THE CONNECTICUT

AGRICULTURAL EXPERIMENT STATION

NEW HAVEN, CONN.

BULLETIN 168, JUNE, 1911.

IMPROVEMENT IN CORN.

BY H. K. HAYES AND E. M. EAST.

CONTENTS.

The Bulletins of this Station are mailed free to citizens of Connecticut who apply for them, and to others as far as the limited edition permit.

Connecticut Agricultural Experiment Station.

OFFICERS AND STAFF

BOARD OF CONTROL.

His Excellency, SIMEON E. BALDWIN, *Ex Officio*, *President.*

PROF. H. W. CONN, *Vice President*	Middletown.
GEORGE A. HOPSON, *Secretary*	Wallingford.
E. H. JENKINS, *Director and Treasurer*	New Haven.
J. W. ALSOP	Avon.
W. H. LEE	Orange.
FRANK H. STADTMUELLER	Elmwood.
JAMES H. WEBB	Hamden.

STATION STAFF.

ADMINISTRATION	E. H. JENKINS, PH. D., *Director and Treasurer.* MISS V. E. COLE, *Librarian and Stenographer.* MISS L. M. BRAUTLECHT, *Bookkeeper and Stenographer.*
CHEMISTRY. ANALYTICAL LABORATORY,	JOHN PHILIPS STREET, M. S., *Chemist in Charge.* E. MONROE BAILEY, PH. D., C. B. MORRISON, B. S., R. B. ROE, A. B., C. E. SHEPARD, *Assistants.* HUGO LANGE, *Laboratory Helper.* V. L. CHURCHILL, *Sampling Agent.*
PROTEID RESEARCH,	T. B. OSBORNE, PH. D., *Chemist in Charge.* MISS E. L. FERRY, A. B., *Assistant.* MISS LUVA FRANCIS, *Stenographer.*
BOTANY.	G. P. CLINTON, S. D., *Botanist.* E. M. STODDARD, B. AGR., *Assistant.* MISS M. H. JAGGER, *Seed Analyst.* MISS E. B. WHITTLESEY, *Herbarium Assistant.*
ENTOMOLOGY.	W. E. BRITTON, PH. D., *Entomologist; also State Entomologist.* B. H. WALDEN, B. AGR., D. J. CAFFREY, B. AGR., A. B. CHAMPLAIN, *Assistants.* MISS E. B. WHITTLESEY, *Stenographer.*
FORESTRY.	SAMUEL N. SPRING, M. F., *Forester; also State Forester and State Forest Fire Warden.* W. O. FILLEY, *Assistant.* MISS E. L. AVERY, *Stenographer.*
PLANT BREEDING.	H. K. HAYES, B. S., *Plant Breeder.* C. D. HUBBELL, *Assistant.*
BUILDINGS AND GROUNDS.	WILLIAM VEITCH, *In Charge.*

IMPROVEMENT IN CORN

BY

By H. K. Hayes and E. M. East.

Introduction.

Logically directed efforts to improve the general field crops of the United States may be said to have begun with the introduction of Vilmorin's Isolation Principle. This principle uses the average character of a plant's progeny as an index of that particular plant's productiveness. When applied to corn breeding the method is commonly known as the "ear to row method," and consists in growing a large number of selected ears in such a way that the yield of each ear may be compared with that of every other ear. Thus if twenty ears are to be compared, a plot of uniform soil is selected in which twenty rows of equal length are marked out. In each of these rows the seeds from a single ear are planted. The crop from each row, harvested and weighed separately, is the basis upon which selections are made, and seed is saved *only* from those rows which have proved the better yielders by this actual field test. Many low yielding ears produce *some* progeny which are as handsome in appearance as any which grow in the high yielding rows but these are invariably discarded because they come from *strains* which have proved their inability to produce an average of high-yielding progeny.

Continued selection by this method yielded very promising results with corn during the early years of its application, but the later generations failed to fulfil this promise. Definite reasons for this comparative failure in the corn breeding work of the United States can now be given, for within the last few years investigators have arrived at some understanding of the underlying principles concerned. These principles are yet but imperfectly understood, but they are sufficiently clear to show that practical corn breeding must undergo a radical change in method if it is to take advantage of the full possibilities which lie open to it. The purpose of this bulletin is to outline these possibilities in the light of the most recent investigations of the subject.

The Two Results Attending the Formation of a Seed.

Our field crops as a rule form seed only after the fertilization of the female reproductive cells — the egg cells — by male reproductive cells contained in the pollen grains. In corn, for example, a single pollen grain alighting upon a silk germinates and grows, forming a tube which reaches the ovary. Through this pollen tube the male cell is carried until it reaches the ovule. There it fuses with the egg cell and fertilization is accomplished. The final result of such fertilization is a mature seed which under proper conditions grows into a new plant.

This fertilization effects two very different results: first, a union of the hereditary characters possessed by the parents; second, a stimulation to the cell division necessary for normal development.

Since the rediscovery of Mendel's Law in 1900 our knowledge of the first process, — the transmission of parental characters — has been greatly increased. It has been clearly proved that a plant or animal does not transmit its characteristics as if the entire organism were the unit, but rather that its various characters are inherited separately. Each heritable character behaves as if it were represented by some special structure found in the reproductive cells. Such characters are known as "unit" characters. If a plant breeds true for one of these characters, its "unit" must have been received from both of the parents. If two plants are crossed one of which lacks the character, however, then the plant is hybrid for that character; and, when its germ cells are formed half of them possess the character and half are without it. Among the progeny of the plant, therefore, are found individuals of each kind.

A cross between two corn varieties will illustrate this matter. If a sugar corn is crossed with a starchy corn, such as a flint or dent, there is produced a hybrid seed of a starchy nature which cannot be distinguished from seeds of the starchy parent. It matters not which variety is the female parent. On growing the hybrid seeds the following year and self-fertilizing the plants,[1] ears are produced which have on the average three starchy seeds to one sugar seed. These results may be understood by the use of the following scheme.

The starchy corn produced in all of its reproductive cells some substance which caused starch to be formed. This substance may be represented by the capital letter S. The sugar corn lacked this substance and therefore wrinkled sugar corn resulted. The lack of the starchy factor may be represented by the small letter s. Therefore the difference between starchy and sugar corn is the presence or absence of the starchy factor. On crossing the starchy and sugar varieties, leaving out of consideration all other characters, — one can easily see that in each case there will be a union of two reproductive cells, one of which contains S and the other s. In some cases it is necessary to receive the character from each parent for it to develop properly. When received from only one parent it develops only partially and the hybrid has what appears to be an intermediate condition. In the case under consideration one "dose" is sufficient and the hybrid seed is completely starchy. In instances of this kind the character is said to be completely *dominant.*

The reproductive cells produced by these crossed plants are of two kinds, one half containing S (the unit causing starchiness) and the other half containing s (the unit causing sugariness) and may be represented as follows:

Male reproductive cells, S+s.
Female reproductive cells, S+s.

A chance union of these cells will give the following results and ratios, 1 SS : 2 Ss : 1 ss. As the SS and Ss forms look alike we will obtain starchy and sugar seeds in the ratio of three to one. Those seeds without starchiness, the ss forms, will breed true to the sugar type; the Ss kernels being hybrid will again produce both starchy and sugar corn in the ratio of three to one; and the SS kernels will produce corn all of the starchy type.

Thus we see that when a character has been received from both the male and female reproductive cells — that is, in double dose — it will breed true. Such a character is said to be in a

[1] By self-fertilization is meant the fertilization of the egg cells of a plant by its own pollen grains.

"homozygous" condition. When a character, however, is found in only half of the reproductive cells it is said to be in a "heterozygous" condition and progeny of different types are produced. This principle shows the reason why among sister seeds or sister plants alike in appearance some produce plants of one nature while others produce progeny with different characteristics. Furthermore, this alternative inheritance, which is very widespread if not universal, is of the utmost importance in obtaining combinations of desirable characters; since one may cross two varieties each having desirable qualities and may rest assured that they will reappear in the grandchildren[2] in all possible combinations even though they may appear to have been blended in the hybrids.

The stimulus to development due to fertilization should not be confused with the union of parental characters. It is believed to be due to the bringing in to the egg cell of some necessary chemical element by the male reproductive cell. Probably in every case where fertilization can take place at all there is a certain amount of this stimulus to development, but the thing of special interest to corn growers is that this stimulus to development is far greater in a hybrid than it is in a pure bred variety.

The fact that a cross between two varieties is more vigorous in its first generation than a self fertilized type has been alluded to by many scientists. Darwin in his "Cross" and Self-fertilization in the Vegetable Kingdom" gives many examples of such increased vigor. Mendel, the discoverer of the only known law of heredity mentions the fact that a first generation hybrid between two of his sweet pea types grew more vigorously and to a greater height than either parent. As this fact had been known for so many years it seems strange that it has not been more widely used in practical work, yet perhaps this was because the precise action of selection was then unknown.

What Selection Does.

Selection by man may be said to acomplish simply the isolation from the commercial variety of those particular types

---

[2] In certain special cases of sexlimited inheritance in animals and probably similar phenomena in plants, there are apparent, but not real exceptions to this rule.

which prove of the greatest promise from the business point of view. With every precaution to prevent, therefore, selection tends toward inbreeding. As we have seen, it is only when a character unit is found pure in both the male and female reproductive cells that it produces progeny all of which exhibit this same character. As selection aims to produce a variety in which all the characters are uniform, it is easy to see how the application of the selection principle tends toward inbreeding. Selection can not make new types but simply isolates the variations produced by nature. Just how this is accomplished is not apparent until one sees clearly that variations are not all alike.

There are two main classes of variations:

1. Fluctuating variations, those which are due solely to surrounding influences, such as better position for development or increased fertility. Such variations are not inherited.

2. Inherited variations, those due to some structure of the reproductive cells, which may depend on environmental conditions for their full development, but not for their transmission. Only these variations are of value as bases for selection.

The experiments of Johannsen, a Danish plant physiologist, which have later been corroborated by many other investigators with very different experimental material, have given the correct interpretation of this matter. Johannsen worked with beans. In one of his experiments the weight of individual beans was the subject under consideration. When the larger beans from a *commercial variety* were selected as seed Johannsen found that the average size of the beans could be increased. If, however, different types (that is, inherited variations) were first isolated by inbreeding; then selection of larger or smaller beans (fluctuating variations) had no effect on the progeny. In both cases the average of the progeny continued true to the type or average of the isolated pure race. Similarly, almost all commercial varieties are mixtures of types, and the sole result of selection is to isolate pure types from such mixtures.

In a naturally cross-fertilized species like corn it is more difficult to isolate pure types by the application of Vilmorin's Selection Principle than in species where self-fertilization is the rule. Certain results of the Illinois Agricultural Experiment Station, however, indicate that such a result is possible. For example, after selecting ears with high oil content for a period of six years, the average oil content was increased from 4.70% to 6.50%. At this time selections were made from this high oil strain for an entirely different purpose. After this new strain had been grown in an isolated plot for a period of six years, during which time no selections for oil content had been made, there was found to be no appreciable loss in oil content. The difference in the difficulties encountered by the selectionist in cross-fertilized and in self-fertilized species will perhaps be made clearer by illustrations, and it happens that two of Connecticut's most important agricultural crops, corn and tobacco, are admirably suited for the purpose.

Comparison of the Effect of Selection upon Corn and Tobacco.

Tobacco is an example of what may be called a close-fertilized species, as the tobacco flower is naturally arranged for self-fertilization. Because of this fact it is a comparatively easy matter to isolate the best types of tobacco from the commercial field and to breed only from them. The reason for the marked similarity of different fields of tobacco without doubt is due to a conscious or unconscious selection of the types which were best adapted to the conditions encountered, and because the nature of the species has allowed the easy elimination of the poorer types.

Indian corn, on the other hand, is naturally arranged for cross-fertilization; the male and female organs, that is, tassels and silks, are borne on widely separated parts of the plant. This fact combined with the enormous production of pollen makes cross-fertilization through the agency of wind an exceedingly common thing. And since an immediate cross between two types is more vigorous and productive than either type in a pure state, when the best ears are selected from a field one is much more likely to select those which are in a hybrid condition and which will not breed true in later generations. This is one reason why so many different varieties of corn are in existence today. It is one reason why such diverse types are found in a single field. It is the reason why constant selection gives more uniform and better types from the standpoint of hereditary characters, but types which have lost something of the vigor that comes from hybridization.

Tobacco and corn may be compared to advantage from another standpoint. Tobacco is of its greatest value when it shows a marked uniformity and quality, both of which are of more importance than total yield per acre. It is fully recognized that a first generation hybrid between two varieties of tobacco is as uniform in field habit as either parent and is more vigorous than either parent; yet cross bred tobacco is coarser and therefore very inferior in quality and in some cases absolutely worthless. We do not mean to condemn improvement in tobacco by hybridization; but careful heredity experiments have shown that the reason for the apparent lack in quality in some of the new varieties recently produced by hybridization, is due to the fact that as yet they have not been selected long enough to be in a pure condition in all characters and therefore cannot produce *uniform* quality.

In the case of corn, however, the important fact from a practical standpoint is total yield in bushels of ears and tons of stover per acre. Many of the conditions of uniformity demanded by the score card fanciers are of no importance at all to the commercial grower. Reasoning from this standpoint, three writers published articles in 1909 suggesting that some method for utilizing the added vigor due to crossing should receive commercial trial. Shull and East from their studies on inheritance in maize concluded that some method whereby only first generation hybrids be grown for the commercial crop would prove of advantage and materially increase the present yield of corn per acre. Toward the same end, Collins collected evidence showing that in nearly every case where such a method had been tried increased yields were obtained by crossing. All methods now in use for the improvement of corn are by the application of the selection principle and tend sooner or later toward inbreeding. As corn naturally produces the best results when crossed we hold that all methods now used are wrong unless combined with some method for continuous crossing.

The Effects of Inbreeding Upon Corn.

It may be interesting to observe the actual effect of the isolation of pure types upon the yield of corn. The data given in Table 1 show the effects of inbreeding and confirm the fact that a commercial variety is composed of many different types.

TABLE 1.

EFFECT OF INBREEDING ON YIELD.

Variety	Year Grown	No. Years Inbred	Yield in Bushels
Watson's Flint, No. 5, Gen. 1	1908	..	75.7
No. 5, Gen. 2	1909	1	47.5
No. 5, Gen. 3	1910	2	36.1
Starchy, No. 10, Gen. 1	1908	..	70.5
No. 10, Gen. 2, Ear 1	1909	1	56.0
No. 10, Gen. 2, Ear 2	1909	1	43.0
No. 10, Gen. 3, Daughter of Ear 1	1910	2	67.0
No. 10, Gen. 3, Daughter of Ear 2	1910	2	48.7
Stowell's Ev., No. 19, Gen. 1	1908	..	93.2
No. 19, Gen. 2, Ear 1	1910	1	53.6
No. 19, Gen. 2, Ear 2	1910	1	58.7
Leaming (the parent), Gen. 1	....	Unselected	88.0
No. 7, Gen. 2	1906	1	60.9
No. 7, Gen. 3	1907	2	59.9
No. 7, Gen. 4	1908	3	46.0
No. 7, Gen. 4	1909	3	59.7
No. 7, Gen. 5, Ear 1	1910	4	63.2
No. 7, Gen. 5, Ear 2	1910	4	68.1
Leaming (the parent), Gen. 1	....	Unselected	88.0
No. 6, Gen. 2	1906	1	59.1
No. 6, Gen. 3	1908	2	95.2
No. 6, Gen. 4	1909	3	57.9
No. 6, Gen. 5	1910	4	80.0
Leaming (the parent), Gen. 1	....	Unselected	88.0
No. 9, Gen. 2	1906	1	42.3
No. 9, Gen. 3	1908	2	51.7
No. 9, Gen. 4	1909	3	35.4
No. 9, Gen. 5	1910	4	47.7
Leaming (the parent), Gen. 1	....	Unselected	88.0
No. 12, Gen. 2	1906	1	38.1
No. 12, Gen. 3	1907	2	32.8
No. 12, Gen. 4	1908	3	46.2
No. 12, Gen. 5, Ear 1	1909	4	23.3
No. 12, Gen. 5, Ear 2	1909	4	28.7
No. 12, Gen. 6, Daughter of Ear 1	1910	5	16.6
No. 12, Gen. 6, Daughter of Ear 2	1910	5	9.5

It will be noted that a column is given showing the year in which each selection was grown. As all strains were grown on the same plot each season but on a different field the following year, some idea can be obtained as to the effects of different environmental conditions. In 1908 the corn plot was on very fertile soil consequently the yields were very good. Four stalks to the hill were grown this season but as only three were grown in later years, the 1908 results were reduced one-fourth, or to a three stalk per hill basis. During 1909 the season was not favorable, consequently the yields for nearly all of the varieties were smaller than in 1910. For example, Starchy No. 10, Leaming No. 6 and Leaming No. 7, strains which presumably were almost pure types, each gave considerable increases in 1910 over their yields for 1909.

A study of this table brings to view several other interesting facts. In nearly all cases the first generation of inbreeding has the greatest detrimental effect. It is also clearly shown that after a type has been inbred until it is in a pure state continued inbreeding does not change its yielding ability. Inbreeding, therefore, has simply isolated the different types from the commercial variety. This last fact is most noticeable from a study of the Leaming strains, all four of which came originally from the same commercial variety. After isolation by inbreeding, during which time all received the same treatment, four types have been obtained which give different yields. The shape of ears, height of plants and general field characters are also different, although within a type they are very uniform. One of these "pure types," No. 6, gave nearly as large a yield as was received from the normal commercial variety from which it was isolated, while on the same field strain No. 12 produced only small immature ears. Thus one sees that some pure strains are so inferior that they can scarcely live when isolated, but have been kept in existence by the increased vigor obtained when in hybrid combinations with other types.

Comparison of Pure Types, Crosses Between Pure Types and Normally Cross-fertilized Varieties.

Table 2 in which crosses are compared with their parents is of still greater practical interest. The number of years which a type has been inbred is given; and, for convenience the letters F_1 and F_2 are used and denote respectively the first and second hybrid generation. Crosses No. (15 x 8) and No. (11 x 8) were between varieties which had not been inbred. The yield of the crosses

TABLE 2.
CROSSED, NORMAL AND SELFED VARIETIES COMPARED.

Variety	Year Grown	No. Yrs. Inbred	Yield in Bushels	Comparison in yield between the original normal fertilized varieties and the cross
Long. Flint No. 15	1908	..	72.0	72.0
Ill, High Protein No. 8	1908	..	121.0	121.0
No. (15 x 8) F_1	1908	..	124.0	124.0
Sturgis' Flint No. 11	1908	..	48.0	48.0
No. 8	1908	..	121.0	121.0
No. (11 x 8) F_1	1908	..	130.0	130.0
No. 8	1908	..	121.0	121.0
Leaming No. 7	1908	3	62.0	88.0
No. (8 x 7) F_1	1908	..	142.0	142.0
No. 7	1910	4	65.5	88.0
Stowell's Ev. No. 19	1910	1	53.6	93.2
No. (7 x 19) F_1	1910	..	142.7	142.7
Watson's Flint No. 5	1909	1	47.5	75.7
No. 11	1909	1	44.2	48.0
No. (5 x 11) F_1	1909	..	76.3	76.3
No. 5	1909	1	47.5	75.7
Leaming No. 6	1909	3	57.9	88.0
No. (5 x 6) F_1	1909	..	88.9	92.2
No. (5 x 6) F_1	1910	..	105.5	
No. (5 x 6)–1 F_2	1910	1	54.1	51.5
No. (5 x 6)–8 F_2	1910	1	48.9	
Starchy No. 10	1910	2	48.7	70.5
Leaming No. 6	1910	4	80.4	88.0
No. (10 x 6) F_1	1910	..	139.0	139.0
Leaming No. 12	1909	3	35.4	88.0
Leaming No. 9	1909	4	23.3	88.0
No. (12 x 9) F_1	1909	..	110.2	113.8
No. (12 x 9) F_1	1910	..	117.5	
No. (12 x 9)–1 F_2	1910	1	102.2	
No. (12 x 9)–4 F_2	1910	1	91.5	98.4
No. (12 x 9)–12 F_2	1910	1	91.5	

is compared with that of the parents, all having been grown on the same field. Increases of 3 bushels per acre in the first case and of 9 bushels per acre in the second were received in favor of the cross over the better yielding parent. The cross between No. 8 and No. 7 shows an increase for the cross of 21 bushels per acre over the naturally open field pollinated parent which gave the highest yield. The remainder of the crosses are between inbred types which are relatively pure. Large increases are received from such crosses. In order to have a standard of comparison other than that between the inbred varieties and their hybrids and a standard of greater commercial importance a column has been added to the table, comparing the cross between two inbred types with the yield of the original variety from which the types were isolated. Increases of from 6 bushels to 59 bushels were obtained in favor of the cross over the better yielding parent, the average for the five crosses so considered being 31 bushels.

Another important fact which is shown by this table is that the F_2 generation gives a much smaller yield than the F_1 generation. The F_1 generation of the cross between No. 5, Watson's White Flint and No. 6, a Leaming strain, produced at the rate of 105.5 bushels per acre, while the F_2 generation grown on the same field produced only 51.5 bushels per acre. The F_1 generation of the cross No. (12 x 9), between two Leaming strains, produced at the rate of 117.5 bushels per acre, although the F_2 generation yielded at the rate of only 98.4 bushels.

These data show that the greatest stimulus to development from crossing two distinct types, is obtained only in the first hybrid generation. Therefore practical utilization of the *total* increase in vigor due to crossing is possible only when the first hybrid generation is the commercial crop. This necessitates making the cross each year. The explanation of the decrease in vigor in the second hybrid generation is exactly the same as the explanation of the apparent deterioration when corn is inbred. Both are caused by recombinations of characters among which *some* "pure type" individuals are obtained. In inbreeding the apparent deterioration is more marked because the percentage of such individuals is likely to be much greater.

Comparisons Between Varieties and First Generation Hybrids.

It is realized that if the theory that germ-cell purity for certain characters causes purity of type is correct, and it has stood the test, then theoretically the best yielding commercial type of corn could be produced by a cross between two selected inbred types which when mated proved the most vigorous, a plan proposed by Shull. The cost of producing seed by first isolating pure types and then crossing them would be very great, however, and the method could be used only by persons willing to spend the necessary time and study, first to isolate the pure types and then *to find out the best yielding combination.* In order to lessen the risk of losing the best pure types a very large number would have to inbred for several years. After this work was finished it would still be necessary to make all possible hybrid combinations between them. A few seedsmen with large resources might be able to accomplish this successfully and profitably, but it does not appear to be practicable for the general corn grower. For him we suggest another plan.

There are in Connecticut many varieties of corn which have been grown in the same locality for long terms of years and which have been continually selected toward some particular type. These varieties are comparatively pure, and it is practically certain that by testing out crosses between them various combinations can be found which will greatly increase the average yield per acre. The operation of crossing is a very simple

TABLE 3.

Results of Morrow and Gardner's Experiments at The Illinois Experiment Station in 1892.

Variety	No. Ears Received	Bushels of Air Dry Corn
Burr's White	9960	64.2
Cranberry	9200	61.6
Average	9580	62.9
Cross	7080	67.1
Burr's White	9960	64.2
Helm's Improved	10880	79.2
Average	10420	71.7
Cross	11000	73.1
Leaming	10440	73.6
Golden Beauty	8280	65.1
Average	9360	69.3
Cross	11520	86.2
Chanpiom White Pearl	11080	60.6
Leaming	10440	73.6
Average	10760	76.1
Cross	8760	76.2
Burr's White	9960	64.2
Edmonds	9040	58.4
Average	9500	61.3
Cross	10400	78.5

matter and can easily be carried out by each farmer for himself. Furthermore, nearly all of these crosses will give a yield sufficiently greater than either of the two parents to pay the farmer for his trouble.

The only previous work of just this kind known to us is that of Morrow and Gardner at the Illinois Experiment Station which was first reported in 1892. Bulletin 25 entitled "Field Experiments with Corn" gives the results of five tests of the comparative yields of first generation hybrids and their parents. Because of our belief in the value of crossing, a summary of the results of Morrow and Gardner's tests is given. Table 3 gives the number of ears obtained and the yield in bushels of air-dry corn per acre for five different crosses. It shows that the yield of the hybrids in the five tests averaged 7.16 bushels more than the average of the parent varieties and 4.66 bushels more than the high yielding parent.

In 1893 four additional tests were reported. Three of the four gave increases over the average of the parents, their average increase of yield being 9.5 bushels per acre with an increase of 2.7 bushels per acre over the high yielding parent. In the fourth test the cross gave a decreased yield but including this we find that the average increase for the crosses over the average of the parents was 2.5 bushels. As has been pointed out by Collins, little confidence can be placed in the results of these four tests. The lack of uniform conditions during this test is indicated by the great difference between the yield of duplicate plots of the different varieties used in this experiment, which ranged as high as 15 bushels per acre.

In 1909 several Connecticut farmers became interested in the production of first generation hybrid corn in co-operation with this Station. A plan was sent to the different co-operators giving directions for the production of crossed seed with the idea of comparing the cross with its parents in 1910. Only ten men from the thirty who had intended to produce hybrid seed actually carried through the operation according to directions. In 1910 seven of these men gave a few ears each of their crossed seed and of one parent variety to the Station, which compared them on a level piece of land of about one and one-third acres. It is to be regretted that in nearly every case only one parent could be compared with the hybrid as it is realized

TABLE 4.
Comparative Yield of First Generation Hybrids and Their Parents. Station Test.

Variety	Average Height	Date of Glazing	Per cent Stand	Bu. per Acre
Longfellow Flint	66″	Sept. 7	90	60.5
Ives Flint	78″	" 14	96	72.3
Average	72″	" 10	93	66.4
Long. x Ives	78″	" 7	91	70.2
Ives x Long.	78″	" 7	92	67.1
Conn. Top Over Flint	78″	" 5	95	58.3
C.T.O. x Canada Imp. Flint	84″	" 5	94	65.3
Woodbridge's Flint	84″	" 10	99	76.3
W. F. x Watson's White Flint	84″	" 10	95	73.3
R. I. White Flint	72″	" 5	Good	74.7
R. I. W. F. x Mammoth White Flint	78″	" 5	Good	76.5
Murdock's Dent	96″	" 14	80	69.7
Funks 90d x Murdocks	108″	" 30	73	96.8
Stadt. Leaming	102″	" 14	93	84.9
S. L. x Reid's Yellow Dent	114″	" 30	88	128.9
Brewer's Dent	96″	" 18	94	77.6
B. D. x Early Dent	96″	" 10	93	94.7

that this does not give an accurate determination of the value of the cross. However, some interesting facts are shown by these tests which confirm our belief in the efficacy of such methods. The yields were determined from the stand of corn and not from the size of the plots. This fact is mentioned and the comparative stand is given in Table 4, for if this test is used as a comparison of the different varieties, it is realized that the corn which germinated poorest has an advantage of increased room over the better germinating varieties. The seed was not received early enough to test its germinating qualities and four kernels were planted per hill, the plants being thinned to three per hill at the first cultivation. It will be noted that in nearly every case the cross was as tall as the parent used. An exact study of crosses between varieties differing widely in height proves a first generation hybrid is not uniformly as tall as the taller parent, but the results show that a first generation hybrid is always taller than the average height of the parents. The results also show an intermediate time of maturity in the hybrid as compared with the parent varieties; and while no exact figures can be given, it is believed that the hybrid matures earlier than the average date of maturity of the parents. The reason for this is that increased vigor due to crossing is often shown by rate of growth as well as by actual size attained.

The yield of corn was taken at husking time and with the exception of the cross between Stadtmueller's Leaming and Reid's Yellow dent, which was in poor condition, is believed to be a fairly accurate comparison. This cross was also tested by Mr. Stadtmueller who received 4½ bushels more per acre for the cross than for the parent grown.

The Brewer's Dent x Early Dent cross is worthy of special mention. This cross was made by Pinney of Suffield, who obtained very few good ears as the Early Dent tasseled much earlier than the Brewer's dent. A comparison of the yields

TABLE 5.
Comparative Yields of Parent and First Generation Hybrid.
Farmers' Tests.

Name of Farmer	Variety	Acreage in sq. ft.	Bu. per Acre
G. A. Cook	Rhode Island White Flint	6000	49.6
	R. I. W. F. x Mammoth White Flint	6000	62.1
E. M. Ives	Ives Flint	9376	66.8
	Long. Flint x I. F.	13280	68.1
	Ives Flint x Long. Flint	66400	60.1
G. W. Woodbridge	Woodbridge's Yellow Flint	8844.5	69.5
	Watson's White Flint x W. Y. F.	8844.5	86.7
F. H. Stadtmueller	Stadtmueller's Leaming	....	66.5
	S. L. x Reid's Yellow Dent	....	71.0
*O. S. Olmstead	Canada Improved Flint	6321	144.6
	C. I. F. x Conn. Top Over Flint	9114	117.0

* These varieties were grown on different fields, and the yield is given in measured bushels. Compare with the Station test which shows a distinct advantage for this cross. Mr. Olmsted was pleased with this cross and intends to make it again.

received gives an increase of 17.1 bushels for the cross over the Brewer dent, as well as an earlier date of maturity. A cross similar to the latter one gives promise of being of value for silage purposes, as large size can be thus combined with an earlier date of maturity. Such a cross could be made by planting the early maturing parent about a week later than the later maturing variety.

Considering the seven crosses together we find that five proved beneficial, showing a crop ranging from 7 bushels to 44 bushels more for the hybrid than for the parent grown. The two crosses which proved no better than the parent variety were also tested by the farmers who made them. Mr. Woodbridge's test of the Watson's white flint x Woodbridge's flint gave a much larger yield for the crossed type than for the Woodbridge flint parent. As may be seen in Table 5, the hybrid outyielded the one parent by 17.2 bushels per acre. The Ives x Longfellow cross and its reciprocal gave about the same yield as the Ives parent and proved of no benefit.

We may conclude, therefore that as a rule, the production of corn by utilization of the increased vigor due to a first generation hybrid, is of commercial importance and is worthy of further trial. It is very much to be desired that the matter be thoroughly tested, and the Station will be glad to co-operate with other farmers in the work.

Some crosses may not prove more vigorous than either parent, but we will wish to know which combinations are of this kind. The reason is that some varieties are *now* in a state of hybridity. Such varieties have already all the growth stimulus possible, *but do not produce high because they have poor types in combination.* In other words these varieties *with the stimulus due to crossing* are only equal to some other varieties without this stimulus.

Method of Producing Cross Bred Seed.

The first important step in the production of crossed seed is the selection of the parent varieties. Two varieties should be selected that have been grown for a number of years in the same locality and are of the type desired. Such varieties should be comparatively pure and will give better results than those that have never received attention as regards selection.

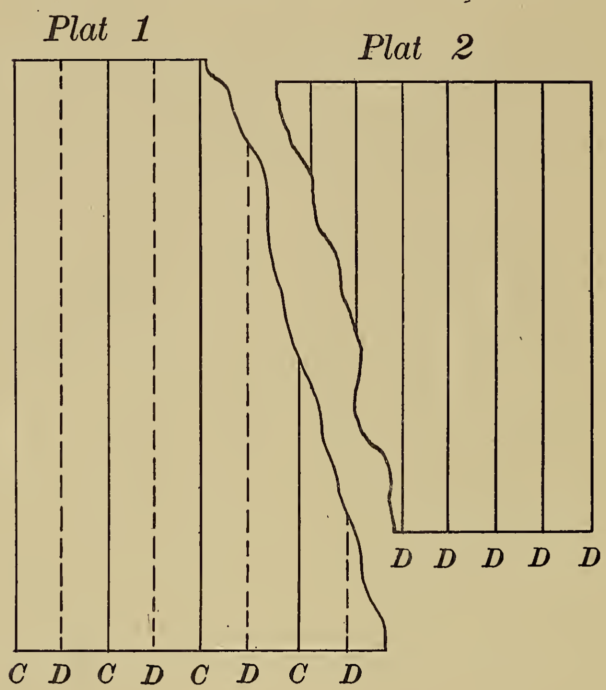
Another point is to select varieties that mature at about the same season, as otherwise the pollen of one will be shed before the silks of the other appear. The varieties which will give best results when crossed, however, can only be determined by actual test. As nearly every test so far has shown as good, and generally better, results for the hybrid than for the better parent, the selection of varieties by test which will prove most beneficial will not cause any actual loss, even if the best combination is not obtained at the first test.

If it is desired to have the corn of a uniform color, varieties with a white and yellow endosperm should not be crossed together as the grains will be of different colors in the year following the cross. Unlike many plants the endosperm color varieties of corn show an immediate effect due to crossing. For example if a white corn is crossed with yellow, no matter which is used as the female parent the immediate result is yellow. If this seed is used the next year, the year in which beneficial results may be expected from crossing, white and yellow seeds will be found on the same ears. It is not believed that the color necessarily changes the composition of the corn, but for the sake of uniformity white and yellow crosses are not so desirable as those between like colors.

A flint-dent cross will be comparatively uniform in the first generation because the property of flintiness or dentness is a plant character due to the amount of horny starch in the endosperm, and is not immediately affected by crossing. To illustrate, no matter which is used as the female parent, no effect will be noticed the year in which the cross is made. The first hybrid generation will not be appreciably more variable than the parent varieties and will be more like the dent parent.

There are in Connecticut many good varieties of both dent and flint types and good results will without doubt be obtained by crosses between different flint corn types for the flint corn grower and crosses between dent varieties for the dent corn grower.

The actual production of crossed seed is an easy matter and with a little attention can be done on any farm. The seed plat should be in an isolated place at some little distance from the commercial corn field. The following diagram illustrates the method to be used.



Plant the varieties in alternate rows in Plat 1, all of one variety as C being planted in the odd rows and the other variety, D, in the even rows. Detassel all of one variety as D. This detasseled variety should be also grown in another isolated plat, Plat 2. Suppose it is determined to use D as the female variety, detassel all of D. The following results will then be obtained at harvest.

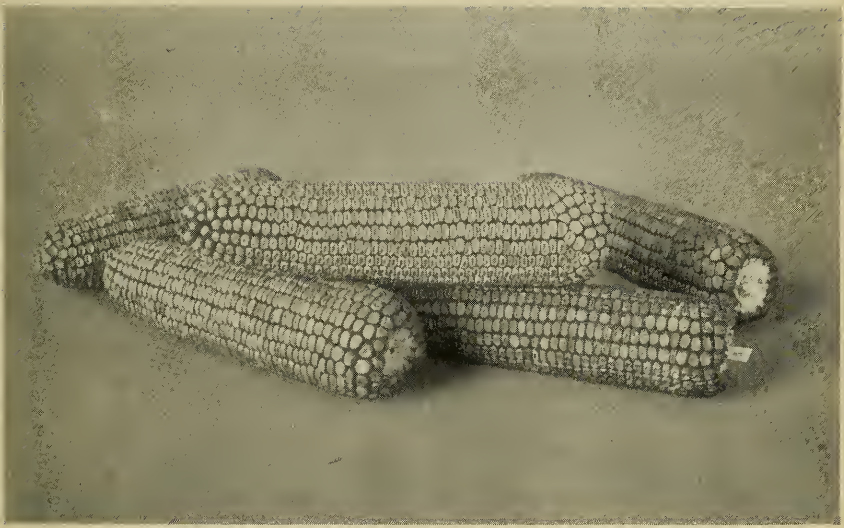
Plat 1. D will be cross pollinated.

Plat 1. C will be self-pollinated or close-pollinated.

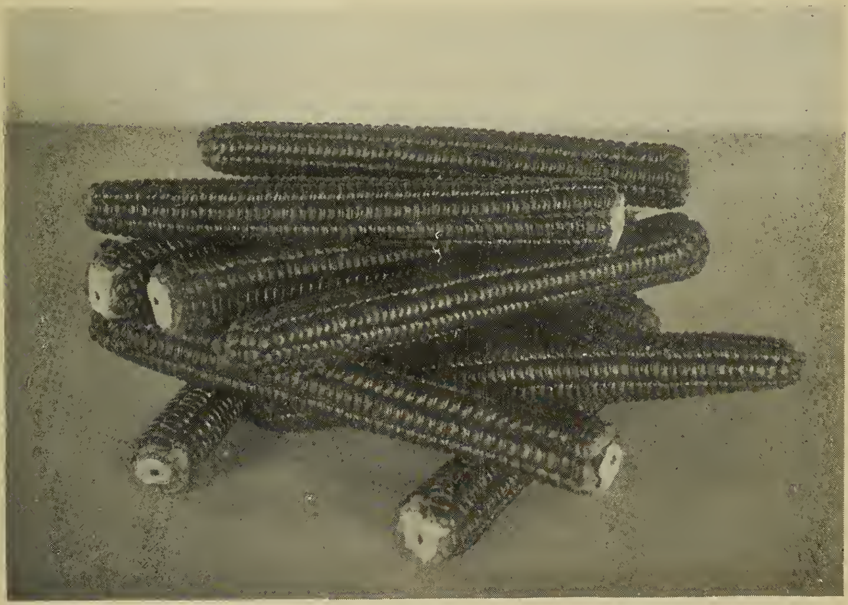
Plat 2. D will be self-pollinated or close-pollinated.

The detasseling should be done before any of the pollen is shed and may be very easily accomplished by taking firmly hold of the young tassel and giving it a steady upward pull. In order to detassel all of a variety it will be necessary to go over the field several times at intervals of a day or two. It is important to have all of the variety detasseled before the shedding of its pollen. If the varieties differ in date of tasseling it is recommended that the variety which tassels first be used for the female parent, as the silks are receptive as a rule for a longer time than during the shedding of the pollen. If the varieties do not differ in the date of maturity, seed may be obtained by the following plan which will necessitate the using of only one plat. To illustrate by the use of the diagram for Plat 1. Reserve some seed of C; detassel all of C this year. On the following year use the reserved seed of C and the open pollinated seed of D for the seed plot, using D this year for the female parent and reserving enough of D for the following year.

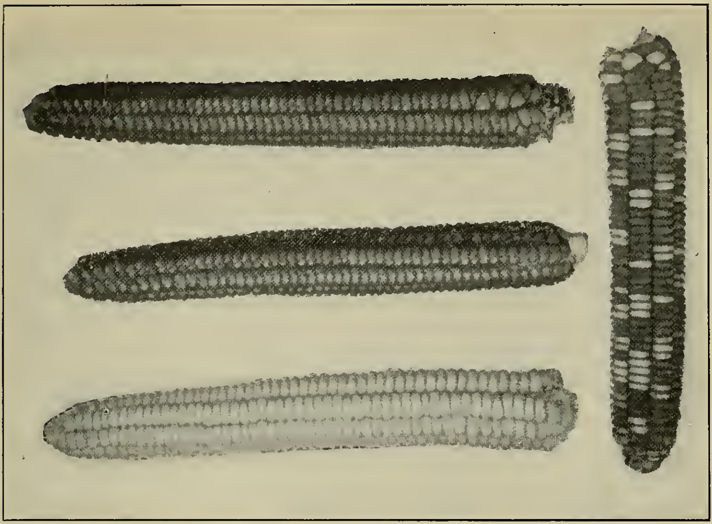
We recommend, no matter what method is used for producing the seed, that in the first year seed of both parent varieties be kept on hand and that a commercial test of the crossed seed and the parents be made in order to determine the value of the particular cross. If the cross proves to be a good one, one of the above outlined methods may be used for the yearly seed plat.



a. Stadtmueller's Leaming. This is a good Connecticut variety.



b. Hopson's Longfellow. This corn breeds very true to type.

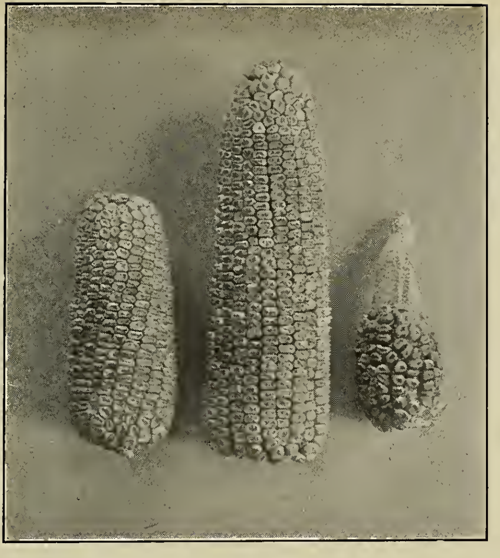


a. The middle ear is the result of an immediate cross between a white and yellow variety, and the ear at the right shows what would be obtained if such parents were used to produce a first generation hybrid.

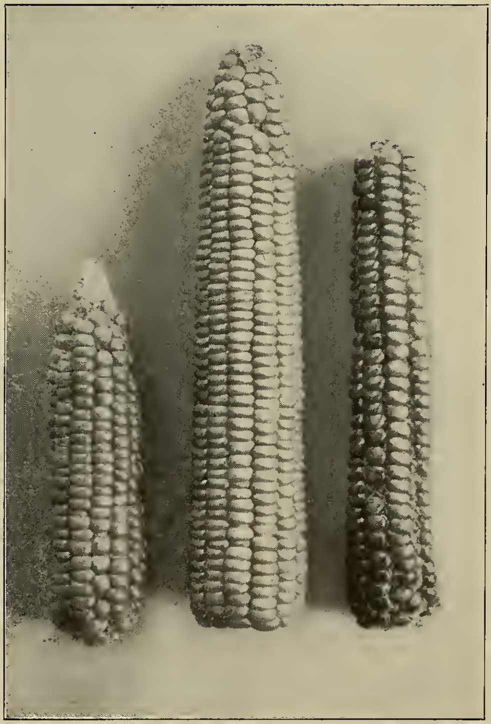
b. At the left and right of the photograph are shown respectively No. 15, Longfellow Flint and No. 8, Ill. High Protein Dent. The two central ears represent the first generation hybrid. This is the first cross of Table II.

a. A comparison of pure lines and the F_1 and F_2 generations. All were grown on the same field. (Photo by Walden).

b. At the right average of the parents after three generations of inbreeding. At the left crop of first generation cross of the inbred strains.



a. Outer ears inbred four generations. Middle ear result of their crossing, first generation.



b. Outer ears inbred one generation. Middle ear result of their crossing, first generation.