.

These cases show that when T. vulgare was used as the mother parent and T. durum or T. dicoccum as the pollen parent, the decrease in percentage germination was slight if any. With emmer or durum as the mother parent, however, the percentage germination was low.

Table II

Germination of Seeds Planted

Name	No.seeds Planted	No.seeds Germinated	Per cent Germination	Av.period of Germination
				days
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H3	14	13	93	9
H3 x H2	28	27	96	8
H3 x H3	49	48	98	9
H3 (Poultofka)	50	43	86	8
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H4	48	40	83	8
H4 x H2	37	33	90	8
H4 x H4	104	97	93	8
H4 (Velvet Chaff)	50	42	85	9
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H5	27	22	81	9
H5 x H2	35	19	54	10
H5 x H5	33	31	94	9
H5 (Barletta)	50	35	70	9
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H6	24	20	83	8
H6 x H2	36	30	83	9
H6 x H6	55	44	80	10
H6 (Penny)	50	40	80	9
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H9	34	33	97	9
H9 x H2	35	34	97	9
H9 x H9	44	36	82	9
H9 (Bobs)	50	39	78	9
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H10	31	28	90	8
H10 x H2	50	38	76	10
H10 x H10	39	33	85	9
H10 (Little Club)	50	38	76	10

Table II (continued)

Name	No.seeds Planted	No.seeds Germinated	Per cent Germination	Av.period of Germination days
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H11	19	16	84	10
H11 x H2	48	4	8	10
H11 x H11	45	32	71	9
H11 (Emmer)	50	41	82	9
H2 (Marquis)	50	48	96	9
H2 x H2	38	34	90	9
H2 x H12	13	5	39	11
H12 x H2	37	14	38	10
H12 x H12	58	54	93	10
H12 (Mindum)	50	36	72	9
H4 (Velvet Chaff)	50	42	85	9
H4 x H4	104	97	93	8
H4 x H5	37	36	97	8
H5 x H4	4	4	100	8
H5 x H5	33	31	94	9
H5 (Barletta)	50	35	70	9
H4 (Velvet Chaff	50	42	85	9
H4 x H4	104	97	93	8
H4 x H6	34	30	88	8
H6 x H4	43	31	72	9
H6 x H6	55	44	80	10
H6 (Penny)	50	40	80	9
H4 (Velvet Chaff)	50	42	85	9
H4 x H4	104	97	93	8
H4 x H9	73	62	85	8
H9 x H4	54	51	94	9
H9 x H9	44	36	82	9
H9 (Bobs)	50	39	78	9
H4 (Velvet Chaff)	50	42	85	9
H4 x H4	104	97	93	8
H4 x H10	47	34	72	8
H10 x H4	17	15	88	10
H10 x H10	39	33	85	9
H10 (Little Club)	50	38	76	10

Table II (continued)

Name	No.seeds Planted	No.seeds Germinated	Per cent Germination	Av.period of Germination days
H4 (Velvet Chaff)	50	42	85	9
H4 x H4	104	97	93	8
H4 x H11	33	30	91	9
H11 x H4	24	0	0	0
H11 x H11	45	32	71	9
H11	50	41	82	9
H4 (Velvet Chaff)	50	42	85	9
H4 x H4	104	97	93	8
H4 x H12	23	18	78	9
H12 x H4	14	4	30	9
H12 x H12	58	54	93	10
H12 (Mindum)	50	36	72	9
H6 (Penny)	50	40	80	9
H6 x H6	55	44	80	10
H6 x H9	53	43	81	8
H9 x H6	24	23	96	9
H9 x H9	44	36	82	9
H9 (Bobs)	50	39	78	9
H10 (Little Club)	50	38	76	10
H10 x H10	39	33	85	9
H10 x H11	24	11	46	12
H11 x H10	15	3	20	10
H11 x H11	45	32	71	9
H11 (Emmer)	50	41	82	9
H10 (Little Club)	50	38	76	10
H10 x H10	39	33	85	9
H10 x H12	2	1	50	11
H12 x H10	8	3	37	10
H12 x H12	58	54	93	10
H12 (Mindum)	50	36	72	9
H7 (Haynes Blue Stem)	50	44	88	8
H7 x H7	49	45	92	8
H7 x H2	26	24	92	9
H2 x H2	38	34	90	9
H2 (Marquis)	50	48	96	9
H8 (Haynes Blue Stem)	50	35	70	8
H8 x H8	69	58	84	8

INFLUENCE OF CROSSING ON VIGOR OF F_1 PLANTS

A positive correlation is often obtained between weight of seed planted and height of resulting seedlings. It seems logical to expect that a large plump seed will supply food for more rapid growth than will a small seed. Where this large seed, however, is due to the stimulus from crossing, the increase in size of F_1 seedling is merely a continuation of the heterosis exhibited in the F_1 seed.

Height of Seedlings at Four Weeks from Planting: In a comparison of average height of seedlings of the parents and those hybrids with approximately the same seed weight as that of parental average, we have the following cases: (See Tables III and IIIA).

Cross	Variation from parental average	Compared with incrossed or normal parents
Marquis x Velvet Chaff	+ 0.6±0.16	incrossed
Marquis x Barletta	+ 0.2±0.28	normal
Velvet Chaff x Marquis	+ 1.3±0.17	normal
Velvet Chaff x Penny	+ 1.2±0.16	normal
Velvet Chaff x Bobs	+ 0.8±0.16	normal
Barletta x Marquis	- 1.3±0.39	normal
Penny x Velvet Chaff	+ 0.4±0.24	incrossed
Penny x Bobs	+ 0.4±0.18	normal
Bobs x Penny	+ 0.1±0.25	normal
Bobs x Velvet Chaff	+ 0.1±0.18	incrossed
Marquis x Emmer	- 0.9±0.31	incrossed
Emmer x Marquis	- 3.5±0.34	normal
Emmer x Little Club	- 1.3±1.25	normal
Little Club x Marquis	- 1.0±0.13	incrossed
Mindum x Marquis	- 1.2±0.41	normal

These cases, with the exception of Barletta x Marquis, show that any significant difference in size in varietal crosses is in favor of the hybrid when compared with the parental average. In interspecific crosses, however, every case shows a decrease. The largest decrease was 3.5±0.34 inches from the parental average of plants grown from normal seed. This decrease was obtained in the case of Emmer x Marquis.

Furthermore, when those crosses are considered which were secured from plants whose average date of pollination was the same as that of the incrossed parent, we have additional evidence that crossing varieties resulted in an increase of vigor in F_1 seedlings. Marquis x Penny showed an increase of 1.1±0.25 inches over the taller parent. Taking all the crosses with a date of pollination the same as that of the incrossed parent we have the following results:

Cross	Variation from parental average Incrossed
Marquis x Velvet Chaff	+ 0.6±0.16
Marquis x Penny	+ 1.1±0.25
Haynes Blue Stem x Marquis	+ 1.2±0.23
Little Club x Marquis	- 1.0±0.13
Marquis x Emmer	- 0.9±0.31
Emmer x Marquis	- 3.5±0.34
Emmer x Little Club	- 0.8±1.25
Mindum x Marquis	+ 0.3±0.41

These facts show that F_1 varietal crosses are more vigorous than the average of their parents. On the other hand, F_1 crosses between species show a decrease in vigor as compared with the parental average.

Table III

Comparison of Seedling Heights in Inches of Parents and F_1 Crosses Four Weeks from Planting.

Name	Average Date Pollination	Height in Inches							Mean	Standard Deviation
		3.50	5.25	7.00	8.75	10.50	12.25	Number		
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H3	7-9	1		5	7			13	7.7±0.26	1.4±0.18
H3 x H2	7-8		2	5	13	6	1	27	8.1±0.19	1.5±0.14
H3 x H3	7-9		4	9	26	9		48	8.5±0.14	1.4±0.10
H3 (Poultofka)		2			21	18		41	9.3±0.16	1.5±0.11
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H4	7-17		6	17	17			40	7.5±0.13	1.2±0.09
H4 x H2	7-8			8	16	8	1	33	8.9±0.15	1.3±0.11
H4 x H4	7-14		15	47	10	17	4	93	7.8±0.13	1.9±0.09
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H5	7-8		1	9	7	3	1	21	8.1±0.25	1.7±0.18
H5 x H2	7-10	3	7	2	3	3		18	6.6±0.37	2.3±0.26
H5 x H5	7-11		1	7	12	7	2	29	8.9±0.20	1.6±0.14
H5 (Barletta)		2	2	5	4	21	1	35	9.2±0.24	2.1±0.17
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H6	7-14	1	1	13	3	1		19	7.2±0.22	1.4±0.15
H6 x H2	7-10		1	15	13	1		30	7.8±0.13	1.1±0.10
H6 x H6	7-14	6	17	10	9			42	6.2±0.18	1.7±0.13
H6 (Penny)		5	9	14	7			35	6.4±0.18	1.6±0.13

Table III (continued)

Name	Average Date Pollination	Height in Inches 3.50	5.25	7.00	8.75	10.50	12.25	Number	Mean	Standard Deviation
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H9	7-9		2	2	24	5		33	8.7±0.14	1.2±0.10
H9 x H2	7-6	1	2	15	15			33	7.6±0.14	1.2±0.10
H9 x H9	7-10	5	6	18	5			34	6.4±0.17	1.5±0.12
H9 (Bobs)		1	4	8	23	1		37	7.9±0.15	1.4±0.11
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H10	7-10	1	1	1	22	1		26	8.4±0.17	1.3±0.12
H10 x H2	7-17	22	12					34	4.1±0.09	0.8±0.07
H10 x H10	7-16	19	9	1				29	4.2±0.11	0.9±0.08
H10 (Little Club)		16	16	2				34	4.6±0.11	1.0±0.08
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H11	7-10	1	2	7	4			14	7.0±0.27	1.5±0.19
H11 x H2	7-10	2	2					4	4.4±0.30	0.9±0.21
H11 x H11	7-10	2		4	1	15	5	27	9.7±0.30	2.3±0.21
H11 (Emmer)		1	1	3	4	19	12	40	10.3±0.21	2.0±0.15
H2 (Marquis)		1	14	28	4			47	6.6±0.10	1.0±0.06
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 x H12	7-12		2	1	1			4	6.6±0.47	1.4±0.33
H12 x H2	7-14	3		5	2			10	6.3±0.40	1.9±0.29
H12 x H12	7-18	8	18	24	2			52	6.0±0.13	1.4±0.09
H12 (Mindum)		3		8	10	13		34	8.5±0.23	2.0±0.16

Table III (continued)

Name	Average Date Pollination	Height in Inches							Mean	Standard Deviation
		3.50	5.25	7.00	8.75	10.50	12.25	Number		
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17	4	93	7.8±0.13	1.9±0.09
H4 x H5	7-11	1		2	18	14		35	9.2±0.16	1.4±0.11
H5 x H4	7-5					4		4	10.5_	--
H5 x H5	7-11		1	7	12	7	2	29	8.9±0.20	1.6±0.14
H5 (Barletta)		2	2	5	4	21	1	35	9.2±0.24	2.1±0.17
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17		93	7.8±0.13	1.9±0.09
H4 x H6	7-10		1	2	23	3		29	8.7±0.11	0.9±0.08
H6 x H4	7-12	1	5	6	12			24	7.4±0.22	1.6±0.16
H6 x H6	7-14	6	17	10	9			42	6.2±0.18	1.7±0.13
H6 (Penny)		5	9	14	7	3		34	6.4±0.18	1.6±0.13
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17	4	93	7.8±0.13	1.9±0.09
H4 x H9	7-12	1		9	34	16	4	60	9.1±0.12	1.4±0.09
H9 x H4	7-9	4	6	19	21			50	7.2±0.15	1.6±0.11
H9 x H9	7-10	5	6	18	5			34	6.4±0.17	1.5±0.12
H9 (Bobs)		1	4	8	23	1		37	7.9±0.15	1.4±0.11
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17		93	7.8±0.13	1.9±0.09
H4 x H10	7-8	2		15	17			34	7.7±0.16	1.4±0.11
H10 x H4	7-11	1	3	10				14	6.4±0.18	1.0±0.13
H10 x H10	7-16	19	9	1				29	4.2±0.11	0.9±0.08
H10 (Little Club)		16	16	2				34	4.6±0.11	1.0±0.08

Table III (continued)

Name	Average Date Pollination	Height in Inches							Mean	Standard Deviation
		3.50	5.25	7.00	8.75	10.50	12.25	Number		
H4 (Velvet Chaff)			1	13	14	4		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17	4	93	7.8±0.13	1.9±0.09
H4 x H11	7-11		1	10	18			29	8.0±0.13	1.0±0.09
H11 x H4	7-11		None germinated						--	--
H11 x H11	7-10	2		4	1	15	5	27	9.7±0.30	2.3±0.21
H11 (Emmer)		1	1	3	4	19	12	40	10.3±0.21	2.0±0.15
H4 (Velvet Chaff)			1	13	14	14		42	8.7±0.16	1.5±0.11
H4 x H4	7-14		15	47	10	17	4	93	7.8±0.13	1.9±0.09
H4 x H12	7-14	1	1	8	7			17	7.4±0.23	1.4±0.16
H12 x H4	7-10	1	1	1	1			4	6.1±0.64	1.9±0.45
H12 x H12	7-18	8	18	24	2			52	6.0±0.13	1.4±0.09
H12 (Mindum)		3		8	10	13		34	8.5±0.23	2.0±0.16
H6 (Penny)		5	9	14	7			35	6.4±0.18	1.6±0.13
H6 x H6	7-14	6	17	10	9			42	6.2±0.18	1.7±0.13
H6 x H9	7-13		9	11	18	1		39	7.5±0.14	1.3±0.10
H9 x H6	7-9	2		12	7			21	7.2±0.22	1.5±0.16
H9 x H9	7-10	5	6	18	5			34	6.4±0.17	1.5±0.12
H9 (Bobs)		1	4	8	23	1		37	7.9±0.15	1.4±0.11
H10 (Little Club)		16	16	2				34	4.6±0.11	1.0±0.08
H10 x H10	7-16	19	9	1				29	4.2±0.11	0.9±0.08
H10 x H11	7-11	8	1					9	3.7±0.11	0.5±0.08
H11 x H10	7-11	1			1			2	6.1±1.24	2.6±0.88
H11 x H11	7-10	2		4	1	15	5	27	9.7±0.30	2.3±0.21
H11 (Emmer)		1	1	3	4	19	12	40	10.3±0.21	2.0±0.15

Table III (continued)

Name	Average Date Pollination	Height in Inches							Mean	Standard Deviation
		3.50	5.25	7.00	8.75	10.50	12.25	Number		
H10 (Little Club)		16	16	2				34	4.6±0.11	1.0±0.08
H10 x H10	7-16	19	9	1				29	4.2±0.11	0.9±0.08
H10 x H12	7-18	1						1	(2.5)	—
H12 x H10	7-16	4						4	3.6	—
H12 x H12	7-18	8	18	24	2			52	6.0±0.13	1.4±0.09
H12 (Mindum)		3		8	10	13		34	8.5±0.23	2.0±0.16
H7 (Haynes Blue Stem)			2	6	26	7		41	8.6±0.13	1.2±0.09
H7 x H7	7-12	2	8	28	2	4		44	6.9±0.15	1.5±0.11
H7 x H2	7-12	1	2	8	12	1		24	7.7±0.20	1.5±0.15
H2 x H2	7-14	3	12	19				34	6.1±0.15	1.3±0.11
H2 (Marquis		1	14	28	4			47	6.6±0.10	1.0±0.06
H8 (Haynes Blue Stem)			6	15	11			32	7.3±0.14	1.2±0.10
H8 x H8			5	23	19	11		58	8.1±0.13	1.5±0.09

Table III (A)

Summarized Comparison of Seedling Heights in Inches of Parents and F Crosses Four Weeks from Planting

Name	Taller Parent				Parental Average				Cross		Increase or Decrease of Cross from			
	Normal Seed		Increased Seed		Normal Seed		Increased Seed				Taller Parent		Parental Average	
	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height Inches	Weight Seed: Planted mgms.	Avg.Height Inches	Weight Seed: Planted mgms.	Normal Seed: inches	Increased Seed inches	Normal Seed inches	Increased Seed inches
Marquis x Poultofka	9.3±0.16	32.3±0.57	8.5±0.14	24.3±0.55	7.9±0.09[a]	24.1±0.36	7.3±0.10	18.4±0.38	7.7±0.26	23.5±1.04	-1.6±0.31	-0.8±0.29	-0.2±0.27	+0.4±0.28
Poultofka x Marquis									8.1±0.19	29.5±1.09	-1.2±0.25	-0.4±0.24	+0.3±0.21	+0.8±0.21
Marquis x Velvet Chaff	8.7±0.16	29.6±0.79	7.8±0.13	19.9±0.62	7.6±0.09	22.8±0.45	6.9±0.10	16.3±0.47	7.5±0.13	15.6±0.53	-1.2±0.21	-0.3±0.18	-0.1±0.16	+0.6±0.16
Velvet Chaff x Marquis									8.9±0.15	25.3±0.90	+0.2±0.22	+1.1±0.20	+1.3±0.17	+2.0±0.18
Marquis x Barletta	9.2±0.24	30.3±0.52	8.9±0.20	22.1±1.05	7.9±0.12	23.1±0.34	7.5±0.12	17.4±0.56	8.1±0.25	24.4±1.23	-1.1±0.35	-0.8±0.32	+0.2±0.28	+0.6±0.28
Barletta x Marquis									6.6±0.37	24.5±1.45	-2.6±0.44	-2.3±0.42	-1.3±0.39	-0.9±0.39
Marquis x Penny	6.6±0.10	15.9±0.45	6.2±0.18	15.8±0.82	6.5±0.10	15.4±0.31	6.1±0.12	14.2±0.53	7.2±0.22	20.2±1.04	+0.6±0.24	+1.0±0.28	+0.7±0.24	+1.1±0.25
Penny x Marquis									7.8±0.13	24.4±0.91	+1.2±0.16	+1.6±0.22	+1.3±0.16	+1.7±0.18
Marquis x Bobs	7.9±0.15	28.7±0.86	6.4±0.17	18.2±1.02	7.3±0.09	22.3±0.48	6.2±0.11	15.4±0.59	8.7±0.14	33.1±0.69	+0.8±0.21	+2.3±0.22	+1.4±0.17	+2.5±0.18
Bobs x Marquis									7.6±0.14	27.1±0.54	-0.3±0.21	+1.2±0.22	+0.3±0.17	+1.4±0.18
Marquis x Little Club	6.6±0.10	15.9±0.45	6.1±0.15	12.6±0.50	5.6±0.07	13.5±0.27	5.1±0.09	11.4±0.34	8.4±0.17	32.6±0.56	+1.8±0.20	+2.3±0.23	+2.8±0.18	+3.3±0.19
Little Club x Marquis									4.1±0.09	9.4±0.31	-2.5±0.13	-2.0±0.17	-1.5±0.11	-1.0±0.13
Marquis x Emmer	10.3±0.21	37.9±0.44	9.7±0.30	26.4±0.76	8.4±0.11	26.9±0.31	7.9±0.16	19.5±0.47	7.0±0.27	14.7±0.80	-3.3±0.34	-2.7±0.40	-1.4±0.29	-0.9±0.31
Emmer x Marquis									4.4±0.30	24.8±0.77	-5.9±0.37	-5.3±0.42	-4.0±0.32	-3.5±0.34
Marquis x Mindum	8.5±0.23	39.9±1.21	6.1±0.15	14.7±0.63	7.5±0.11	27.9±0.64	6.0±0.10	13.7±0.48	6.6±0.47	11.5±0.84	-1.9±0.52	+0.5±0.49	-0.9±0.48	+0.6±0.48
Mindum x Marquis									6.3±0.40	26.4±1.13	-2.2±0.46	+0.2±0.43	-1.2±0.41	+0.3±0.41
Velvet Chaff x Barletta	9.2±0.24	30.3±0.52	8.9±0.20	22.1±1.05	8.9±0.14	29.9±0.47	8.3±0.11	21.0±0.53	9.2±0.16	23.2±0.74	0.0	+0.3±0.26	+0.3±0.21	+0.9±0.19
Barletta x Velvet Chaff									10.5	38.4±0.71	+1.3	+1.6	+1.6	+2.2

Table III (A) (continued)

Name	Taller Parent				Parental Average				Cross		Increase or Decrease of Cross from			
	Normal Seed		Incrossed Seed		Normal Seed		Incrossed Seed				Taller Parent		Parental Average	
	Avg. Height inches	Weight Seed Planted mgms.	Avg. Height inches	Weight Seed Planted mgms.	Avg. Height inches	Weight Seed Planted mgms.	Avg. Height inches	Weight Seed Planted mgms.	Avg. Height inches	Weight Seed Planted mgms.	Normal Seed inches	Incrossed Seed inches	Normal Seed inches	Incrossed Seed inches
Velvet Chaff x Penny	8.7±0.16	29.6±0.79	7.8±0.13	19.9±0.62	7.5±0.12	22.2±0.45	7.0±0.10	17.9±0.49	8.7±0.11	23.1±0.76	0.0	+0.9±0.17	+1.2±0.16	+1.7±0.15
Penny x Velvet Chaff									7.4±0.22	15.7±0.65	-1.3±0.27	-0.4±0.26	-0.1±0.25	+0.4±0.24
Velvet Chaff x Bobs	8.7±0.16	29.6±0.79	7.8±0.13	19.9±0.62	8.3±0.11	29.2±0.58	7.1±0.10	19.1±0.53	9.1±0.12	26.1±0.53	+0.4±0.20	+1.3±0.18	+0.8±0.16	+2.0±0.16
Bobs x Velvet Chaff									7.2±0.15	19.9±0.54	-1.5±0.22	-0.6±0.20	-1.1±0.19	+0.1±0.18
Velvet Chaff x Little Club	8.7±0.16	29.6±0.79	7.8±0.13	19.9±0.62	6.6±0.10	20.4±0.42	6.0±0.10	15.0±0.47	7.7±0.16	23.2±0.55	-1.0±0.23	-0.1±0.21	+1.1±0.19	+1.7±0.19
Little Club x Velvet Chaff									6.4±0.18	20.0±0.62	-2.3±0.24	-1.4±0.22	-0.2±0.21	+0.4±0.21
Velvet Chaff x Emmer	10.3±0.21	37.9±0.44	9.7±0.30	26.4±0.76	9.5±0.13	33.8±0.45	8.7±0.12	23.2±0.49	8.0±0.13	13.3±0.32	-2.3±0.25	-1.7±0.33	-1.5±0.18	-0.7±0.18
Emmer x Velvet Chaff									--	--	--	--	--	--
Velvet Chaff x Mindum	8.7±0.16	29.6±0.79	7.8±0.13	19.9±0.62	8.6±0.13	34.8±0.72	6.9±0.10	17.3±0.46	7.4±0.23	15.9±0.56	-1.3±0.28	-0.4±0.26	-1.2±0.26	+0.5±0.25
Mindum x Velvet Chaff									6.1±0.64	27.5±1.42	-2.6±0.66	-1.7±0.65	-2.5±0.65	-0.8±0.65
Penny x Bobs	7.9±0.15	28.7±0.86	6.4±0.17	18.2±1.03	7.1±0.12	21.8±0.48	6.3±0.12	17.0±0.64	7.5±0.14	21.5±0.69	-0.4±0.20	+1.1±0.22	+0.4±0.18	+1.2±0.18
Bobs x Penny									7.2±0.22	22.9±1.17	-0.7±0.27	+0.8±0.28	+0.1±0.25	+0.9±0.25
Little Club x Emmer	10.3±0.21	37.9±0.44	9.7±0.30	26.4±0.76	7.4±0.12	24.5±0.27	6.9±0.15	18.3±0.46	3.7±0.11	7.7±0.34	-6.6±0.24	-6.0±0.32	-3.7±0.16	-3.2±0.19
Emmer x Little Club									6.1±1.24	25.0±1.18	-4.2±1.26	-3.6±1.28	-1.3±1.25	-0.8±1.25
Little Club x Mindum	8.5±0.23	39.9±1.21	6.0±0.13	14.7±0.63	6.5±0.13	25.5±0.62	5.1±0.09	12.4±0.42	2.5	5.0	-6.0	-3.5	-4.0	-2.6
Mindum x Little Club									3.6	13.1±0.57	-4.9	-2.4	-2.9	-1.5
Haynes Blue Stem x Marquis	8.6±0.13	26.0±0.54	6.9±0.15	17.2±0.77	7.6±0.08	21.0±0.35	6.5±0.11	14.9±0.48	7.7±0.20	23.5±0.67	-0.9±0.24	+0.8±0.25	+0.1±0.22	+1.2±0.23
Average											-1.4	-0.6	-0.4	+0.4

a. The probable error of an average of averages was calculated according to the formula:

$$E = \frac{1}{N}\sqrt{n_1^2 e_1^2 + n_2^2 e_2^2 + \ldots\ldots n_m^2 e_m^2}$$

in which n is the number of individuals in the generation, e the probable error and N the the total number of individuals. Roberts (78).

Height of Seedlings at Nine Weeks from Planting: Considering those crosses in which the weight of seed planted was approximately the same as that of the parental average, we have some crosses showing significant increases over the average of the parents. (See Tables IV and IVA). Velvet Chaff x Bobs had an increase of 1.6±0.19 inches over the parental average from normal seed. Bobs x Velvet Chaff showed an increase of 1.2±0.21 inches over the parental average from incrossed seed. In no case did a varietal cross show a significant decrease from the parental average from incrossed seed.

In the interspecific crosses, with the exception of Emmer x Little Club, all significant variations from the parental average were decreases. Emmer x Little Club had an increase of 1.3±0.23 inches from the parental average grown from normal seed. However, Marquis x Emmer showed a decrease of 1.5±0.38 inches from the parental average of seedlings grown from incrossed seed and Emmer x Marquis a decrease of 2.5±0.27 inches from the parental average of seedlings grown from normal seed.

Comparing those crosses which had an average date of pollination comparable to that of the average of the incrossed parents we have the following cases:

Cross	Difference from parental average Incrossed seed
Marquis x Velvet Chaff	+ 0.6±0.30
Marquis x Penny	+ 2.0±0.43
Haynes Blue Stem x Marquis	+ 1.9±0.30
Velvet Chaff x Bobs	+ 3.1±0.18
Penny x Bobs	+ 1.5±0.28
Little Club x Marquis	+ 0.2±0.29
Marquis x Emmer	- 1.5±0.38
Emmer x Marquis	- 1.9±0.31
Emmer x Little Club	+ 0.6±0.22
Mindum x Marquis	+ 0.2±0.66
Mindum x Little Club	- 1.8±0.73

In the varietal crosses the difference in favor of the hybrids was even greater at nine weeks than at four weeks. In the case of interspecific crosses, however, the hybrid Little Club x Marquis had overcome the difference shown at four weeks and here showed no significant decrease from parental average. Marquis x Emmer and the reciprocal, on the other hand, still showed a significant decrease from parental average as compared with seedlings from incrossed seed.

Table IV

Comparison of Height in Inches of Tallest Culm of Parents and F_1 Crosses at Nine Weeks from Planting.

Name	Average Date Pollination	Height of Tallest Culm (inches)															
		5.5	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.5	22.0	23.5	Number	Mean	Standard Deviation
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H3	7-9				1			5	2	3	1				12	15.5±0.43	2.2±0.30
H3 x H2	7-8					1	3	8	11	3					26	15.2±0.16	1.2±0.11
H3 x H3	7-9				1	3	4	7	12	11	5	3			46	16.6±0.24	2.4±0.17
H3 x (Poultofka)						1	2	4	13	12	6	2			40	16.7±0.20	1.9±0.14
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H4	7-17				3	7	3	9	9	6	2				40	14.5±0.27	2.5±0.19
H4 x H2	7-8						1	7	7	14	3				32	16.5±0.18	1.5±0.13
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H5	7-8						4	6	4	4		2			20	15.7±0.33	2.2±0.23
H5 x H2	7-10		1		1	3	2	5	6						18	13.6±0.38	2.4±0.27
H5 x H5	7-11				1	2	1	9	7	5	2	1			28	15.5±0.29	2.3±0.21
H5 (Barletta)						2	3	3	9	7	9	1			34	16.6±0.27	2.3±0.19
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H6	7-14				2		2	8	3	1	2				18	14.8±0.38	2.4±0.27
H6 x H2	7-10					1	2	7	11	4	3				28	15.7±0.22	1.7±0.15
H6 x H6	7-14	1		2	4	8	9	4	8	5		1			42	13.5±0.31	3.0±0.22
H6 (Penny)					1	3	14	6	10						34	13.9±0.18	1.6±0.13

Table IV (continued)

Name	Average Date Pollination	Height of Tallest Culm (inches) 5.5	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.5	22.0	23.5	Number	Mean	Standard Deviation
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H9	7-9				1	1	3	8	7	6	4	2			32	15.9±0.29	2.4±0.20
H9 x H2	7-6		1			1		7	18	6	1				34	15.6±0.23	2.0±0.16
H9 x H9	7-10			3	2	4	4	14	7						34	13.5±0.27	2.3±0.19
H9 (Bobs)					1	2	6	12	14	1					36	14.6±0.18	1.6±0.13
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H10	7-10				1	1	1	5	11	5	2				26	15.7±0.26	2.0±0.19
H10 x H2	7-17		1	3	1	15	7	6	3						36	12.2±0.24	2.1±0.17
H10 x H10	7-16		1	1	4	12	8	3	1						30	11.9±0.22	1.8±0.16
H10 (Little Club)		1	4	4	5	7	7	7	1						36	11.3±0.29	2.6±0.21
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H11	7-10			1		1	4	5	3	1					15	14.1±0.33	1.9±0.23
H11 x H2	7-17						2	2							4	13.7±0.24	0.7±0.17
H11 x H11	7-10						1	1	1	6	3	13	1		26	19.0±0.26	2.0±0.19
H11 (Emmer)								2	8	9	12	6		1	38	18.1±0.21	1.9±0.15
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 x H12	7-12					3		1							4	12.3±0.44	1.3±0.31
H12 x H2	7-14			1	2		2	1	2	2					10	13.6±0.64	3.0±0.45
H12 x H12	7-18		1	2	1	1	4	21	16	6					52	14.7±0.21	2.2±0.14
H12 (Mindum)					1	1	1	7	11	9	4				34	16.0±0.23	2.0±0.16

Table IV (continued

Name	Average Date Pollination	Height of Tallest Culm (inches) 5.5	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.5	22.0	23.5	Number	Mean	Standard Deviation
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H5	7-11				2		1	4	9	5	10	3			34	16.9±0.29	2.5±0.20
H5 x H4	7-5									3	1				4	17.9±0.20	0.6±0.14
H5 x H5	7-11				1	2	1	9	7	5	2	1			28	15.5±0.29	2.3±0.21
H5 (Barletta)						2	3	3	9	7	9	1			34	16.6±0.27	2.3±0.19
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H6	7-10						3	8	8	8	1				28	15.8±0.20	1.6±0.14
H6 x H4	7-12				1		5	4	5	6	1				22	15.3±0.30	2.1±0.21
H6 x H 6	7-14	1		2	4	8	9	4	8	5		1			42	13.5±0.31	3.0±0.22
H6 (Penny)					1	3	14	6	10						34	13.9±0.18	1.6±0.13
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H9	7-12						1	1	14	22	19	2			59	17.6±0.13	1.5±0.09
H9 x H4	7-9					2	2	14	16	13	2	1			50	15.7±0.16	1.7±0.11
H9 x H9	7-10			3	2	4	4	14	7						34	13.5±0.27	2.3±0.19
H9 (Bobs)					1	2	6	12	14	1					36	14.6±0.18	1.6±0.13
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H10	7-8					1	1	1	13	16	2				34	16.6±0.17	1.5±0.12
H10 x H4	7-11						1	2	6	5					14	16.1±0.23	1.3±0.17
H10 x H10	7-16		1	1	4	12	8	3	1						30	11.9±0.22	1.8±0.16
H10 (Little Club)		1	4	4	5	7	7	7	1						36	11.3±0.29	2.6±0.21

Table IV (continued)

Name	Average Date Pollination	Height of Tallest Culm (inches)														Mean	Standard Deviation
		5.5	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.5	22.0	23.5	Number		
H4 (Velvet Chaff							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H11	7-11						1	4	7	9	7				28	16.9±0.22	1.7±0.15
H11 x H11	7-10						1	1	1	6	3	13	1		26	19.0±0.26	2.0±0.19
H11 (Emmer)	7-10							2	8	9	12	6		1	38	18.1±0.21	1.9±0.15
H4 (Velvet Chaff)							2	4	6	18	5	3	2		40	17.4±0.21	2.0±0.15
H4 x H4	7-14				1	3	10	34	17	12	14	1			92	15.6±0.15	2.2±0.11
H4 x H12	7-14					1	1	2	4	6	2				16	16.3±0.34	2.0±0.24
H12 x H4	7-10							2	1						3	15.0±0.27	0.7±0.19
H12 x H12	7-18		1	2	1	1	4	21	16	6					52	14.7±0.21	2.2±0.14
H12 (Emmer)					1	1	1	7	11	9	4				34	16.0±0.23	2.0±0.16
H6 (Penny)					1	3	14	6	10						34	13.9±0.18	1.6±0.13
H6 x H6	7-14	1		2	4	8	9	4	8	5		1			42	13.5±0.31	3.0±0.22
H6 x H9	7-13					3	4	13	13	4	1				38	15.1±0.19	1.7±0.13
H9 x H6	7-9		1				3	8	10						22	14.6±0.27	1.9±0.19
H9 x H9	7-10			3	2	4	4	14	7						34	13.8±0.27	2.3±0.19
H9 (Bobs)					1	2	6	12	14	1					36	14.6±0.18	1.6±0.13
H10 (Little Club)		1	4	4	5	7	7	7	1						36	11.3±0.29	2.6±0.21
H10 x H10	7-16		1	1	4	12	8	3	1						30	11.9±0.22	1.8±0.16
H10 x H11	7-11				1	6	3								10	11.8±0.19	0.9±0.14
H11 x H10	7-11						1				1				2	16.0±0.14	3.0±0.10
H11 x H11	7-10						1	1	1	6	3	13	1		26	19.0±0.26	2.0±0.19
H11 (Emmer)								2	8	9	12	6		1	38	18.1±0.21	1.9±0.15

Table IV (continued)

Name	Average Date Pollination	Height of Tallest Culm (inches)													Number	Mean	Standard Deviation
		5.5	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.5	22.0	23.5			
H10 (Little Club)		1	4	4	5	7	7	7	1						36	11.3±0.29	2.6±0.21
H10 x H10	7-16		1	1	4	12	8	3	1						30	11.9±0.22	1.8±0.16
H12 x H10	7-16				1		1								2	11.5±0.71	1.5±0.51
H12 x H12	7-18		1	2	1	1	4	21	16	6					52	14.7±0.21	2.2±0.14
H12 (Mindum)					1	1	1	7	11	9	4				34	16.0±0.23	2.0±0.16
H7 (Haynes Blue Stem)				1		1		5	16	11	6				40	16.4±0.21	2.0±0.15
H7 x H7	7-12					1	2	10	13	13	2	1			42	16.1±0.18	1.7±0.12
H7 x H2	7-12					1	3	2	9	7	2				24	16.0±0.26	1.9±0.18
H2 x H2	7-14		1	2	7	6	7	6	3						32	12.2±0.27	2.3±0.19
H2 (Marquis)						3	10	18	11	4					46	14.6±0.15	1.5±0.11
H8 (Haynes Blue Stem)							4	6	7	9	5	1			32	16.4±0.24	2.0±0.17
H8 x H8								5	14	17	9	10	2	1	58	17.8±0.19	2.1±0.13

Table IV (A)

Summarized Comparison of Height in Inches of Tallest Culm of Parents and F_1 Crosses at Nine Weeks from Planting.

Name	Taller Parent				Parental Average				Cross		Increase or Decrease of Cross from			
	Normal Seed		Incrossed Seed		Normal Seed		Incrossed Seed				Taller Parent		Parental Average	
	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted: mgms.	Normal Seed: inches	Incrossed Seed: inches	Normal Seed: inches	Incrossed Seed inches
Marquis x Poultofka	16.7±0.20	32.3±0.57	16.6±0.24	24.3±0.55	15.6±0.12	24.1±0.36	14.4±0.18	18.4±0.38	15.5±0.43	23.5±1.04	-1.2±0.47	-1.1±0.49	-0.1±0.44	+1.1±0.46
Poultofka x Marquis									15.2±0.16	29.5±1.09	-1.5±0.25	-1.4±0.29	-0.4±0.20	+0.8±0.24
Marquis x Velvet Chaff	17.4±0.21	29.6±0.79	15.6±0.15	19.9±0.62	16.0±0.13	22.8±0.45	13.9±0.13	16.3±0.47	14.5±0.27	15.6±0.53	-2.9±0.34	-1.1±0.31	-1.5±0.30	+0.6±0.30
Velvet Chaff x Marquis									16.5±0.18	25.3±0.90	-0.9±0.28	+0.9±0.23	+0.5±0.22	+2.6±0.22
Marquis x Barletta	16.6±0.27	30.3±0.52	15.5±0.29	22.1±1.05	15.6±0.14	23.1±0.34	13.8±0.20	17.4±0.56	15.7±0.33	24.4±1.23	-0.9±0.43	+0.2±0.44	+0.1±0.36	+1.9±0.39
Barletta x Marquis									13.6±0.38	24.5±1.45	-3.0±0.47	-1.9±0.48	-2.0±0.41	-0.2±0.43
Marquis x Penny	14.6±0.15	15.9±0.45	13.5±0.31	15.8±0.82	14.2±0.13	15.4±0.31	12.8±0.21	14.2±0.53	14.8±0.38	20.2±1.04	+0.2±0.41	+1.3±0.49	+0.6±0.40	+2.0±0.43
Penny x Marquis									15.7±0.22	24.4±0.91	+2.2±0.27	+1.8±0.38	+1.5±0.25	+2.9±0.30
Marquis x Bobs	14.6±0.18	28.7±0.86	13.5±0.27	18.2±1.02	14.6±0.12	22.3±0.48	12.8±0.19	15.4±0.59	15.9±0.29	33.1±0.69	+1.3±0.34	+2.4±0.40	+1.3±0.31	+3.1±0.35
Bobs x Marquis									15.6±0.23	27.1±0.54	+1.0±0.29	+2.1±0.35	+1.0±0.26	+2.8±0.30
Marquis x Little Club	14.6±0.15	15.9±0.45	12.2±0.27	12.6±0.50	12.9±0.16	13.5±0.27	12.0±0.17	11.4±0.34	15.7±0.26	32.6±0.56	+1.1±0.30	+3.5±0.37	+2.8±0.31	+3.7±0.31
Little Club x Marquis									12.2±0.24	9.4±0.31	-2.4±0.28	0.0	-0.7±0.29	+0.2±0.29
Marquis x Emmer	18.1±0.21	37.9±0.44	19.0±0.26	26.4±0.76	16.3±0.12	26.9±0.31	15.6±0.19	19.5±0.47	14.1±0.33	14.7±0.80	-4.0±0.39	-4.9±0.42	-2.2±0.35	-1.5±0.38
Emmer x Marquis									13.7±0.24	24.8±0.77	-4.4±0.32	-5.3±0.35	-2.6±0.27	-1.9±0.31
Marquis x Mindum	16.0±0.23	39.9±1.21	14.7±0.21	14.7±0.63	15.3±0.13	27.9±0.64	13.4±0.16	13.7±0.43	12.3±0.44	11.5±0.84	-3.7±0.50	-2.4±0.49	-3.0±0.45	-1.1±0.47
Mindum x Marquis									13.6±0.64	26.4±1.13	-2.4±0.68	-1.1±0.67	-1.7±0.65	+0.2±0.66
Velvet Chaff x Barletta	17.4±0.21	29.6±0.79	15.6±0.15	19.9±0.62	17.0±0.17	29.9±0.47	15.5±0.13	21.0±0.53	16.9±0.29	23.2±0.74	-0.5±0.36	+1.3±0.33	-0.1±0.34	+1.4±0.32
Barletta x Velvet Chaff									17.9±0.20	38.8±0.71	+0.5±0.29	+2.3±0.25	+0.9±0.26	+2.4±0.24

Table IV (A) (continued)

Name	Taller Parent				Parental Average				Cross		Increase or Decrease of Cross from			
	Normal Seed		Incrossed Seed		Normal Seed		Incrossed Seed				Taller Parent		Parental Average	
	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Avg.Height inches	Weight Seed: Planted mgms.	Normal Seed: Inches	Incrossed Seed: inches	Normal Seed: Inches	Incrossed Seed inches
Velvet Chaff x Penny	17.4±0.21	29.6±0.79	15.6±0.15	19.9±0.62	15.6±0.14	22.2±0.45	14.5±0.14	17.9±0.49	15.8±0.20	23.1±0.76	-1.6±0.29	+0.2±0.25	+0.2±0.24	+1.3±0.24
Penny x Velvet Chaff									15.3±0.30	15.7±0.65	-2.1±0.37	-0.3±0.34	-0.3±0.33	+0.8±0.33
Velvet Chaff x Bobs	17.4±0.21	29.6±0.79	15.6±0.15	19.9±0.62	16.0±0.14	29.2±0.58	14.5±0.13	19.1±0.53	17.6±0.13	26.1±0.53	+0.2±0.25	+2.0±0.20	+1.6±0.19	+3.1±0.18
Bobs x Velvet Chaff									15.7±0.16	19.9±0.54	-1.7±0.26	+0.1±0.22	-0.3±0.21	+1.2±0.21
Velvet Chaff x Little Club	17.4±0.21	29.6±0.79	15.6±0.15	19.9±0.62	14.3±0.17	20.4±0.42	13.7±0.12	15.0±0.47	16.6±0.17	23.2±0.55	-0.8±0.27	+1.0±0.23	+2.3±0.24	+2.9±0.21
Little Club x Velvet Chaff									16.1±0.23	20.0±0.62	-1.3±0.31	+0.5±0.27	+1.8±0.29	+2.4±0.26
Velvet Chaff x Emmer	18.1±0.21	37.9±0.44	19.0±0.26	26.4±0.76	17.7±0.15	33.5±0.45	17.3±0.13	23.0±0.49	16.9±0.22	13.3±0.32	-1.2±0.30	-2.1±0.34	-0.8±0.27	-0.4±0.26
Emmer x Velvet Chaff									--	--	--	--	--	--
Velvet Chaff x Mindum	17.4±0.21	29.6±0.79	15.6±0.15	19.6±0.62	16.7±0.15	34.8±0.72	15.1±0.12	17.3±0.46	16.3±0.34	15.9±0.56	-1.1±0.40	+0.7±0.37	-0.4±0.37	+1.2±0.36
Mindum x Velvet Chaff									15.0±0.27	27.5±1.42	-2.4±0.34	-0.6±0.31	-1.7±0.31	-0.1±0.30
Penny x Bobs	14.6±0.18	28.7±0.86	13.8±0.27	18.2±1.03	14.2±0.13	21.8±0.48	13.6±0.21	17.0±0.64	15.1±0.19	21.5±0.69	+0.5±0.26	+1.3±0.33	+0.9±0.23	+1.5±0.26
Bobs x Penny									14.6±0.27	22.9±1.17	0.0	+0.8±0.36	+0.4±0.30	+1.0±0.34
Little Club x Emmer	18.1±0.21	37.9±0.44	19.0±0.26	26.4±0.76	14.7±0.18	24.5±0.27	15.4±0.17	18.3±0.46	11.8±0.19	7.7±0.34	-6.3±0.26	-7.2±0.32	-2.9±0.26	-3.6±0.25
Emmer x Little Club									16.0±0.14	25.0±1.18	-2.1±0.25	-3.0±0.30	+1.3±0.23	+0.6±0.22
Little Club x Mindum	16.0±0.23	32.9±1.21	14.7±0.21	14.7±0.63	13.6±0.19	25.5±0.62	13.3±0.15	12.4±0.42	--	--	--	--	--	--
Mindum x Little Club									11.5±0.71	13.1±0.57	-4.5±0.75	-3.2±0.74	-2.1±0.73	-1.8±0.73
Haynes Blue Stem x Marquis	16.4±0.21	26.0±0.54	16.1±0.18	17.2±0.77	15.5±0.13	21.0±0.35	14.1±0.15	14.9±0.48	16.0±0.26	23.5±0.67	-0.4±0.33	-0.1±0.32	+0.5±0.29	+1.9±0.30
Average											-1.4	-0.4	-0.1	+1.0

Width of Leaf at Nine Weeks from Planting: As another measure of vegetative vigor a measurement was made of leaf width. An increase in leaf area gives a larger field for photosynthetic processes and thus aids materially in augmenting the elaboration of plant food.

Measurements were taken of the width of the fourth leaf from the base about four inches from the proximal end. If we consider those hybrids which had the same F_1 seed weight as the parental average, we find in every such varietal cross a significant increase in the width of leaf. The increases in leaf width of Marquis x Velvet Chaff, Velvet Chaff x Marquis and Velvet Chaff x Penny over parental average were 1.1±0.15 millimeters, 1.1±0.15 millimeters, 1.1±0.11 millimeters, respectively. The cross Penny x Bobs showed an increase of 1.3±0.14 millimeters over the parental average of seedlings grown from incrossed seed.

Furthermore, in some interspecific crosses a significant increase is shown. Marquis x Emmer showed an increase of 0.9±0.22 millimeters over the parental average of seedlings grown from incrossed seed. On the other hand, Emmer x Marquis showed a decrease of 1.1±0.14 millimeters from the average of seedlings from normal seed. The other interspecific crosses showed no significant differences as compared with the parental average.

A comparison was made of F_1 hybrids with their parental averages for those crosses in which the average date of pollination was as late or later than that for the average of the parents. Summarized results as given are taken from last column of Table VA.

Cross	Difference from leaf width of parental average Incrossed seed
Marquis x Velvet Chaff	+ 1.1±0.15
Marquis x Penny	+ 1.3±0.17
Haynes Blue Stem x Marquis	+ 0.7±0.16
Velvet Chaff x Bobs	+ 0.9±0.12
Penny x Bobs	+ 1.3±0.14
Little Club x Marquis	+ 0.3±0.12
Marquis x Emmer	+ 0.9±0.22
Emmer x Marquis	- 0.6±0.15
Emmer x Little Club	+ 0.6±0.72
Mindum x Marquis	+ 0.5±0.19
Mindum x Little Club	- 0.4±0.17

These cases show in every varietal cross a significant increase of leaf width over that of the parental average of seedlings grown from incrossed seed. The largest increase is 1.3±0.14 millimeters which occured in the case of Penny x Bobs. The interspecific crosses showed no significant decreases and one, Marquis x Emmer, showed a significant increase in leaf width over the parental average of seedlings from incrossed seed. Therefore, the evidence is conclusive that an increase in leaf width over the average of parents often occurs in crosses between varieties and sometimes in interspecific crosses as well.

Table V

Comparison of Leaf Width, in Millimeters of Fourth Leaf From Base, of Parents and F_1 Crosses Nine Weeks from Planting.

Name	Average Date Pollination	Width in Millimeters											Mean	Standard Deviation
		3	4	5	6	7	8	9	10	11	12	Number		
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H3	7-9			2	5	5						12	6.3±0.14	0.7±0.10
H3 x H2	7-8			2	2	5	13	3	1			26	7.6±0.14	1.1±0.10
H3 x H3	7-9		1	9	15	18	3					46	6.3±0.09	0.9±0.06
H3 (Poultofka)				7	11	15	6	1				40	6.6±0.11	1.0±0.07
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H4	7-17			10	8	7	11	4				40	6.8±0.14	1.3±0.10
H4 x H2	7-8			2	6	8	9	6	1			32	7.4±0.14	1.3±0.11
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H5	7-8		1		4	8	4	1	1	1		20	7.3±0.23	1.5±0.16
H5 x H2	7-10		2	5	6	3	2					18	5.8±0.17	1.1±0.12
H5 x H5	7-11			5	9	10	4					28	6.5±0.11	0.9±0.08
H5 (Barletta)			2	8	4	11	8	1				34	6.5±0.15	1.3±0.11
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H6	7-14			1	4	8	3	2				18	6.9±0.16	1.0±0.08
H6 x H2	7-10			3	4	11	9	1				28	7.0±0.13	1.0±0.09
H6 x H6	7-14	1	5	15	11	8	2					42	5.7±0.11	1.1±0.08
H6 (Penny)			1	7	16	7						31	5.9±0.08	0.7±0.06

Table V (continued)

Name	Average Date Pollination	Width in Millimeters										Number	Mean	Standard Deviation
		3	4	5	6	7	8	9	10	11	12			
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H9	7-9				2	8	12	8	2			32	8.0±0.12	1.0±0.08
H9 x H2	7-6			1	1	6	17	9				34	7.9±0.10	0.9±0.07
H9 x H9	7-10			5	3	8	13	4	1			34	7.3±0.15	1.3±0.11
H9 (Bobs)				1	3	6	14	9	3			36	8.0±0.12	1.1±0.09
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H10	7-10			2		8	10	5	1			26	7.7±0.15	1.1±0.10
H10 x H2	7-17		2	10	13	10	1					36	5.9±0.10	0.9±0.07
H10 x H10	7-16			11	14	4	1					30	5.8±0.10	0.8±0.07
H10 (Little Club)		2	6	14	11	3						36	5.2±0.11	1.0±0.08
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H11	7-10			1	4	7	3					15	6.7±0.21	1.2±0.15
H11 x H2	7-17			3	1							4	5.2±0.13	0.4±0.09
H11 x H11	7-10		1	5	11	8	1					26	6.1±0.11	0.8±0.07
H11 (Emmer)			1	6	24	6	1					38	6.0±0.08	0.7±0.05
H2 (Marquis)				1	18	19	8					46	6.7±0.08	0.8±0.05
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 x H12	7-12				1	2	1					4	7.0±0.24	0.7±0.17
H12 x H2	7-14		2	1	5	6						14	6.1±0.18	1.0±0.13
H12 x H12	7-18	1	3	21	14	11	2					52	5.7±0.09	1.0±0.07
H12 (Mindum)			1	3	12	15	3					34	6.5±0.09	0.8±0.06

Table V (continued)

Name	Average Date Pollination	Width in Millimeters											Mean	Standard Deviation
		3	4	5	6	7	8	9	10	11	12	Number		
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H5	7-11		2		7	21	4					34	6.7±0.10	0.9±0.07
H5 x H4	7-5					2	2					4	7.5±0.17	0.5±0.12
H5 x H5	7-11			5	9	10	4					28	6.5±0.11	0.9±0.08
H5 (Barletta)			2	8	4	11	8	1				34	6.5±0.15	1.3±0.11
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H6	7-10			2	2	19	3	2				28	7.0±0.10	0.8±0.07
H6 x H4	7-12			6	8	7	1					22	6.1±0.11	0.8±0.08
H6 x H6	7-14	1	5	15	11	8	2					42	5.7±0.11	1.1±0.08
H6 (Penny)			1	7	16	7						31	5.9±0.08	0.7±0.06
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H9	7-12				6	30	15	1	5		1	58	7.5±0.11	1.2±0.08
H9 x H4	7-9			4	6	21	19					50	7.1±0.09	0.9±0.06
H9 x H9	7-10			5	3	8	13	4	1			34	7.3±0.15	1.3±0.11
H9 (Bobs)				1	3	6	14	9	3			36	8.0±0.12	1.1±0.09
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H10	7-8			1	13	15	5					34	6.7±0.08	0.7±0.06
H10 x H4	7-11			1	8	5						14	6.3±0.11	0.6±0.08
H10 x H10	7-16			11	14	4	1					30	5.8±0.10	0.8±0.07
H10 (Little Club)		2	6	14	11	3						36	5.2±0.11	1.0±0.08

Table V (continued)

Name	Average Date Pollination	Width in Millimeters											Mean	Standard Deviation
		3	4	5	6	7	8	9	10	11	12	Number		
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H11	7-11			6	12	10						28	6.1±0.09	0.7±0.06
H11 x H11	7-10		1	5	11	8	1					26	6.1±0.11	0.8±0.07
H11 (Emmer)			1	6	24	6	1					38	6.0±0.08	0.7±0.05
H4 (Velvet Chaff)			2	7	21	9	1					40	6.0±0.07	0.7±0.05
H4 x H4	7-14			39	24	28	1					92	5.9±0.06	0.9±0.04
H4 x H12	7-14	1		2	7	5	1					16	6.1±0.19	1.1±0.13
H12 x H4	7-10				4							4	6.0	....
H12 x H12	7-18	1	3	21	14	11	2					52	5.7±0.09	1.0±0.07
H12 (Mindum)			1	3	12	15	3					34	6.5±0.09	0.8±0.06
H6 (Penny)			1	7	16	7						31	5.9±0.07	0.7±0.06
H6 x H6	7-14	1	5	15	11	8	2					42	5.7±0.06	1.1±0.08
H6 x H9	7-13			2	2	9	15	9	1			38	7.8±0.12	1.1±0.09
H9 x H6	7-9	1			1	7	3	9	1			22	7.9±0.20	1.4±0.12
H9 x H9	7-10			5	3	8	13	4	1			34	7.3±0.15	1.3±0.11
H9 (Bobs)				1	3	6	14	9	3			36	8.0±0.12	1.1±0.09
H10 (Little Club)		2	6	14	11	3						36	5.2±0.11	1.0±0.08
H10 x H10	7-16			11	14	4	1					30	5.8±0.10	0.8±0.07
H10 x H11	7-11		1	4	4	1						10	5.5±0.17	0.8±0.12
H11 x H10	7-11			1			1					2	6.5±0.72	1.5±0.51
H11 x H11	7-10		1	5	11	8	1					26	6.1±0.11	0.8±0.07
H11 x (Emmer)			1	6	24	6	1					38	6.0±0.08	0.7±0.05

Table V (continued)

Name	Average Date Pollination	Width in Millimeters											Mean	Standard Deviation
		3	4	5	6	7	8	9	10	11	12	Number		
H10 (Little Club)		2	6	14	11	3						36	5.2±0.11	1.0±0.08
H10 x H10	7-16			11	14	4	1					30	5.8±0.10	0.8±0.07
H12 x H10	7-16			2	1							3	5.3±0.16	0.4±0.11
H12 x H12	7-18	1	3	21	14	11	2					52	5.7±0.09	1.0±0.07
H12 (Mindum)			1	3	12	15	3					34	6.5±0.09	0.8±0.06
H7 (Haynes Blue Stem)		1		15	16	8						40	5.7±0.06	0.6±0.05
H7 x H7	7-12			14	11	12	4	1				42	6.2±0.10	1.0±0.07
H7 x H2	7-12		1	2	7	11	3					24	6.5±0.14	1.0±0.10
H2 x H2	7-14		2	15	11	4						32	5.5±0.09	0.8±0.07
H2 (Marquis)				1	18	18	8					46	6.7±0.08	0.8±0.05
H8 (Haynes Blue Stem)				10	18	2						30	5.7±0.07	0.6±0.05
H8 x H8				8	28	19	3					58	6.3±0.07	0.8±0.05

Table V (A)

Summarized Comparison of Leaf Width of Parents and F_1 Crosses at Nine Weeks from Planting.

Name	Wider Parent				Parental Average				Cross		Increase or Decrease of Cross From			
	Normal Seed		Incrossed Seed		Normal Seed		Incrossed Seed				Wider Parent		Parental Average	
	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Normal Seed: mms.	Incrossed Seed: mms.	Normal Seed: mms.	Incrossed Seed mms.
Marquis x Poultofka	6.7±0.08	15.9±0.45	6.3±0.09	24.3±0.55	6.6±0.07	24.1±0.36	5.9±0.06	18.4±0.38	6.3±0.14	23.5±1.04	-0.4±0.16	0.0	-0.3±0.16	+0.4±0.15
Poultofka x Marquis									7.6±0.14	29.5±1.09	+0.9±0.16	+1.3±0.17	+1.0±0.16	+1.7±0.15
Marquis x Velvet Chaff	6.7±0.08	15.9±0.45	5.9±0.06	19.9±0.62	6.3±0.05	22.8±0.45	5.7±0.05	16.3±0.47	6.8±0.14	15.6±0.53	+0.1±0.16	+0.9±0.15	+0.5±0.15	+1.1±0.15
Velvet Chaff x Marquis									7.4±0.14	25.3±0.90	+0.7±0.16	+1.5±0.15	+1.1±0.15	+1.7±0.15
Marquis x Barletta	6.7±0.08	15.9±0.45	6.5±0.11	22.1±1.05	6.6±0.08	23.1±0.34	6.0±0.07	17.4±0.56	7.3±0.23	24.4±1.23	+0.6±0.24	+0.8±0.25	+0.7±0.24	+1.3±0.24
Barletta x Marquis									5.8±0.17	24.5±1.45	-0.9±0.19	-0.7±0.20	-0.8±0.19	-0.2±0.18
Marquis x Penny	6.7±0.08	15.9±0.45	5.7±0.11	15.8±0.82	6.3±0.07	15.4±0.31	5.6±0.07	14.2±0.53	6.9±0.16	20.2±1.04	+0.2±0.18	+1.2±0.19	+0.6±0.17	+1.3±0.17
Penny x Marquis									7.0±0.13	24.4±0.91	+0.3±0.15	+1.3±0.17	+0.7±0.15	+1.4±0.15
Marquis x Bobs	8.0±0.12	28.7±0.86	7.3±0.15	18.2±1.02	7.3±0.07	22.3±0.48	6.4±0.09	15.4±0.59	8.0±0.12	33.1±0.69	0.0	+0.7±0.19	+0.7±0.14	+1.6±0.15
Bobs x Marquis									7.9±0.10	27.1±0.54	-0.1±0.16	+0.6±0.18	+0.6±0.12	+1.5±0.13
Marquis x Little Club	6.7±0.08	15.9±0.45	5.8±0.10	10.1±0.47	5.9±0.06	13.5±0.27	5.6±0.07	11.4±0.34	7.7±0.15	32.6±0.56	+1.0±0.17	+1.9±0.18	+1.8±0.16	+2.1±0.16
Little Club x Marquis									5.9±0.10	9.4±0.31	-0.8±0.13	+0.1±0.14	0.0	+0.3±0.12
Marquis x Emmer	6.7±0.08	15.9±0.45	6.1±0.11	26.4±0.76	6.3±0.06	26.9±0.31	5.8±0.07	19.5±0.47	6.7±0.21	14.7±0.80	0.0	+0.6±0.24	+0.4±0.22	+0.9±0.22
Emmer x Marquis									5.2±0.13	24.8±0.77	-1.5±0.15	-0.9±0.17	-1.1±0.14	-0.6±0.15
Marquis x Mindum	6.7±0.08	15.9±0.45	5.7±0.09	14.7±0.63	6.6±0.06	27.9±0.64	5.6±0.06	13.7±0.43	7.0±0.24	11.5±0.84	+0.3±0.29	+1.3±0.26	+0.4±0.25	+1.4±0.25
Mindum x Marquis									6.1±0.18	26.4±2.13	-0.6±0.20	+0.4±0.20	-0.5±0.19	+0.5±0.19
Velvet Chaff x Barletta	6.7±0.15	30.3±0.52	6.6±0.11	22.1±1.05	6.2±0.08	29.9±0.47	6.2±0.05	21.0±0.53	6.7±0.10	23.2±0.74	0.0	+0.1±0.15	+0.5±0.13	+0.5±0.11
Barletta x Velvet Chaff									7.5±0.17	38.8±0.71	+0.8±0.23	+0.9±0.20	+1.3±0.19	+1.3±0.18

Table V (A) (continued)

Name	Wider Parent				Parental Average				Cross		Increase or Decrease of Cross from			
	Normal Seed		Incrossed Seed		Normal Seed		Incrossed Seed							
	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Avg. Width mms.	Weight Seed: Planted mgms.	Normal Seed: mms.	Incrossed Seed: mms.	Normal Seed: mms.	Incrossed Seed mms.
Velvet Chaff x Penny	6.0±0.07	29.6±0.79	5.9±0.06	19.9±0.62	5.9±0.05	22.3±0.45	5.8±0.06	17.9±0.49	7.0±0.10	23.1±0,76	+1.0±0.12	+1.1±0.12	+1.1±0.11	+1.2±0.12
Penny x Velvet Chaff									6.1±0.11	15.7±0.65	+0.1±0.13	+0.2±0.13	+0.2±0.12	+0.3±0.13
Velvet Chaff x Bobs	8.0±0.12	28.7±0.86	7.3±0.15	18.2±1.02	7.0±0.07	29.2±0.58	6.6±0.06	19.1±0.53	7.5±0.11	26.1±0.53	-0.5±0.16	+0.2±0.19	+0.5±0.13	+0.9±0.12
Bobs x Velvet Chaff									7.1±0.09	19.9±0.54	-0.9±0.15	-0.3±0.17	+0.1±0.11	+0.5±0.11
Velvet Chaff x Little Club	6.0±0.07	29.6±0.79	5.9±0.06	19.9±0.62	5.6±0.05	20.4±0.42	5.8±0.05	15.0±0.47	6.7±0.08	23.2±0.55	+0.7±0.11	+0.8±0.10	+1.1±0.09	+0.9±0.09
Little Club x Velvet Chaff									6.3±0.11	20.0±0.62	+0.3±0.13	+0.4±0.13	+0.7±0.12	+0.5±0.12
Velvet Chaff x Emmer	6.0±0.08	37.9±0.44	6.1±0.11	26.4±0.76	6.0±0.05	33.8±0.45	6.0±0.05	23.2±0.49	6.1±0.09	13.3±0.32	+0.1±0.12	0.0	+0.1±0.10	+0.1±0.10
Emmer x Velvet Chaff									--	--	--	--	--	--
Velvet Chaff x Mindum	6.5±0.09	39.9±1.21	5.9±0.06	19.9±0.62	6.2±0.06	34.8±0.72	5.8±0.05	17.3±0.46	6.1±0.19	15.9±0.56	-0.4±0.21	+0.2±0.20	-0.1±0.20	+0.3±0.20
Mindum x Velvet Chaff									6.0	27.5±1.42	-0.5	+0.1	-0.2	+0.2
Penny x Bobs	8.0±0.12	28.7±0.86	7.3±0.15	18.2±1.02	6.9±0.07	21.8±0.48	6.5±0.07	17.0±0.64	7.8±0.12	21.5±0.69	-0.2±0.17	+0.5±0.19	+0.9±0.14	+1.3±0.14
Bobs x Penny									7.9±0.20	22.9±1.17	-0.1±0.23	+0.6±0.25	+1.0±0.21	+1.4±0.21
Little Club x Emmer	6.0±0.08	37.9±0.44	6.1±0.11	26.4±0.76	5.6±0.07	24.5±0.27	5.9±0.07	18.3±0.46	5.5±0.17	7.7±0.34	-0.5±0.19	-0.6±0.20	-0.1±0.18	-0.4±0.18
Emmer x Little Club									6.5±0.72	25.0±1.18	+0.5±0.72	+0.4±0.73	+0.9±0.72	+0.6±0.72
Little Club x Mindum	6.5±0.09	39.9±1.21	5.8±0.10	10.1±0.48	5.8±0.07	25.5±0.62	5.7±0.07	12.4±0.42	--	--	--	--	--	--
Mindum x Little Club									5.3±0.16	13.1±0.57	-1.3±0.18	-0.5±0.19	-0.5±0.17	-0.4±0.17
Haynes Blue Stem x Marquis	6.7±0.08	15.9±0.45	6.2±0.10	17.2±0.77	6.2±0.05	21.0±0.35	5.8±0.07	14.9±0.48	6.5±0.14	23.5±0.67	-0.2±0.16	+0.3±0.17	+0.3±0.15	+0.7±0.16
Average											0.0	+0.5	+0.4	+0.8

SUMMARY OF EXPERIMENTAL RESULTS

1. The F_1 seeds of some interspecific crosses were shown to be markedly wrinkled while those of varietal crosses were slightly or not at all wrinkled.

2. With the exception of Penny, incrossed seed of all varieties was smaller than the normal seed.

3. Crosses between varieties showed an increase in seed size as an immediate effect of pollination. On the other hand, interspecific crosses gave either no increase or a decrease when compared with incrossed seed of the mother.

4. When weight of seed planted was considered, most varietal crosses and some interspecific crosses showed an increased vigor in F_1 seedling stage when compared with parental average. This vigor was manifested in increased height of seedlings at four weeks and nine weeks from planting, and in an increased leaf width. Some interspecific crosses, however, showed a decrease in vigor when compared with the average of the parents.

CONCLUSION

It has been shown conclusively that an increase in vigor occurs in crosses between some varieties and species of wheat. This increase was manifested in an increase in size of seed as an immediate effect of pollination and in an augmented vigor of F_1 seedlings. The results show that some of these wheat varieties contain growth factors not common to all. The increase in vigor of F_1 over the parental average was due to the combining of a larger number of growth factors in the F_1 generation than was contained by either parent. Furthermore, it is necessary to assume that a factor has more than half the effect in the heterozygous condition that it has in the homozygous condition.

A method, as outlined previously in this discussion, for utilizing this increase of vigor in the third or fourth generation from a cross may be expected to produce an increase in yield over the average of the parents. Where the parents are nearly equal in yield, an increase over either parent may be expected. Before attempting such a method, however, the breeder should combine in one variety the maximum number of growth factors possible in a homozygous condition. The results of studies in wheat breeding indicate that the limits of high yielding wheat varieties have not yet been reached. When these limits have been reached, the increased vigor obtained thru heterosis may be utilized in further increasing the yield.

BIBLIOGRAPHY

(1) Anderson, T. 1919. The Improvement of Agricultural Crops by Selection and Hybridization. The Scottish Jour. of Agr. 2 , No. 1: 10-20.

(2) Audronescu, D.I. 1915. The Physiology of the Pollen of Zea Mays with Special Regard to Vitality. Thesis, Ill., 1915:36. Exp. Sta. Rec. 33: 433.

(3) Arny, A.C. and Garber, R.J. 1918. Variation and Correlation in Wheat, with Special Reference to Weight of Seed Planted. Jour. Agr. Res. 14, No. 9: 359-392.

(4) Balls, W.L. 1912. The Cotton Plant in Egypt. Studies in Physiology and Genetics: 201.

(5) Bayla, A.M. 1918. Hybridization of Eggplants. Philippine Agr. 7, No. 3: 66-71.

(6) Beal, W.J. 1876. Changing Seeds. Michigan State Bd. Agr. Rpt. 15: 206-207.

(7) ——— 1878. The Improvement of Grains, Fruits, and Vegetables. Michigan State Bd. Agr. Rpt. 17: 445-457.

(8) ——— 1880. Crossing with Foreign Stock. Michigan State Bd. Agr. Rpt. 19: 287, 288.

(9) ——— 1880-1882. Crossing with Foreign Stock. Michigan State Bd. Agr., Bienn. Rpt. 1: 135, 136.

(10) Belling, J. 1910. Velvet Bean Crossed with Lyon Bean. Florida Exp. Sta. Rpt. 1908-1912: LXXIX.

(11) ——— 1912. Hybrid Corn. Florida Exp. Sta., Press. Bul. 196.

(12) Bruce, A.B. 1910. A Mendelian Theory of Heredity and the Augmentation of Vigor. Science N.S. 32: 627-628.

(13) Card, F.W. and Adams, G.E.
1901. Horticultural Division, Rhode Island Exp. Sta. Rpt. 1901: 227-244.

(14) Carrier, Lyman
1913. The Immediate Effect on Yield of Crossing Strains of Corn. Virginia Exp. Sta. Bul. 202.

(15) Castle, W.E., Carpenter, F.W., et al
1906. The Effects of Inbreeding, Cross-breeding and Selection upon the Fertility and Variability of Drosophila. Proc. Am. Acad. of Arts and Sciences. 41: 731-786.

(16) Collins, G.N.
1909. A New Type of Indian Corn from China. U.S. Dept. of Agr., Bur. Plant Ind. Bul. 161.

(17) ——————
1910a. Value of First-generation Hybrids in Corn. U.S. Dept. of Agr., Bur. Plant Ind. Bul. 191.

(18) ——————
1910b. Increased Yield of Corn from Hybrid Seed. U.S. Dept. of Agr. Year Book, 1910: 319-328.

(19) ——————
1914. A More Accurate Method of Comparing First Generation Hybrids with their Parents. Jour. Agr. Res. 3: 85-91.

(20) Collins, G.N. and Kempton, J.K.
1913. Effect of Cross-pollination on the Size of Seed in Maize. Misc. Papers, U.S. Dept. of Agr., Bur. Plant Ind. Circ. 124: 9-15.

(21) Crampe, H.
1883. Zucht-Versuche mit Zahmen Wanderratten. Landwirtsch. Jahrbücher 12: 389-458.

(22) Darwin, C.
1877. The Effects of Cross- and Self-fertilization in the Vegetable Kingdom. pp. VIII-482. London. Appleton & Co.

(23) East, E.M.
1908. Inbreeding in Corn. Connecticut Exp. Sta. Rpt. for 1907: 419-428.

(24) East, E.M. and Hayes, H.K.
1912. Heterozygosis in Evolution and in Plant Breeding. U.S. Dept. of Agr., Bur. Plant Ind. Bul. 243.

(25) East, E.M. and Park, J.B.
1917. Studies on Self-sterility I. The Behavior of Self-Sterile Plants. Genetics 2: 505-609.

(26) Emerson, R.A.
1910. Inheritance of Size and Shapes in Plants. A Preliminary Note. Amer. Nat. 44: 739-746.

(27) Emerson, R.A. and East, E.M.
1912. The Inheritance of Certain Abnormalities in Maize. Rpt. Amer. Breeders' Assoc. . 8: 385-399.

(28) Emerson, R.A. and East, E.M.
1913. The Inheritance of Quantitative Characters in Maize. Nebr. Exp. Sta. Res. Bul. 2: 120.

(29) Fabre-Dominique, P.
1898. Unions consanguines chez les Colombins. L'Intermediarie des Biologistes 1: 203.

(30) Fischer, E.
1913. Die Rehobother Bastards und das Bastardierungsproblem beim Menschen. Jena. Reviewed in Jour. Heredity, 1914, 5: 465-468.

(31) Fisher, M.L.
1911. Report of the Work in Corn Pollination. III. Proc. Ind. Acad. Sci. 1911: 283, 284.

(32) Focke, W.O.
1881. Die Pflanzen-Mischlinge. pp. iv+569. Berlin: Borntraeger.

(33) Freeman, G.F.
1917. Linked Quantitative Characters in Wheat Crosses. Amer. Nat. 51: 683-689.

(34) ________
1919. Heredity of Quantitative Characters in Wheat. Genetics, 4, No. 1: 1-93.

(35) Gardner, F.D.
1894. Cross-fertilization in Field Experiments of Corn. Illinois Exp. Sta. Bul. 37: 20, 21.

(36) Gärtner, C.F.
1849. Versuche und Beobachtungen über die Bastarderzeugung im Pflanzenreich, pp. xvi+791. Stuttgart: Hering & Comp.

(37) Gerschler, M.W.
1914. Über alternative Vererbung bei Kreuzung von Cyprinodontiden-Gattungen. Zeitschr. f. ind. Abst. u. Vererb. 12: 73-96.

(38) Hartley, C.P., Brown, E.B., Kyle, C.H., and Zook, L.L.
1912. Cross-breeding corn. U.S. Dept. of Agr., Bur. Plant Ind. Bul. 218: 72.

(39) Hayes, H.K.
1912. Correlation and Inheritance in Nicotiana Tabacum. Connecticut Sta. Bul. 171. 45 pp.

(40) Hayes, H.K.
1913. The Corn Plant and Seed Selection. Connecticut Exp. Sta. Rpt. 1913, pt. 6: 353-384.

(41) ______
1918. Normal Self-fertilization in Corn. Jour. Amer. Soc. of Agron. 10, No. 3: 123-126.

(42) Hayes, H.K. and East, E.M.
1911. Improvement in Corn. Connecticut Exp. Sta. Bul. 168: 3-21.

(43) Hayes, H.K., East, E.M., and Beinhart, E.G.
1913. Tobacco Breeding in Connecticut. Connecticut Exp. Sta. Bul. 176.

(44) Hayes, H.K. and Garber, R.J.
1919. Synthetic Production of High-Protein Corn in Relation to Breeding. Amer. Soc. of Agron. 11, No. 8: 309-317.

(45) Hayes, H.K. and Jones, D.F.
1917. The Effects of Cross- and Self-fertilization in Tomatoes. Connecticut Exp. Sta. Rpt. for 1916, Part V: 305-318; 318-322.

(46) Hayes, H.K. and Olson, P.J.
1919. First Generation Crosses Between Standard Minnesota Corn Varieties. Minnesota Exp. Sta. Bul. 193.

(47) Hedrick, U.P. and Booth, N.O.
1907. Mendelian Characters in Tomatoes. Proc. of Soc. Hort. Sci. 1907: 19-24.

(48) Houser, True
1912. Comparison of Yields of First-generation Tobacco Hybrids and Those of Parent Plants. Rpt. Amer. Breeders' Assoc. 7 : 155.

(49) Hutcheson, T.B. and Wolfe, T.K.
1917. The Effect of Hybridization on Maturity and Yield in Corn. Virginia Exp. Sta. Tech. Bul. 18: 161-70.

(50) Huth, A.H.
1875. The Marriage of Near Kin. pp. lxvii+359. London: Churchill.

(51) Hyde, R.H.
1914. Fertility and Sterility in *Drosophila amelophila*. i-iv, Jour. Exper. Zool., 17:141-171.

(52) Jennings, H.S.
1912. Age, Death and Conjugation in the Light of Work on Lower Organisms. Pop. Science Monthly 80: 563-577.

(53) ______
1913. The Effect of Conjugation in Paramecium. Jour. Exp. Zool. 14: 279-391.

(54) Jones, D.F.
1916. Inbreeding in Maize. Abs. in Science, N.S. 43, No. 1104: 290.

(55) ——— 1917. Dominance of Linked Factors as a Means of Accounting for Heterosis. Proc. Nat. Acad. of Sciences 3: 310-312 and also Genetics 2: 466-479.

(56) ——— 1918. The Effects of Inbreedings and Crossbreeding upon Development. Connecticut Exp. Sta. Bul. 207.

(57) Jones, D.F., Hayes, H.K., Slate, W.L. and Southwick, B.G.
1916. Increasing the Yield of Corn by Crossing. Connecticut Exp. Sta. Rpt. 1916. pt. 5: 323-347.

(58) Keeble, F. and Pellew, C.
1910. The Mode of Inheritance of Stature and of Time of Flowering in Peas (Pisum sativum). Jour. Genetics . I: 47-56.

(59) Kiesselbach, T.A.
1918. Studies Concerning the Elimination of Experimental Error in Comparative Crop Tests. Nebraska Exp. Sta. Res. Bul. 13.

(60) King, H.D.
1916. Experiments of Miss King on Inbreeding Rats for 22 Generations. Discussed in Jour. Heredity 7: 70-76.

(61) Knight, T.A.
1799. An Account of Some Experiments on the Fecundation of Vegetables. Philosophical Trans. of the Roy. Soc. of London 89: 195-204.

(62) Kock, L.
1917. Experiments on the Artificial Hybridization of Rice in Java. Int. Rev. Sci. and Prac. Agr. Year 8, No. 9: 1240.

(63) Koernicke, Max
1896. Untersuchung über die Entstehung und Entwicklung der Sexualorgane von Triticum. Verhandlungen. d. naturhist. Ver. d. preuss. Rheinlande, Westf. u.d. Regierungsbezirks Osnabrück, 53, 174.

(64) Kölreuter, J.G.
1766. Dritte Fortsetzung der Vorläufigen Nachricht von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen. Gleäitschen Handlung. Reprinted 1893 in Ostwald's Klassiker der Exakten Wissenschaften, No. 41. Leipzig: Engelmann.

(65) Kraemer, H.
1913. Uber die ungünstigen wirkungen naher Inzucht. Mitteilung der Deutsches Landwirtschafts Gesellschaft, 6 and 13 Sept., 1913. Translated in Jour. Heredity 5: 226-234.

(66) Lewis, C.I. and Vincent, C.C.
1909. Pollination of the Apple. Oregon Exp. Sta. Bul. 104: 27.

(67) Look, R.H.
1905. Studies in Plant Breeding in the Tropics; III. Annals Roy. Bot. Gar., Peradeniya, 2 and 3.

(68) Mell, P.H.
1896. Hybrids from American and Foreign Cotton. Alabama Exp. Sta. Bul. 83: 385-412.

(69) Mendel, G.
1865. Versuche über Pflanzen-Hybriden. Verh. Naturf. Ver. Brünn., 10. English translation in Castle's Genetics and Eugenics.

(70) Moenkhaus, W.J.
1911. The effects of Inbreeding and Selection on the Fertility, Vigor and Sex-ratio of *Drosophila amelophila*. Jour. Morph. 22: 123-154.

(71) Morrow, G.E. and Gardener, F.D.
1893. Field Experiments with Corn. Illinois Exp. Sta. Bul. 25: 173-203.

(72) ————————
1893. Cross-fertilization of Corn. Illinois Exp. Sta. Bul. 31: 359-360.

(73) Olson, P.J., Bull, C.P., and Hayes, H.K.
1918. Ear-type Selection and Yield in Corn. Minnesota Exp. Sta. Bul. 174: 3-60.

(74) Orton, W.A.
1911. The Development of Disease Resistant Varieties of Plants. Proc. 4th Int. Genet. Conf.: 247-265.

(75) Pammel, L.H.
1893. Results of Crossing Cucurbits. Iowa Exp. Sta. Bul. 23: 906-917.

(76) Price, H.L. and Drinkard, A.W.
1908. Inheritance in Tomato Hybrids. Virginia Exp. Sta. Bul. 177: 17-53.

(77) Ritzema Bos, (J.),
1894. Untersuchungen über die Folgen der Zucht in engster Blutsverwandtschaft. Die Biologisches Centralblatt 14: 75-81.

(78) Roberts, Elmer
1918. Fluctuations in a Recessive Mendelian Character and Selection. Jour. Exp. Zoology, . 27, No. 2: 157-192.

(79) Roberts, H.F.
1912. First Generation Hybrids of American and Chinese Corn. Rpt. Amer. Breeders' Assoc., 8 : 367-384.

(80) ———— 1919a. The Contribution of Carl Friedrich von Gärtner to the History of Plant Hybridization. Amer. Nat. 53 , No. 628: 431-445.

(81) ———— 1919b. The Founders of the Art of Breeding. Jour. of Heredity, 10, No. 3: 99-106.

(82) Selby, A.D. and Houser, T.
1911. Tobacco: Breeding Cigar Filler in Ohio. Ohio Exp. Sta. Bul. 239: 361-479.

(83) Shamel, A.D.
1904. The Improvement of Tobacco by Breeding and Selection. U.S. Dept. of Agr. Year Book 1904: 435-452.

(84) Shull, A.F.
1912a. The Influence of Inbreeding on Vigor in *Hydatina Senta*. Biol. Bul. 24: 1-13.

(85) ———— 1912b. Studies in the Life Cycle of *Hydatina Senta*. III. Jour. Exp. Zool. 12: 283-317.

(86) Shull, G.H.
1908a. The Composition of a Field of Maize. Rpt. Am. Breeders' Assoc. 4: 296-301.

(87) ———— 1908b. Breeding Strains of Plants. Carnegie Inst. Washington Year Book, 7: 92-96.

(88) ———— 1910. New Hybridization Method for Corn. Amer. Breeders Mag. I, No. 2: 98-107.

(89) ———— 1911. The Genotypes of Maize. Am. Nat. 45: 234-252.

(90) Webber, H.J.
1901. Loss of Vigor in Corn from Inbreeding. Abs. in Science, N.S., 13, No. 320: 257, 258.

(91) Wellington, R.
1912. Influence of Crossing in Increasing the Yield of the Tomato. New York Exp. Sta. Bul. 346: 57-76.

(92) Whitney, D.D.
1912. Reinvigoration produced by Cross-fertilization in *Hydatina Senta*. Jour. Exp. Zool. 12: 337-362.

(93) Wichura, M.
1865. Die Bastardbefruchtung im Pflanzenreich erläutert an den Bastarden der Weiden. pp. iv+95. Breslau: Morganstern.

(94) Williams, C.G. and Welton, F.A.
1915. Corn Experiments. Ohio Exp. Sta. Bul. 282: 84-91.

(95) Wolfe, T.K.
1915. Further Evidence of the Immediate Effect of Crossing Varieties of Corn on the Size of Seed Produced. Jour. Amer. Soc. Agron. 7, No. 6: 265.