RESEARCH BULLETIN NO. 20

THE UNIVERSITY OF NEBRASKA

BULLETIN

OF THE

AGRICULTURAL EXPERIMENT STATION

OF

NEBRASKA

# CORN INVESTIGATIONS

By T. A. Kiesselbach

ACCEPTED FOR PUBLICATION JANUARY, 1922

JUNE, 1922

LINCOLN, NEBRASKA
U. S. A.

RESEARCH BULLETIN NO. 20

THE UNIVERSITY OF NEBRASKA

BULLETIN

OF THE

AGRICULTURAL EXPERIMENT STATION

OF

NEBRASKA

# CORN INVESTIGATIONS

By T. A. Kiesselbach

ACCEPTED FOR PUBLICATION JANUARY, 1922

JUNE, 1922

LINCOLN, NEBRASKA

U. S. A.

# AGRICULTURAL EXPERIMENT STATION OF NEBRASKA



THE STATION OFFICERS

E. A. BURNETT, D. SC., *Director*
W. W. BURR, B. SC., *Assistant Director*
W. H. BROKAW, *Director of Extension Service*
R. P. CRAWFORD, B. A., *Bulletin Editor*

THE WORKING STAFF

ARTHUR ANDERSON, B. SC., *Assistant in Agronomy*
M. J. BLISH, PH. D., *Chemistry*
E. E. BRACKETT, B. SC. IN E. E., *Associate in Agricultural Engineering*
E. M. BROUSE, B. SC., *Superintendent Experimental Substation,* Valentine
W. W. BURR, B. SC., *Agronomy (Chairman)*
H. P. DAVIS, M. SC., *Dairy Husbandry (Chairman)*
R. W. DAWSON, B. SC., *Assistant in Entomology*
H. C. FILLEY, A. M., *Rural Economics (Chairman)*
R. W. GOSS, M. S., *Assistant in Plant Pathology*
H. J. GRAMLICH, B. SC., *Animal Husbandry (Chairman)*
J. W. HENDRICKSON, A. M., *Assistant in Dairy Husbandry*
J. A. HOLDEN, B. SC., *Superintendent Experimental Substation,* Mitchell
R. F. HOWARD, A. M., *Horticulture (Chairman)*
F. D. KEIM, M. SC., *Assistant in Agronomy*
T. A. KIESSELBACH, PH. D., *Agronomy*
W. J. LOEFFEL, B. SC., *Assistant in Animal Husbandry*
G. A. LOVELAND, A. M., LL. B., *Meteorology*
JOHN A. LUITHLY, B. SC., *Assistant in Dairy Husbandry*
W. E. LYNESS, B. SC. IN AGR., *Assistant in Agronomy*
H. M. MARTIN, V. M. D., *Assistant in Animal Pathology and Hygiene*
B. I. MASUROVSKY, B. SC., *Assistant in Dairy Husbandry*
F. E. MUSSEHL, B. SC., *Poultry Husbandry*
F. R. NOHAVEC, B. SC. IN A. E., *Assistant in Agricultural Engineering*
G. L. PELTIER, PH. D., *Plant Pathology*
J. O. RANKIN, A. M., *Assistant in Rural Economics*
J. C. RUSSEL, M. S., *Assistant in Agronomy*
W. H. SAVIN, M. S., *Assistant in Animal Husbandry*
O. W. SJOGREN, B. SC. IN A. E., *Agricultural Engineering (Chairman)*
W. P. SNYDER, M. S., *Superintendent Experimental Substation,* North Platte
M. H. SWENK, A. M., *Entomology (Chairman)*
L. VAN ES, M. D., V. S., *Animal Pathology and Hygiene (Chairman)*
E. E. WEHR, M. S., *Assistant in Entomology*
H. O. WERNER, B. SC., *Assistant in Horticulture*
C. C. WIGGANS, PH. D., *Assistant in Horticulture*
[1]L. L. ZOOK, B. SC., *Agronomist,* North Platte

[1]Detailed from Office of Dry Land Agriculture, United States Department of Agriculture, Washington, D. C.

## CONTENTS

## SUMMARY

1. One of the outstanding considerations developed by these experiments concerning seed corn is the importance of adaptation. It is possible to move corn which is well adapted in one section of this State to another within the State where it will prove an almost complete failure. The degree of adaptation is dependent upon the degree of equilibrium between the plant requirements and its environmental growth conditions. The chief conflicting factors in this adjustment are: (1) Too late plant maturity for the length and character of the growing season; (2) too large inherent vegetative development with its proportional demand upon soil moisture, under conditions of moisture shortage; (3) too early maturity for the length of growing season available, which limits unnecessarily the length of time during which the plant may elaborate and accumulate organic materials; and (4) too small inherent vegetative development with its unnecessary physical limitation upon synthetic and accumulative processes.

Surveys of corn production in this State suggest that, in the main, corn types are being grown which meet the local environmental conditions fairly well. Marked cases of inadaptation are the exception. It may be readily observed that there is a gradual transition in the vegetative and associated ear characteristics of corn which is parallel with the transition in the climatic values from one region to another. Such transition is found both within standard varieties and between different varieties. There is an apparent tendency among growers to select corn types which are slightly too late maturing to produce the best results under their environment.

The corn crop has been found rather plastic, due to its heterozygous or complex hybrid composition, and may be made earlier or later, larger or smaller, thru selection. Such changes may be brought about by either direct or indirect modes of selection. Because of promiscuous wind pollination, selection for specific plant characters is somewhat complicated by the segregation and recombination of individual or linked characters. The progeny seldom represents as extreme a type as the plants which provide the seed. By means of ordinary selection continued thru a number of years, the type may be materially changed.

Many of the plant characters which are involved in adaptation are not inherited singly, but commonly go in groups of associated characters. As a consequence the selection for some single specific character is frequently attended by the indirect selection of a group of characters. Some of the adaptive characters which tend strongly to be associated or transmitted in groups are early maturity, small stature, ears low on the stalk, small leaf area, slender ears, and smooth, shallow kernels with horny endosperm. Selection toward the opposite extreme of any of these characters tends to result in a rather corresponding transition in all of the other associated characters. Exceptions occasionally occur to these groupings of plant characters.

2. Continuous selection within a commercial variety at this Station during four years for opposite extremes in the ratio of leaf area to dry plant substance resulted in seven "high leaf area" and nine "low leaf area" strains of corn, in which the former, in comparison with the latter, averaged 23 per cent more leaf area per unit dry matter, 29 per cent greater actual leaf area, and five days later maturity. The high leaf area selections had ears of larger circumference, and deep, rough, starchy grain, whereas the low leaf area strains had more slender ears, with smooth, shallow, horny kernels. In a succeeding seven-year yield test, the low leaf area yielded 7 per cent more shelled corn per acre than the high leaf area type, but produced 4 per cent less than the original corn from which it was selected. An $F_1$ cross between these two leaf area types yielded 2 per cent more than the original corn during the seven years. The data suggest superiority of the low leaf over the high leaf area strains but also that some reduction in yield has resulted from narrow breeding brought about by too restricted type selection.

3. Annual selections of various ear types of a standard local variety, Nebraska White Prize, during a six-year period, indicate that long, slender, smooth seed ears with a relatively short and flinty kernel excelled large, rough, deep, and starchy grained seed ears by 9 per cent and the original unselected corn by 1.4 per cent. In another six-year test with standard Reid's Yellow Dent in which continuous selection was practiced, the long, smooth type of ears surpassed the standard medium, rough type 7 per cent. In a two-year test with local Hogue's Yellow Dent corn, long, slender ears with a rather smooth, shallow kernel excelled ears with deep, rough kernels 9 per cent and the original corn 8 per cent in yield of grain. While complete notes descriptive of the plant development resulting from these ear

type selections were not taken thruout the entire period of the tests, the measurements and observations made lead to the conclusion that ear type selections indirectly result in a selection of correlated plant characteristics which differ in their adaptation to various environmental conditions. Selection of long, slender, smooth ears results in the isolation of types having a smaller and earlier maturing vegetative development than where the opposite large, rough type of ear is selected.

4. In an extensive comparative one-year test of ears disease free versus ears infected with root-rot diseases, as determined by the germinator test, the original unselected corn yielded 49.7 bushels, the disease free 50.2 bushels, and that designated as badly diseased corn 50.6 bushels per acre. No advantage resulted in regard to grain yield, barrenness, lodging, or soundness from such disease free selection. On the other hand, when the ear-to-row plats involved in this test are classified into rough, medium, and smooth groups without any reference to the presence or absence of root-rot diseases, the respective relative yields of shelled grain per acre are 100, 103, 106 as compared with 102 for the original unselected corn. Previous correlation of the germinator results with the various ear and kernel types indicates from 10 to 20 per cent greater freedom from root-rot diseases in case of the slender, smooth ear with horny kernels than in case of the large, rough, starchy, deep-grained ear. It seems possible that the increased yield secured by some investigators following selection of disease-free ears by the germinator test is, in part at least, associated with their prescribed preliminary selection of the smooth, slender, horny ears for seed purposes. Wherever corn types are being grown which tend to be somewhat too large and late maturing for their environmental conditions, selection of this smooth type of ear, whether because of root-rot disease considerations or otherwise, is likely to result in increased production because of the better adaptation of plant types represented in this type of ear. These type considerations apply where the various types are selected from the same general variety of corn.

In the case of seed grown under field conditions of promiscuous pollination, the progeny shows a tendency to come true to the ear type planted. In 1921, the percentages of rough, medium, and smooth ears harvested from large rough ears, long smooth ears, and the original unselected Nebraska White Prize corn were respectively 52, 35, and 13 per cent, 16, 40, and 44 per cent, and 30, 38, and 32 per cent. The difference in ear circumference, number of rows on an ear, and kernel length between these rough and smooth ear types averaged during six years approximately one-third as great for the ears harvested as for the ears planted. The progeny of the rough ears used in our disease study contained approximately 14 per cent more rough ears than did the progeny of the smooth ears; while on the other hand, the progeny of the smooth ears contained approximately 13 per cent more smooth ears than did the progeny of the rough ears. The progeny of the medium smooth ears was intermediate in both cases.

5. Continuous selection and testing of ears high versus ears low on the stalk during five years resulted in a spread of 23 per cent in ear height and a corresponding spread of 10 per cent in stalk height, based on the low ear selections. The low ear selections yielded 3.9 per cent more grain than the high ear selections, but 3.0 per cent less than the original corn. During the same period continuous selection and testing of seed ears from standing versus lodged plants resulted in a yield 10.9 per cent greater for the standing than for the lodged plants, and 2.9 per cent greater yield than was secured from the original corn. Continuously selected, during five years, ears borne erect on the stalk, as compared with drooping ear selections, yielded respectively 5.1 and 0.7 per cent less than the original corn.

6. In a six-year test, seed from the butts, tips, and middles yielded respectively 59.4, 60.4, and 60.2 bushels per acre. Little is to be gained from discarding butts or tips, aside from securing a more even stand, and a better germination under certain conditions of freezing injury. In a two-year test, corn selected when fully mature and at five weekly intervals before maturity yielded respectively 64.5, 64.0, 65.0, 63.0, 64.0, and 63.4 bushels per acre. The earlier selections required great care in curing. The data suggest that the selection of slightly immature seed corn to avoid freezing injury or for any other reason would not be objectionable if it is properly cured.

7. Seed selections of high viability made during three years from the field in September, November, and March gave respective yields of 47.0, 48.3, and 49.8 bushels per acre, as compared with 49.2 bushels for corn selected in the ordinary manner at husking time. Altho the time of selecting seed corn is not a vital factor if good viability is secured, the most rational time suggested is just prior to any likelihood of fall freezing injury. Storage difficulties are reduced by permitting the corn to undergo as thoro curing as practicable in the field.

8. Four methods of ear-to-row breeding have been compared.

These methods differ primarily in the manner of continuing the high yielding ear-to-row strains as established in the initial ear-to-row tests. They are: (1) Continuous ear-to-row breeding; (2) increasing a single high yielding strain in isolation; (3) increasing a composite of several high yielding strains in isolation; and (4) crossing several high yielding strains.

During a seven-year yield test, seed derived by these four practices yielded respectively 0.6 per cent less, 10.9 per cent less, 2.6 per cent more, and 1.7 per cent more than the original corn. The great reduction in yield resulting from a single high yielding ear-to-row strain continuously grown in isolation is doubtless due to close breeding.

In a five-year test of ear-to-row strains with a different local variety, (1) continuous ear-to-row breeding resulted in 0.8 per cent lower yield than the original, (2) increasing the eight best strains in composite under isolation yielded 4.7 per cent less than the original, and (3) crossing of ear-to-row strains yielded 1.7 per cent more than the original corn.

Improvement in yield of an adapted variety thru ear-to-row breeding seems rather uncertain, and 2.6 per cent increase is the maximum attained in these experiments. In the initial ear-to-row tests, the strains which were continued in these experiments had yielded approximately 20 per cent more than the original corn.

9. As an average for eleven years, corn selected from an isolation seed plat in which the poorest half of the stalks were annually detasseled gave a grain yield 1.8 per cent greater than seed from a corresponding plat in which the best half of the stalks were kept detasseled. However, both yielded slightly less than the original, thus indicating that no actual improvement resulted from continuous detasseling of the stalks that appeared to be inferior.

10. Three plants per hill in hills 42 inches apart is regarded as the standard planting rate for corn in eastern Nebraska and in a large part of the corn growing area elsewhere. Seed selected continuously from corn grown at this rate has yielded, during seven years, 0.6 per cent less than seed grown at the heavy planting rate of five plants per hill and 4.0 per cent more than seed grown continuously at the rate of one plant per hill. In all cases the best developed seed ears were selected from each seed plat, and compared for yield at a standard uniform planting rate. In a similar eight-year test with a different variety, the best ears selected from continuous planting rates of

1, 3, and 5 plants per hill yielded relatively 99.8, 100.0, and 100.4 per cent. It does not appear advantageous to select seed from corn planted thicker than the standard planting rate; and as an average for the two varieties, a reduction in yield not greater than 2 per cent is suggested in case the seed is all continuously selected from such a very thin stand as one plant per hill.

11. Self-fertilization as it occurs ordinarily in the field seems not to exceed 1 per cent under our conditions. Our tests indicate that only 0.7 per cent of the kernels were actually selfed under natural field conditions.

12. In an eight-year yield test, seed selected from detasseled rows in a seed plat yielded 0.6 per cent more than did seed taken from normally field pollinated rows. This would indicate that no extensive self-fertilization had taken place, since selfing reduces the yield approximately one-third in the first generation. The immediate effect of detasseling upon the current crop was an increased grain yield of one per cent for the detasseled plants.

13. Extensive observations have shown that in general the pollinating period of the tassel materially overlaps the silking period. Self-pollination might occur extensively were it not for the overwhelming preponderance of foreign pollen scattered promiscuously thru the air.

14. The continuous natural segregation and recombination of elemental hybridizing characters together with the natural element of survival of the fittest accentuated by man's repeated selection of well-developed ears for seed may account in a large measure for the inherently high productivity of field corn as now grown.

15. More than one hundred distinct pure lines or elemental strains have been developed in these experiments by continuous self-fertilization for seven or more years. Such self-fertilization gradually so purifies the chromosome composition of the plant that both male and female gametes of all its progeny plants are alike and carry the same inheritance. All hybrid vigor has then been eliminated and the resultant pure lines have become stabilized in plant size and growth habit and no further heritable reduction occurs. In a seven-year test, eight to twelve inbred strains of Hogue's Yellow Dent corn tested for yield in composite produced 32 per cent as much grain as the original Hogue's Yellow Dent corn. In a five-year test of eight inbred strains of Nebraska White Prize corn planted in composite, the

yield of grain was 35 per cent of the original corn. Individual yield tests of 32 inbred strains of Hogue's Yellow Dent corn for briefer periods indicate considerable variation in grain yield. In one experiment, the use of the lowest yielding pure lines as one of the parents resulted in hybrid yields of 13.5 bushels less per acre than where both inbred parents were relatively higher yielding. In another two-year test with eighteen $F_1$ hybrids, groups of the five highest, eight intermediate, and five lowest yielding hybrids produced relative grain yields of 100, 89, and 65; while the average grain production per plant of the inbred parent strains of these three groups was respectively 100, 86, and 65 per cent. This suggests that crossing the more productive pure lines is likely to result in the most productive hybrids.

16. In a four-year test of eight $F_1$ hybrids between pure lines, the average yield surpassed the original corn 17.2 per cent while the most productive hybrid excelled the original by 30 per cent. A perplexing question arises from the fact that during one year of this test the same eight hybrids averaged 9 per cent less than the original. Altho the grain yields of these hybrids averaged 9.7 per cent more than the original corn during 1915 and 1916, their plant development was smaller. They were four inches shorter and had 18 per cent less leaf area. This does not suggest a correlation between grain production and vegetative vigor as measured in plant size. It doubtless indicates both the complete elimination of some deleterious factors which were present in the original variety and also the isolation and recombination of superior factors thru the inbreeding and hybridizing processes.

17. During two years, 29 $F_1$ hybrids between pure lines were compared with the original corn from which they were developed. The inbred parents of these hybrids were derived from plant types which had been partially fixed by continuous plant type selection for either a high proportion or a low proportion of leaf area per unit of mature dry plant weight. The relative grain yields of the (1) original corn, (2) low leaf area hybrids, (3) high leaf area by low leaf area hybrids, and (4) high leaf area hybrids were 100.0, 112.0, 107.4, and 100.9. The highest yielding individual hybrid surpassed the original corn 34 per cent. The correlated low leaf area ratio and slender, smooth, horny ear and low actual leaf area on the one hand, and the high leaf area ratio and large, rough, starchy ear and high actual leaf area on the other hand, were retained thruout the inbreeding process and transmitted to their hybrid offspring.

Comparing the low leaf area and high leaf area groups (1) before inbreeding, (2) as inbred strains, and (3) as $F_1$ hybrids between these strains, the respective relative values for the following characters were: (1) Ratio of leaf area to dry matter, 82:100, 84:100, and 82:100; (2) actual leaf area per plant, 77:100, 76:100, and 82:100: (3) total dry matter, 95:100, 94:100, and 99:100; (4) ear weight per plant, 99:100, 125:100, and 107:100.

These data indicate that the outcome of inbreeding and hybridizing experiments may be quite extensively directed thru previous selection.

18. In a two-year test in which seven first and second generation hybrids were compared with the original corn, the respective relative yields were 125, 67, and 100. If the segregation of factors pertaining to grain yield should occur in the simple Mendelian ratio, the yield of the $F_2$ hybrids might be expected to center between the average of the pure line parents and their $F_1$ hybrids. During 1916 and 1917 the pure line parents approximated 24 per cent of the $F_1$ yield. A theoretical $F_2$ yield intermediate between these pure line and $F_1$ hybrid yields would have been 62 per cent of the hybrid yield, whereas the $F_2$ actually yielded 53 per cent as much.

These data show very definitely the inadvisability of selecting seed corn from an $F_1$ hybrid between such pure lines, no matter how productive the $F_1$ generation may be.

19. Very different results were obtained from hybrids between ordinary commercial varieties. In a four-year test, the yield of thirteen variety hybrids averaged 4 per cent less than the average of both parents, and 9 per cent less than the best parent. No hybrid equaled the best variety parent in grain yield. This failure of the $F_1$ hybrid to be more productive than the average of the two parents may be accounted for by the fact that the varieties are already fully heterozygous. For the same reason the $F_2$ generation of the variety hybrids yielded fully up to the $F_1$ generation. All plants of the second generation were as heterozygous as were plants of the $F_1$ generation.

In these experiments, seed for the $F_2$ generations for both pure line and variety hybrids was produced by crossing $F_1$ plants, and not by self-fertilization. The latter procedure would doubtless have reduced the $F_2$ variety yield approximately the same as the $F_2$ pure line yield was reduced. The method employed in these experiments corresponds to a farmer's procedure in selecting seed ears from an $F_1$ hybrid field.

20. A histological study of ten pure line hybrids and their pure line parents indicates that the increased growth of the hybrid has its basis in both increased size and increased numbers of cells. Thru hybridization (1) the stalk diameter was increased 46 per cent, (2) the number of vascular bundles 45 per cent, (3) the bundle diameter 15 per cent, (4) the number of pith cells along one stalk diameter 38 per cent, (5) the diameter of one pith cell 8 per cent, (6) the length of one pith cell 10 per cent, (7) the leaf thickness 14 per cent, (8) the leaf epidermal thickness 4 per cent, (9) the number of vascular bundles in one cm. leaf width was reduced 8 per cent, which suggests larger cellular development within the leaf, and (10) the average width of the leaf epidermal cell was increased 4 per cent, which suggests greater number as well as greater size of the cells, since the total leaf area per plant increased 45 per cent. As an average for seven of these hybrids, the stalk volume was increased 235 per cent, whereas the stalk pith cell was increased only 26 per cent in volume. Approximately 90 per cent of the increase in plant size due to crossing results from an increase in cell numbers and 10 per cent from an increase in cell size.

21. During seven years, comparative yields are available for several different degrees of inbreeding as applied to ear-to-row strains. These degrees differ in the likelihood of related gametes being involved in the fertilization process. Four successive degrees of complexity in the gametic relationship resulted in yields of 16.8, 42.2, 49.2, and 54 bushels per acre as compared with 53.1 bushels for the original corn.

In another five-year comparison with a different variety, seed of ear-to-row strains continuously subjected to different degrees of gametic relationship yielded successively 22.3, 42.7, 46.8, 51.3, and 64.8 bushels per acre as compared with 63.7 bushels for the original corn. It becomes apparent from these tests that any selection or breeding practice which so restricts the breadth of the parental relationship as to increase the likelihood of identical Mendelian factors being paired upon fertilization is likely to give reduced yields.

22. In previous statements concerning first generation corn hybrids, it was pointed out that in case of pure line hybrids great increase in production over the parents resulted, whereas this did not hold in case of hybrids between fully heterozygous commercial varieties. A similar situation was found in the immediate effect of crossing upon kernel weight. Both the embryo and endosperm of the corn kernel being subject to crossing, we

have in the embryo and endosperm of the kernel an actual hybrid product, just as we have in the plant produced when the seed is planted. We should expect increased hybrid vigor or a lack of it to be imparted to the kernel to correspond with that of the hybrid plant which it produces. In these experiments the immediate effect of foreign pollen from one commercial variety upon another was negligible, whereas hybrid kernels on pure line ears were increased relatively an average of 11 per cent.

There is nothing in these data which suggests that the results from comparative tests of commercial varieties of dent corn, as now conducted, are seriously invalidated because of any complicating immediate effect of fertilization by foreign pollen.

23. As an average for seven years, Hogue's Yellow Dent corn yielded 36.6, 44.6, and 40.3 bushels per acre, respectively, when grown at the rates of one, three, and five plants per hill in hills 3.5 feet apart. At similar rates in an eight-year test, Nebraska White Prize corn yielded 37.1, 52.9, and 49.4 bushels respectively. In a four-year test, the planting rates of one, two, three, four, and five plants per hill yielded respectively 40.7, 49.4, 52.9, 50.7, and 49.3 bushels per acre. Evidently there may be considerable variation in stand, fluctuating about three plants per hill, under Experiment Station conditions, without a material effect upon yield.

24. In a five-year test to determine the effect of ununiform distribution of plants in the field, the following varied distributions were compared: (1) Uniformly three plants per hill, (2) alternating hills with two and four plants, (3) alternating hills with one, two, three, four, and five plants, and (4) alternating hills with one, three, and five plants. The respective yields of grain per acre for these methods of distribution were: 59.0, 59.2, 58.6, and 56.0 bushels.

# CORN INVESTIGATIONS

By T. A. Kiesselbach

## INTRODUCTION

The purpose of the investigations reported in this bulletin has been primarily to determine some of the underlying principles involved in corn improvement. The work comprises a study of some of the physiological characteristics of the crop together with a comparison of various selection, breeding, and cultural practices in their relation to grain yield. The experiments were made largely on the Agricultural Experiment Station farm or within its immediate vicinity, at Lincoln, Nebraska, except in a few instances where the nature of the investigation required other designated locations.

The investigations reported herein are in part a continuation and extension of work done by Lyon and Montgomery prior to 1911 and reported by them in earlier publications. There has been perfect continuity in some of these experiments for the last eighteen years. This has been made possible by the complete records kept thruout their progress, and also by the fact that Montgomery and the writer were each in turn associated for a number of years with their predecessors in these corn experiments.

The acreage devoted to these studies during the last ten years has varied from thirty to sixty acres annually. The seasons of 1918 and 1919 were so dry at the Station that the corn grown in these experiments was virtually a failure both years and was used for silage without yield determinations. Thus, many of the data in the following tables terminate with the 1917 crop.

[1] Acknowledgment for efficient assistance at various times during the course of these experiments is made to Messrs. J. A. Ratcliff, C. A. Helm, F. D. Keim, H. G. Gould, Arthur Anderson, W. E. Lyness, H. A. Jones, and Enoch Nelson.

Many of the problems investigated in these experiments have been studied elsewhere by other workers,[1] with varied results and conclusions. One probable cause for this diversity of results from certain selection and breeding practices is the use, by different investigators, of varieties differing in their degree of local adaptation. It is reasonable that a poorly adapted variety is more likely to respond favorably to selection and breeding than is a well-adapted variety. The process of improvement in such a case may simply be that of directed acclimatization. This diversity of results is doubtless also to be accounted for, in part, by experimental errors which have unconsciously modified the correct indications. Method studies, such as reported in Nebraska Agricultural Experiment Station Research Bulletin No. 13, indicate many sources of possible error. These chiefly arise from irregularities in stand and soil, insufficient numbers of individuals and replications of plats, competition with adjacent unlike sorts, and insufficient duration of tests.

Some experiments are greatly subject to seasonal effects and require continuation thru a period of years in order to secure average indications. The nature of other experiments is such that the seasonal variation is not a vital factor, and dependable indications may be had in a much shorter time, provided the number of replications is ample and the method employed is correct.

## ECONOMIC CONSIDERATIONS

The United States produces, in round numbers, 3,000,000,000 bushels of corn annually. Nebraska's normal corn crop approaches 200,000,000 bushels. (Table 1.) An increase in the acre yields accompanied by an improvement in or at least maintenance of commercial quality would be a matter of no small moment. The significance of improvement along these lines, even tho slight, is so profound that agricultural agencies seem justified in the expenditure of great effort to establish the essential considerations in such improvement. An annual increase of approximately seven million bushels in Nebraska's corn crop would result from increasing the average yield one bushel per acre.

---

[1]The literature bearing upon many of the problems investigated herein is so extensive that it has seemed expedient to completely omit all literature citations.

Furthermore, negative data which fail to show constructive improvement in productivity have often positive values in indicating practices which fail to promote desired results. Strictly technical investigations sometimes reveal quite unexpected practical possibilities.

## TECHNIQUE OF THE FIELD PLAT YIELD DETERMINATIONS

Since 1911, except where the nature of the experiment required otherwise, the corn has been planted thick and thinned to the desired uniform rate. In the main, the corn rows have been

TABLE 1.—*Annual acreage and yield of corn, wheat, and oats in Nebraska, 1890 to 1921.*

| Crop | Total acreage | Yield per acre |
|---|---|---|
| | *Acres* | *Bushels* |
| NINE-YEAR PERIOD, 1890 TO 1898 | | |
| Corn | 5,419,000 | 20.5 |
| Wheat | 1,399,000 | 14.7 |
| Oats | 1,482,000 | 24.9 |
| NINE-YEAR PERIOD, 1899 TO 1907 | | |
| Corn | 6,256,000 | 28.6 |
| Wheat | 2,269,000 | 18.1 |
| Oats | 1,970,000 | 28.5 |
| NINE-YEAR PERIOD, 1908 TO 1916 | | |
| Corn | 6,530,000 | 25.7 |
| Wheat | 3,131,000 | 17.9 |
| Oats | 2,219,000 | 27.6 |
| FIVE-YEAR PERIOD, 1917 TO 1921 | | |
| Corn | 7,641,000 | 26.6 |
| Wheat | 3,321,000 | 14.0 |
| Oats | 2,537,000 | 30.9 |
| FOUR-YEAR PERIOD, 1918 TO 1921 | | |
| Corn | 7,240,000 | 26.4 |
| Wheat | 3,902,000 | 14.0 |
| Oats | 2,412,000 | 29.2 |
| THIRTY-TWO YEAR PERIOD, 1890 TO 1921 | | |
| Corn | 6,314,000 | 25.2 |
| Wheat | 2,431,000 | 16.4 |
| Oats | 1,991,000 | 27.6 |

Due to the severe winterkilling of the 1917 crop, much of the wheat acreage was replanted to other crops. The 4-year average, 1918 to 1921, therefore represents more nearly a normal average of the various crops than does the 1917-1921 average. These data are compiled from the annual reports of the Nebraska State Board of Agriculture.

72 hills long, and the yields have been based on the first 50 hills in the row containing, and adjacent to hills having, a full stand of plants. All discarded and surplus hills are removed from the row, just previous to husking. Error in comparative yields due to accidental variation in stand is thus eliminated.

Wherever varieties or types under comparison were distinctly dissimilar in growth habits, three-row plats, rather than single rows, have been used to reduce error due to unequal plant competition in adjoining plats, and the middle row only was used for tests.

After marking the land off crosswise into rows 3.5 feet apart by means of a four-row sled marker, the corn was dropped into the hills by means of modified hand corn planters from which the internal mechanism had been removed. The kernels were space planted in the hill about four inches apart in order that the number of individual plants in the hill might be determined with ease before harvest without confusing suckers and main stalks. The customary rate has been three plants per hill.

The grain yields reported in the following experiments are for air-dry shelled corn per acre. Shrinkage and shelling percentages have been determined for each sort, from representative samples of ear corn saved in the fall at time of husking. These samples, commonly weighing about 30 to 40 pounds, were stored in a slightly heated seed house from November till March, when the percentages of water loss and of shelled corn were determined.[1]

In several instances, grain yields for 1911 do not correspond exactly with earlier published results for that year. This is due to the fact that the earlier published figures have been revised for air-dry shelled corn per acre.

Yield tests of corn resulting from breeding or selection experiments have always included the original variety, to serve as a measure of progress made in the selected stock. Since the breeding work has been confined to two varieties, it has been relatively simple to continue the original corn year after year, without materially altering its hereditary constitution.

Corn improvement work began with Nebraska White Prize corn in 1911. Since then several acres of the original variety

---

[1]An exception to this rule was made with the 1921 crop. Corn ripened and cured so abnormally early this year that it graded No. 1 as to moisture content when husked. The shrinkage and shelling per cent were determined in January.

have been grown annually in isolated fields at the Experiment Station. The seed has been continued from five hundred or more ears annually, selected at random after husking, the only requirement being that the ears so selected are well developed and sound. The original Hogue's Yellow Dent variety has been continued in the same manner at the Experiment Station since 1910. During the period of 1903 to 1910, seed of the original Hogue's Yellow Dent corn, to be used as a check, was obtained each year (at a distance of 30 miles) from the original grower.

These two varieties, Hogue's Yellow Dent and Nebraska White Prize corn, are both standard full season varieties, locally grown seed of which is well acclimated to conditions prevailing at this Station. Neither variety had ever been subjected to close type selection.

## ADAPTATION

Under our conditions the importance of growing adapted corn can not be too strongly emphasized. It is the outstanding quality to be sought in seed corn. It surmounts all question of variety, ear and kernel type, color, and breeding. The characteristic differences between corn types adapted to various regional areas of Nebraska have been presented in Nebraska Research Bulletin No. 19. The following data in Table 2 and figures 1, 2, and 3, extracted from the above bulletin, illustrate the significance of growing well-adapted corn.

In figures 1 and 2 are shown the mean climatic factors for this State, being compiled from thirty or more years' data by the Nebraska Weather Bureau under the direction of G. A. Loveland. Progressing westward in the State, the rainfall decreases, the growing season shortens, and the temperature lowers. The westward lowering of temperature is due primarily to a rather gradual increase in altitude from 1,000 feet in the extreme east (Richardson County) to 5,000 feet in the extreme west (Kimball County). While there are also distinct soil differences within the State, they are far less potent factors in the local adaptation of corn than is climate.

Native full-season seed corn typical of the region was obtained from each of the eleven counties indicated by number in figure 1. These seed sources represent widely differing climatic areas, ranging from a relatively favorable corn climate in the east to a relatively less favorable corn climate in the west.

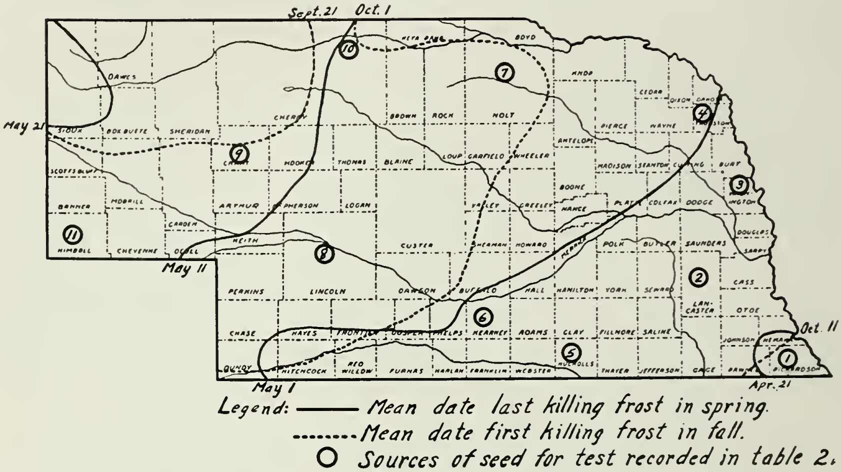



FIG. 1.—Average dates of the last killing frost in the spring and the first killing frost in autumn for various regions of Nebraska. The hereditary type of corn grown in different regions should vary in order to fit the length of frost free period available for growth.

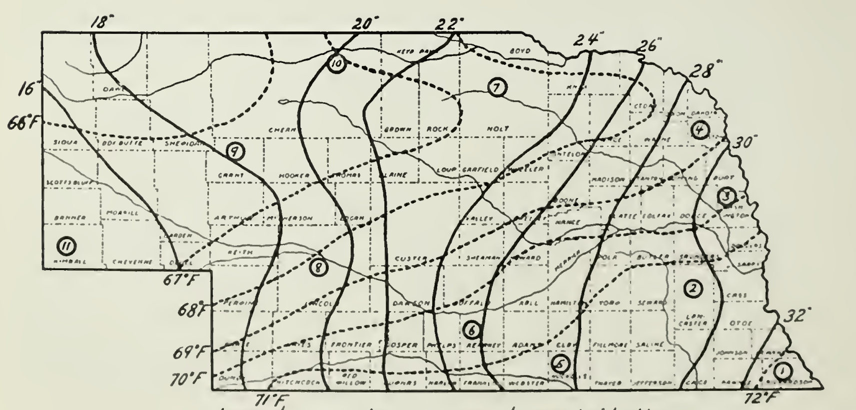
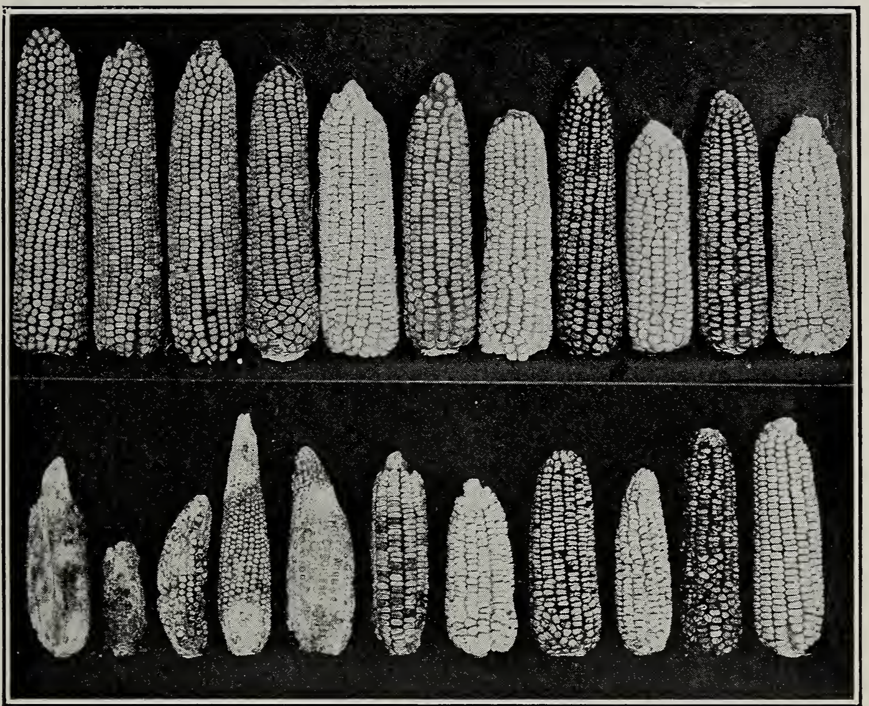



FIG. 2.—Average annual precipitation and normal isotherms for the corn growing season of May, June, July, and August. The hereditary type of corn grown in different regions should vary in accordance with the precipitation and heat units available for growth.



1 2 3 4 5 6 7 8 9 10 11

FIG. 3.—Representative ears of corn grown from native seed from eleven regional areas in Nebraska.

Top row: Corn grown in Lancaster County; Bottom row: Corn grown in Kimball County.

Sources of seed: 1, Richardson County; 2, Lancaster County; 3, Washington County; 4, Thurston County; 5, Nuckolls County; 6, Kearney County; 7, Holt County; 8, Lincoln County; 9, Grant County; 10, Cherry County; 11, Kimball County.

These eleven native corn types were grown comparatively in 1916 in Lancaster, eastern Cherry, and Kimball Counties. The rate of planting in these three cases was normal for each region and was uniform for all types. Corn is seldom planted more than two-thirds as thick in western as in eastern Nebraska.

When compared under the favorable conditions of Lancaster County, seed from all sources matured satisfactorily. Grown in Kimball County, maturity was rather proportional to the proximity to the seed's source. In Cherry County, with its

TABLE 2.—*Comparative measurements of corn plants adapted to various regions of Nebraska, when grown in Lancaster, Cherry, and Kimball Counties. 1916.*

| Source of seed | Height | | Leaf area per | | Dry matter | | Shelling per cent |
|---|---|---|---|---|---|---|---|
| | Stalk | Ear | Plant | Pound dry matter | Grain | Total | |
| *County* (1) | *Feet* (2) | *Feet* (3) | *Sq. in.* (4) | *Sq. in.* (5) | *Pounds* (6) | *Pounds* (7) | *Per cent* (8) |
| WHEN PLANTED IN EASTERN NEBRASKA (LANCASTER COUNTY) | | | | | | | |
| Richardson | 8.3 | 4.2 | 1,298 | 1,165 | .548 | 1.114 | 87 |
| Lancaster | 7.5 | 4.2 | 1,414 | 1,369 | .528 | 1.033 | 87 |
| Washington | 7.8 | 4.3 | 1,407 | 1,506 | .388 | .934 | 85 |
| Thurston | 7.4 | 3.3 | 1,209 | 1,480 | .363 | .817 | 84 |
| Nuckolls | 7.5 | 3.4 | 1,459 | 1,325 | .504 | 1.101 | 81 |
| Kearney | 6.9 | 3.5 | 1,259 | 1,570 | .328 | .802 | 83 |
| Holt | 6.8 | 3.2 | 1,219 | 1,390 | .337 | .877 | 78 |
| Cherry | 6.0 | 2.8 | 833 | 1,178 | .289 | .707 | 79 |
| Lincoln | 6.1 | 3.1 | 849 | 1,059 | .352 | .802 | 81 |
| Grant | 5.7 | 2.0 | 775 | 1,096 | .284 | .707 | 82 |
| Kimball | 5.4 | 1.7 | 594 | 1,167 | .211 | .509 | 78 |
| WHEN PLANTED IN NORTH CENTRAL NEBRASKA (EASTERN CHERRY COUNTY) | | | | | | | |
| Richardson | 6.6 | 2.6 | 1,094 | 1,602 | .249 | .683 | 79 |
| Lancaster | 7.1 | 2.9 | 959 | 1,475 | .207 | .650 | 72 |
| Washington | 7.4 | 2.7 | 991 | 1,573 | .196 | .630 | 72 |
| Thurston | 6.8 | 2.2 | 891 | 1,314 | .286 | .678 | 80 |
| Nuckolls | 7.3 | 3.1 | 1,066 | 1,485 | .240 | .718 | 77 |
| Kearney | 6.3 | 2.0 | 820 | 1,488 | .141 | .551 | 68 |
| Holt | 6.4 | 2.1 | 954 | 1,435 | .262 | .665 | 80 |
| Cherry | 5.8 | 1.7 | 624 | 1,042 | .267 | .599 | 80 |
| Lincoln | 6.4 | 2.1 | 840 | 1,321 | .247 | .636 | 77 |
| Grant | 5.4 | 1.3 | 587 | 1,075 | .247 | .546 | 79 |
| Kimball | 4.7 | 1.0 | 376 | 954 | .194 | .394 | 81 |
| WHEN PLANTED IN WESTERN NEBRASKA (KIMBALL COUNTY) | | | | | | | |
| Richardson | 6.9 | 3.0 | 1,050 | 3,144 | .039 | .334 | 74 |
| Lancaster | 6.0 | 2.2 | 1,100 | 4,089 | .004 | .269 | 55 |
| Washington | 7.4 | 3.0 | 1,140 | 3,238 | .015 | .352 | 41 |
| Thurston | 5.5 | 3.1 | 563 | 2,093 | .033 | .269 | 70 |
| Nuckolls | 6.0 | 2.0 | 1,042 | 2,463 | .062 | .423 | 77 |
| Kearney | 5.9 | 1.9 | 718 | 1,894 | .119 | .379 | 77 |
| Holt | 5.7 | 1.9 | 759 | 2,193 | .073 | .346 | 68 |
| Cherry | 4.9 | 1.4 | 536 | 1,605 | .137 | .334 | 78 |
| Lincoln | 5.1 | 1.6 | 491 | 1,705 | .088 | .288 | 73 |
| Grant | 4.9 | 1.6 | 426 | 1,479 | .081 | .288 | 70 |
| Kimball | 4.2 | 1.1 | 425 | 1,221 | .161 | .348 | 80 |

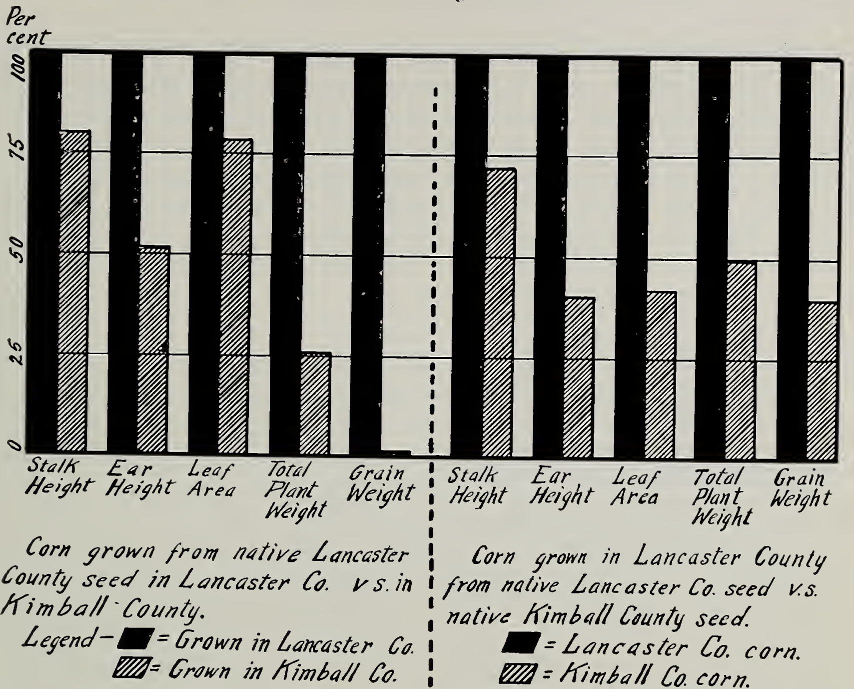



CHART 1.—Showing the significance of adaptation in corn production. At the left is shown the relative adaptation of a given lot of corn to two different environments. At the right is shown the comparative plant growth in a given favorable environment of two lots of corn adapted to two different environments. Compiled from Table 2.

rather intermediate climate, corn from the less favorable sources matured well, while from the sources of more favorable climate the corn was immature and chaffy.

Representative ears of corn from each source when grown in Lancaster and Kimball Counties are shown in figure 3. These data show some of the profound hereditary differences between native types from various climatic areas within the State.

## VARIETY SIGNIFICANCE

Local adaptations within some of our standard varieties of corn are so marked that variety name has lost much of its significance in Nebraska. These distinct local variety types or subvarieties originate thru the natural processes of adaptation and thru the controlled selections by man. These controlled selections may be along the natural line of adaptation or to secure other economic advantages, or they are mere fanciful individualistic variations without immediate practical importance.

Such local type differences within a variety may be illustrated by Table 3, which shows the comparative growth habits of typical Lancaster County and Thurston County Reid's Yellow Dent corn when grown comparably at the Experiment Station in Lancaster County. The northern seed obtained from one hundred miles farther north matured a week earlier and the plants were distinctly shorter and lighter weight, the ears were smaller and the kernels shorter and smoother, and the shelling percentage and shrinkage of ear corn were also somewhat less.

TABLE 3.—*Effect of adaptation upon variety characteristics. Thurston County acclimated and Lincoln County acclimated corn grown for the first year at the Experiment Station in Lancaster County in comparison with locally acclimated corn of the same varieties.*[1] *1916.*

| Plant characters | Reid's Yellow Dent acclimated to | | Calico acclimated to | |
|---|---|---|---|---|
| | Lancaster County | Thurston County | Lancaster County | Lincoln County |
| 1 Date tasseling | 7/31 | 7/25 | 7/31 | 7/15 |
| 2 Date ripe | 9/21 | 9/14 | 9/20 | 9/8 |
| 3 Plant height (feet) | 7.25 | 6.25 | 7.75 | 6.50 |
| 4 Ear height (feet) | 3.75 | 3.25 | 3.50 | 3.00 |
| 5 Shrinkage of ear corn (per cent) | 7.2 | 4.5 | 3.8 | 2.0 |
| 6 Shelling percentage (per cent) | 85 | 82 | 83.6 | 79.6 |
| 7 Two-eared stalks, per 100 plants | 7 | 7 | 0 | 3 |
| 8 Barren plants, per 100 | 2 | 2 | 9 | 3 |
| 9 Lodged plants, per 100 | 9 | 8 | 8 | 16 |
| 10 Yield of dry shelled corn per acre (bushels) | 61.0 | 45.6 | 58.3 | 40.5 |
| 11 Leaf area, per stalk (sq. in.) | 1,414 | 1,209 | 1,323 | 849 |
| 12 Stover weight, per stalk, moisture free (grams) | 193 | 174 | 182 | 167 |
| 13 Ear weight, per stalk, moisture free (grams) | 276 | 197 | 277 | 197 |
| 14 Total weight, per stalk, moisture free (grams) | 469 | 371 | 459 | 364 |
| 15 Grain weight, per stalk, moisture free (grams) | 234.6 | 165 | 231.6 | 160 |
| 16 Ear length (inches) | 7.8 | 7.0 | 7.8 | 7.4 |
| 17 Ear circumference (inches) | 6.4 | 6.1 | 6.5 | 5.8 |
| 18 Kernel length (inches) | .51 | .47 | .49 | .45 |

[1] The first ten characters are the composite data for three field plats of 600 plants. The other measurements are based on ten representative successive plants for each plat. 1916 was a fairly normal year for corn.

The table gives a similar comparison of Lancaster County and Lincoln County acclimated calico corn. When compared at the Experiment Station, Lincoln County seed, acclimated 210 miles west, produced plants which ripened twelve days earlier, were fifteen inches shorter, and had a somewhat lower shelling percentage and shrinkage of ear corn. The leaf area was only about two-thirds as great, the ears were smaller and smoother, and the kernel length shorter.

1 2 3 4 5 6

FIG. 4.—Illustrating character of varieties acclimated to various regions. Typical plants grown at the Nebraska Experiment Station from seed obtained from the sources indicated. (1) Martens' White Dent from Kimball County, Nebraska; (2) Calico from Lincoln County, Nebraska; (3) Hogue's Yellow Dent from Lancaster County, Nebraska; (4) Minnesota No. 13 from North Dakota; (5) Commercial White from southeastern Kansas; (6) Reid's Yellow Dent from Indiana.

It is more important to know what conditions a corn has become adapted to than to know the variety to which it belongs. The original variety name of many of our best Nebraska corns is obscure.

While many of the older varieties have come into use over a wide territory with striking environmental differences and therefore represent many local adaptations, each local type has become fairly well fixed and affords the grower something definite in the way of hereditary growth characteristics. Some of the more recently named or introduced varieties have not yet been

TABLE 4.—*Comparative test of corn varieties. Four-year average, 1914-1917.*

| Description | Date in tassel | Date ripe | Stalk height | Ear height | Suckers per 100 plants | Ears per 100 plants | Two-eared plants per 100 | Shrinkage of ear corn | Shelling percentage | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Inches* | *Inches* | | | | *Per cent* | *Per cent* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Hogue's Yellow Dent | 8/1 | 9/23 | 88 | 43 | 24 | 84 | 4 | 10.19 | 84 | 46.5 |
| Reid's Yellow Dent | 8/1 | 9/23 | 85 | 44 | 17 | 87 | 5 | 7.63 | 85.1 | 46.3 |
| Calico | 8/4 | 9/28 | 86 | 43 | 13 | 81 | 3 | 7.40 | 82.4 | 43.3 |
| Leaming | 7/29 | 9/23 | 87 | 43 | 13 | 80 | 3 | 8.46 | 82.8 | 43.1 |
| University No. 3 | 7/29 | 9/21 | 78 | 40 | 11 | 81 | 1 | 8.85 | 82.7 | 43.0 |
| Bloody Butcher | 8/5 | 9/28 | 88 | 41 | 12 | 81 | 2 | 8.34 | 82.1 | 42.7 |
| Nebraska White Prize | 8/4 | 9/27 | 91 | 46 | 9 | 83 | 3 | 11.81 | 83.2 | 42.5 |
| St. Charles White | 7/30 | 9/22 | 82 | 39 | 2 | 82 | 1 | 7.92 | 84.3 | 40.1 |
| Pride of the North | 7/26 | 9/14 | 78 | 38 | 14 | 90 | 8 | 5.08 | 82.0 | 40.1 |
| Iowa Silver Mine | 8/1 | 9/25 | 83 | 40 | 10 | 80 | 2 | 9.44 | 82.2 | 39.3 |
| Iowa Gold Mine | 7/29 | 9/24 | 86 | 42 | 13 | 78 | 4 | 7.58 | 84.9 | 39.1 |
| White Cap | 7/28 | 9/21 | 78 | 41 | 5 | 86 | 3 | 4.96 | 83.9 | 37.1 |
| Minnesota No. 13 | 7/22 | 9/10 | 68 | 35 | 4 | 86 | 2 | 3.98 | 81.9 | 35.7 |
| Boone County White | 8/7 | 9/29 | 91 | 41 | 5 | 78 | 3 | 19.26 | 80.7 | 35.6 |

The data are based on center rows of duplicate three-row plats, thinned to a uniform stand. The first fifty consecutive hills with normal stand were harvested from rows containing 72 hills.

widely disseminated, and their name is more suggestive of the region to which they are adapted.

In the conduct of corn variety tests, it is difficult to eliminate from the seed the qualifying effect of local adaptations, especially when obtained from distant points. Yield differences in such tests are frequently the result of the combined effects of variety difference and local adaptation. Variety performance is subject to variation due to the source of the seed. Table 4 reports the yields during a four-year period of fourteen varieties, subject to local adaptation.

### HOME GROWN VERSUS IMPORTED SEED CORN

During the three years 1915-1917, seed of acclimated corn being grown by ten local Lancaster County farmers living within five miles of the Experiment Station was compared for yield with seed corn obtained from seven more distant eastern Nebraska farmers, most of whom were making a specialty of seed corn production. The object was to determine the variation in the inherent productivity of corn grown by different farmers in a community such as this one, and the likelihood of advantageous substitution of some other local or imported corn. The results are given in Table No. 5.

Of the ten selections from local farmers, six yielded within 2½ bushels, or 4 per cent, as much as the average of the two standard Experiment Station varieties, viz, Hogue's Yellow Dent and Nebraska White Prize. The other four varieties yielded respectively 3.2, 4.1, 5.6, and 6 bushels, or 5.1, 6.5, 8.9, and 9.5 per cent, less than this average. Of the seven varieties from a distance, four yielded within one and one-half bushels, or 3 per cent, as much as the average for the two standard Experiment Station varieties. The other three yielded 4.6, 8.8, and 15 bushels, or 7.3, 14.0, and 23.8 per cent, less, respectively.

The results suggest that the majority of farmers in a community are probably growing corn of about equal productivity. A few have corn sufficiently inferior to invite substitution. No individual farmer's corn is likely to be very outstanding in its superiority.

The best imported seed did not surpass the best local seed, which is rather encouraging for the use of home grown seed corn. The least productive of the imported varieties was far inferior to the lowest yielding home grown kind, which suggests the need for great caution when procuring seed corn from a distance.

TABLE 5.—*Comparative test of corn varieties obtained from farmers in the vicinity of the Experiment Station and varieties obtained from somewhat distant eastern Nebraska counties. Three year average, 1915, 1916, and 1917.*

| Source of seed | | Variety | Date in tassel | Date ripe | Stalk height | Ear height | Suckers per 100 plants | Ears per 100 plants | 2-eared plants per 100 | Shrinkage of ear corn | Shelling per cent | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grower of seed | County | | | | *In.* | *In.* | | | | *Per cent* | *Per cent* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| Nebr. Exp. Station | Lancaster | Hogue's Yellow Dent | 8/6 | 9/27 | 94 | 46 | 24 | 95 | 23 | 15.4 | 84.0 | 66.7 |
| R. B. Roberts | Lancaster | Reid's Yellow Dent | 8/8 | 9/26 | 91 | 47 | 10 | 92 | 24 | 14.6 | 84.8 | 62.6 |
| S. Moore | Lancaster | Moore's White Dent | 8/7 | 9/26 | 91 | 45 | 13 | 94 | 25 | 13.2 | 83.4 | 65.3 |
| S. Stanley | Lancaster | St. Charles White | 8/5 | 9/26 | 90 | 45 | 6 | 95 | 22 | 14.8 | 84.9 | 63.1 |
| J. T. Graham | Lancaster | Reid's Yellow Dent | 8/7 | 9/26 | 94 | 48 | 13 | 90 | 23 | 17.0 | 84.6 | 61.8 |
| J. T. Graham | Lancaster | Boone County White | 8/9 | 9/26 | 93 | 45 | 12 | 85 | 21 | 18.0 | 82.4 | 59.4 |
| L. K. Schoenleber | Lancaster | White Dent | 8/6 | 9/27 | 92 | 46 | 16 | 88 | 22 | 16.5 | 82.9 | 60.9 |
| E. Arenson | Lancaster | Chase's White Dent | 8/6 | 9/26 | 86 | 44 | 15 | 86 | 20 | 14.2 | 83.2 | 63.6 |
| J. F. Jensen | Lancaster | Chase's White Dent | 8/7 | 9/27 | 92 | 43 | 21 | 92 | 19 | 16.2 | 82.5 | 64.6 |
| C. W. Clark | Lancaster | St. Charles' White | 8/5 | 9/26 | 87 | 43 | 9 | 98 | 25 | 12.1 | 82.9 | 65.9 |
| Emery Darby | Lancaster | Darby's Yellow Dent | 8/7 | 9/27 | 98 | 47 | 8 | 90 | 19 | 15.3 | 82.9 | 59.0 |
| Nebr. Exp. Station | Lancaster | Nebraska White Prize | 8/7 | 9/27 | 97 | 49 | 13 | 91 | 24 | 14.3 | 82.6 | 63.4 |
| | | Average | 8/7 | 9/26 | 92 | 46 | 13 | 91 | 22 | 15.1 | 83.4 | 63.0 |
| VARIETIES FROM VARIOUS EASTERN NEBRASKA COUNTIES | | | | | | | | | | | | |
| C. J. Brush | Nemaha | Boone County White | 8/11 | 10/3 | 96 | 44 | 9 | 83 | 6 | 29.0 | 80.2 | 50.0 |
| F. J. Rist | Richardson | Reid's Yellow Dent | 8/9 | 9/28 | 95 | 47 | 13 | 96 | 21 | 18.3 | 84.1 | 64.6 |
| William Ernst | Johnson | Nebraska White Prize | 8/7 | 9/28 | 97 | 48 | 8 | 90 | 22 | 18.61 | 82.8 | 56.2 |
| Lee Smith | Washington | Nebraska White Prize | 8/8 | 9/27 | 93 | 46 | 12 | 90 | 22 | 13.20 | 83.5 | 60.4 |
| Anderson Bros. | Wayne | Reid's Yellow Dent | 8/5 | 9/24 | 81 | 43 | 11 | 92 | 24 | 6.93 | 84.8 | 63.5 |
| F. H. Roggenbach | Cuming | Reid's Yellow Dent | 8/6 | 9/27 | 93 | 46 | 11 | 93 | 20 | 10.89 | 85.3 | 65.8 |
| R. R. Seymour | Dodge | Reid's Yellow Dent | 8/8 | 9/27 | 97 | 49 | 7 | 95 | 23 | 11.83 | 83.4 | 65.0 |
| | | Average | 8/8 | 9/28 | 93 | 46 | 10 | 91 | 20 | 15.5 | 83.4 | 60.8 |

Plats replicated six and seven times annually. Yields based on center rows of three-row blocks.

## BROAD FERTILIZATION IN CORN THE RULE

### RELATION OF SILKING AND POLLINATION

Knowledge that inbreeding of corn is injurious has caused considerable speculation relative to the amount of inbreeding that actually occurs in the open field pollination of corn.

For the purpose of determining the opportunity for cross-fertilization, the natural silking and tasseling relationships were studied during 1914 and 1915 for fourteen varieties. The varieties under comparison were grown at the normal rate of planting (three per hill) in adjacent three-row plats of sixteen rods length. One hundred and twenty consecutive plants were tagged and numbered in each plat just before the blooming period. With the initial advent of tassels and silks, individual plant records were kept of their daily development. The correlations between the shedding of pollen and the pollination of silks and, indirectly, the fertilization of the ovules, are presented in Tables 6 to 8 and summarized in Table 9. Data bearing upon the same relationships were obtained on a smaller scale with nine varieties in 1920 and are included in the summary table.

The upper portion of the central tassel spike is commonly the seat of the initial shedding of pollen. From here it extends downward and laterally to the tassel branches. The shedding of pollen begins with elongation of the anther filament and the extrusion and dehiscence of the anthers. Receptive silks are subject to self-fertilization as long as the plant bearing them sheds pollen. The exact time at which the pollen falls upon the silk which fertilizes the kernel is not directly apparent. This time can be approximated by noting the date upon which the characteristic slight discoloration and withering of the silk consequent upon fertilization is first apparent.

In 1921 the time of discoloration and withering of the silks, which is evidence of fertilization having been effected, ranged from 42 to 72 hours after the pollen had been applied to the silks. For this determination the ears of 100 plants were covered with paper bags before the silks appeared. Upon removal of the bags following silking, pollen was artificially applied and the time determined for each plant to show the effects. The data are given in Table 10.

Varieties as well as individual plants were found to vary somewhat in the sequence of the various flowering stages of tassel and silk. With all varieties, however, as an average for the two years and with most individual plants, it appears that

TABLE 6.—*Relationship between the shedding of pollen, silking, and fertilization of corn. 1914.*

| Variety | Number of plants averaged | Pollination period for variety (days): Maximum length | Pollination period for variety (days): More than 12% plants shedding pollen | Number of days shedding pollen (individual plant average): Entire period | Before silks appear | After silks appear | Before fertilization is apparent | After fertilization is apparent | Pollen maximum before silks indicate fertilization (days) | Maximum length of silks (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Reid's Yellow Dent | 99 | 14 | 10 | 6.5 | 2.4 | 4.1 | 6.1 | +0.4 | 2.8 | 2.2 |
| Hogue's Yellow Dent | 102 | 13 | 10 | 6.1 | 2.8 | 3.3 | 6.4 | —0.3 | 3.6 | 2.1 |
| Iowa Gold Mine | 110 | 13 | 10 | 5.6 | 2.1 | 3.5 | 5.7 | —0.1 | 2.8 | 2.0 |
| Leaming | 111 | 12 | 9 | 5.9 | 2.1 | 3.8 | 5.6 | +0.3 | 2.5 | 2.2 |
| Calico | 109 | 12 | 9 | 5.7 | 2.5 | 3.2 | 6.0 | —0.3 | 2.8 | 2.1 |
| Bloody Butcher | 110 | 13 | 10 | 5.7 | 2.2 | 3.5 | 6.3 | —0.6 | 2.9 | 2.2 |
| Boone County White | 98 | 14 | 10 | 6.6 | 4.5 | 2.1 | 9.3 | —2.7 | 5.8 | 2.1 |
| St. Charles White | 113 | 11 | 9 | 5.6 | 2.0 | 3.6 | 5.8 | —0.2 | 3.2 | 2.3 |
| Iowa Silver Mine | 109 | 13 | 10 | 6.2 | 4.6 | 1.6 | 8.6 | —2.4 | 5.7 | 2.3 |
| Nebraska White Prize | 103 | 13 | 10 | 6.2 | 5.1 | 1.1 | 8.1 | —1.9 | 4.8 | 2.2 |
| Pride of the North | 102 | 12 | 9 | 6.0 | 0.6 | 5.4 | 4.6 | +1.4 | 1.8 | 3.0 |
| Minnesota No. 13 | 113 | 12 | 10 | 5.9 | 0.3 | 5.6 | 4.5 | +1.4 | 1.0 | 2.9 |
| White Cap | 109 | 11 | 8 | 4.6 | 2.2 | 2.4 | 5.9 | —1.3 | 3.3 | 2.2 |
| University No. 3 | 110 | 12 | 9 | 5.5 | 2.9 | 2.6 | 6.3 | —0.8 | 3.3 | 2.3 |
| Average | 107 | 12.5 | 9.5 | 5.9 | 2.6 | 3.3 | 6.4 | —0.4 | 3.3 | 2.3 |

| Variety | Fertilization first apparent on silks: Before pollen maximum: Per cent of plants | Before pollen maximum: Days | After pollen maximum: Per cent of plants | After pollen maximum: Days | Before pollen begins: Per cent of plants | Before pollen begins: Days | After pollen ceases: Per cent of plants | After pollen ceases: Days | Number of days after silks appear | Barren plants per 100 | Plants with sterile tassels per 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) |
| Reid's Yellow Dent | 2 | 1.0 | 98 | 2.9 | 0 | 0 | 16 | 1.5 | 3.6 | 6 | 0 |
| Hogue's Yellow Dent | 0 | 0.0 | 100 | 3.6 | 0 | 0 | 10 | 1.9 | 3.6 | 3 | 0 |
| Iowa Gold Mine | 1 | 1.0 | 99 | 2.8 | 0 | 0 | 24 | 1.7 | 3.6 | 5 | 0 |
| Leaming | 1 | 1.0 | 99 | 2.5 | 0 | 0 | 14 | 3.2 | 3.5 | 5 | 0 |
| Calico | 1 | 1.0 | 99 | 2.8 | 0 | 0 | 33 | 2.1 | 3.5 | 5 | 0 |
| Bloody Butcher | 0 | 0.0 | 100 | 2.9 | 0 | 0 | 33 | 2.2 | 3.9 | 2 | 0 |
| Boone County White | 0 | 0.0 | 100 | 5.8 | 0 | 0 | 39 | 3.3 | 4.3 | 7 | 0 |
| St. Charles White | 0 | 0.0 | 100 | 3.2 | 0 | 0 | 11 | 2.6 | 3.8 | 4 | 0 |
| Iowa Silver Mine | 0 | 0.0 | 100 | 5.7 | 0 | 0 | 13 | 2.7 | 3.9 | 6 | 0 |
| Nebraska White Prize | 0 | 0.0 | 100 | 4.8 | 0 | 0 | 15 | 2.5 | 4.0 | 7 | 0 |
| Pride of the North | 6 | 2.3 | 94 | 2.1 | 0 | 0 | 9 | 1.0 | 4.1 | 2 | 8 |
| Minnesota No. 13 | 9 | 1.4 | 91 | 1.2 | 0 | 0 | 15 | 1.5 | 4.1 | 0 | 0 |
| White Cap | 0 | 0.0 | 100 | 3.3 | 0 | 0 | 43 | 1.8 | 3.7 | 1 | 0 |
| University No. 3 | 0 | 0.0 | 100 | 3.3 | 0 | 0 | 26 | 1.5 | 3.5 | 4 | 0 |
| Average | 1.4 | 0.5 | 98.6 | 3.3 | 0 | 0 | 21.5 | 2.1 | 3.8 | 4 | 0.5 |

TABLE 7.—*Relationship between the shedding of pollen, silking, and fertilization of corn. 1915.*

| Variety | Number of plants averaged | Pollination period for variety (days): Maximum length | Pollination period for variety (days): More than 12% plants shedding pollen | Number of days shedding pollen (individual plant average): Entire period | Number of days shedding pollen (individual plant average): Before silks appear | Number of days shedding pollen (individual plant average): After silks appear | Number of days shedding pollen (individual plant average): Before fertilization is apparent | Number of days shedding pollen (individual plant average): After fertilization is apparent | Pollen maximum before silks indicate fertilization (days) | Maximum length of silks (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Reid's Yellow Dent | 120 | 13 | 11 | 5.9 | 0.3 | 5.6 | 3.9 | 2.0 | 0.3 | 2.8 |
| Hogue's Yellow Dent | 113 | 16 | 10 | 6.5 | 1.1 | 5.4 | 5.0 | 1.5 | 1.2 | 2.6 |
| Iowa Gold Mine | 117 | 14 | 10 | 5.6 | 0.9 | 4.7 | 4.1 | 1.5 | 0.6 | 2.3 |
| Leaming | 115 | 13 | 10 | 5.4 | 0.6 | 4.8 | 4.2 | 1.2 | 1.0 | 2.7 |
| Calico | 110 | 13 | 9 | 6.0 | 1.8 | 4.2 | 4.7 | 1.3 | 1.3 | 2.4 |
| Bloody Butcher | 113 | 14 | 11 | 5.9 | 2.0 | 3.9 | 4.6 | 1.3 | 1.2 | 2.2 |
| Boone County White | 105 | 16 | 12 | 6.8 | 2.5 | 4.3 | 6.1 | 0.7 | 2.4 | 2.0 |
| St. Charles White | 118 | 13 | 10 | 7.0 | 1.4 | 5.6 | 5.2 | 1.8 | 0.8 | 2.4 |
| Iowa Silver Mine | 116 | 14 | 11 | 6.7 | 1.2 | 5.5 | 5.3 | 1.4 | 1.3 | 2.5 |
| Nebraska White Prize | 107 | 18 | 14 | 7.5 | 1.6 | 5.9 | 5.4 | 2.1 | 1.4 | 2.5 |
| Pride of the North | 118 | 14 | 11 | 6.2 | 0.8 | 5.4 | 4.1 | 2.1 | 0.0 | 2.5 |
| Minnesota No. 13 | 120 | 11 | 8 | 5.3 | 0.9 | 4.4 | 4.1 | 1.2 | 0.6 | 2.2 |
| White Cap | 117 | 13 | 10 | 6.3 | 0.8 | 5.5 | 4.3 | 2.0 | 0.2 | 2.4 |
| University No. 3 | 117 | 12 | 9 | 6.4 | 1.9 | 4.5 | 5.2 | 1.2 | 0.7 | 2.2 |
| Average | 115 | 13.9 | 10.4 | 6.25 | 1.3 | 5.0 | 4.7 | 1.5 | 0.9 | 2.4 |

| Variety | Fertilization first apparent on silks: Before pollen maximum: Per cent of plants | Before pollen maximum: Days | After pollen maximum: Per cent of plants | After pollen maximum: Days | Before pollen begins: Per cent of plants | Before pollen begins: Days | After pollen ceases: Per cent of plants | After pollen ceases: Days | Number of days after silks appear | Barren plants per 100 | Plants with sterile tassels per 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) |
| Reid's Yellow Dent | 48 | 1.4 | 52 | 1.8 | 0 | 0 | 0 | 0 | 3.6 | 0 | 0 |
| Hogue's Yellow Dent | 42 | 0.9 | 58 | 2.7 | 0 | 0 | 0 | 0 | 3.9 | 6 | 1 |
| Iowa Gold Mine | 61 | 0.8 | 39 | 2.9 | 0 | 0 | 3 | 3 | 3.2 | 3 | 0 |
| Leaming | 45 | 0.6 | 55 | 2.4 | 0 | 0 | 0 | 0 | 3.6 | 4 | 0 |
| Calico | 45 | 0.6 | 55 | 2.9 | 0 | 0 | 0 | 0 | 2.9 | 7 | 2 |
| Bloody Butcher | 50 | 0.6 | 50 | 3.1 | 0 | 0 | 1 | 3 | 2.6 | 7 | 0 |
| Boone County White | 19 | 0.9 | 81 | 3.2 | 0 | 0 | 1 | 2 | 3.6 | 6 | 0 |
| St. Charles White | 48 | 1.1 | 52 | 2.5 | 0 | 0 | 2 | 2 | 3.8 | 0 | 0 |
| Iowa Silver Mine | 41 | 0.9 | 59 | 2.9 | 0 | 0 | 1 | 1 | 4.1 | 2 | 1 |
| Nebraska White Prize | 38 | 1.1 | 63 | 2.9 | 0 | 0 | 1 | 2 | 3.8 | 3 | 0 |
| Pride of the North | 68 | 0.9 | 32 | 1.8 | 0 | 0 | 0 | 0 | 3.3 | 1 | 0 |
| Minnesota No. 13 | 52 | 0.4 | 48 | 1.7 | 0 | 0 | 1 | 2 | 3.2 | 0 | 0 |
| White Cap | 63 | 0.8 | 37 | 2.0 | 1 | 1 | 0 | 0 | 3.5 | 2 | 1 |
| University No. 3 | 65 | 1.1 | 45 | 3.0 | 0 | 0 | 0 | 0 | 3.3 | 3 | 0 |
| Average | 49 | 0.9 | 52 | 2.6 | 0 | 0 | 0.7 | 1.0 | 3.5 | 3 | 0.4 |

TABLE 8.—*Relationship between the shedding of pollen, silking, and fertilization of corn. Two-year average, 1914-1915.*

| Variety | Number of plants averaged | Pollination period for variety (days) | | Number of days shedding pollen (individual plant average) | | | | | Pollen maximum before silks indicate fertilization (days) | Maximum length of silks (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum length | More than 12% plants shedding pollen | Entire period | Before silks appear | After silks appear | Before fertilization is apparent | After fertilization is apparent | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Reid's Yellow Dent | 219 | 13.5 | 10.5 | 6.2 | 1.3 | 4.8 | 5.0 | +1.2 | 1.5 | 2.5 |
| Hogue's Yellow Dent | 215 | 14.5 | 10.0 | 6.3 | 1.9 | 4.3 | 5.7 | +0.6 | 2.4 | 2.3 |
| Iowa Gold Mine | 227 | 13.5 | 10.0 | 5.6 | 1.5 | 4.1 | 4.9 | +0.7 | 1.7 | 2.1 |
| Leaming | 226 | 12.5 | 9.5 | 5.6 | 1.3 | 4.3 | 4.9 | +0.7 | 1.7 | 2.4 |
| Calico | 219 | 12.5 | 9.0 | 5.8 | 2.1 | 3.7 | 5.3 | +0.5 | 2.0 | 2.2 |
| Bloody Butcher | 223 | 13.5 | 10.5 | 5.8 | 2.1 | 3.7 | 5.4 | +0.3 | 2.0 | 2.2 |
| Boone County White | 203 | 15.0 | 11.0 | 6.7 | 3.0 | 3.2 | 7.7 | —1.0 | 4.1 | 2.0 |
| St. Charles White | 231 | 12.0 | 9.5 | 6.3 | 1.7 | 4.6 | 5.5 | +0.8 | 2.0 | 2.3 |
| Iowa Silver Mine | 225 | 13.5 | 10.5 | 6.4 | 2.9 | 3.5 | 6.9 | —0.5 | 3.5 | 2.4 |
| Nebraska White Prize | 210 | 15.5 | 12.0 | 6.8 | 3.3 | 3.5 | 6.7 | +0.1 | 3.1 | 2.3 |
| Pride of the North | 220 | 13.0 | 10.0 | 6.1 | 0.7 | 5.4 | 4.3 | +1.7 | 0.9 | 2.7 |
| Minnesota No. 13 | 233 | 11.5 | 9.0 | 5.6 | 0.6 | 5.0 | 4.3 | +1.3 | 0.8 | 2.5 |
| White Cap | 226 | 12.0 | 9.0 | 5.4 | 1.5 | 3.9 | 5.1 | +0.3 | 1.7 | 2.3 |
| University No. 3 | 227 | 12.0 | 9.0 | 5.9 | 2.4 | 3.5 | 5.7 | +0.2 | 2.0 | 2.2 |
| Average | 222 | 13.1 | 9.9 | 6.0 | 1.9 | 4.1 | 5.5 | +0.5 | 2.1 | 2.3 |

| Variety | Fertilization first apparent on silks | | | | | | | | | Barren plants per 100 | Plants with sterile tassels per 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before pollen maximum | | After pollen maximum | | Before pollen begins | | After pollen ceases | | Number of days after silks appear | | |
| | Per cent of plants | Days | Per cent of plants | Days | Per cent of plants | Days | Per cent of plants | Days | | | |
| (1) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) |
| Reid's Yellow Dent | 25 | 1.38 | 75 | 2.52 | 0 | 0 | 8.0 | 1.5 | 3.6 | 3.0 | 0.0 |
| Hogue's Yellow Dent | 21 | .90 | 79 | 3.27 | 0 | 0 | 5.0 | 1.9 | 3.7 | 4.5 | 0.5 |
| Iowa Gold Mine | 31 | .80 | 69 | 2.82 | 0 | 0 | 13.5 | 1.8 | 3.4 | 4.0 | 0.0 |
| Leaming | 23 | .60 | 77 | 2.46 | 0 | 0 | 7.0 | 3.2 | 3.5 | 4.5 | 0.0 |
| Calico | 23 | .60 | 77 | 2.83 | 0 | 0 | 16.5 | 2.1 | 3.2 | 6.0 | 1.0 |
| Bloody Butcher | 25 | .60 | 75 | 2.97 | 0 | 0 | 17.0 | 2.2 | 3.2 | 4.5 | 0.0 |
| Boone County White | 9 | .90 | 91 | 4.63 | 0 | 0 | 20.0 | 3.3 | 3.9 | 6.5 | 0.0 |
| St. Charles White | 24 | 1.10 | 76 | 2.96 | 0 | 0 | 6.5 | 2.5 | 3.8 | 2.0 | 0.0 |
| Iowa Silver Mine | 20 | .90 | 80 | 4.66 | 0 | 0 | 7.0 | 2.6 | 4.0 | 4.0 | 0.5 |
| Nebraska White Prize | 19 | 1.10 | 81 | 4.06 | 0 | 0 | 8.0 | 2.5 | 3.9 | 5.0 | 0.0 |
| Pride of the North | 37 | 1.10 | 63 | 2.02 | 0 | 0 | 4.5 | 1.0 | 3.7 | 1.5 | 4.0 |
| Minnesota No. 13 | 30 | .55 | 70 | 1.37 | 0 | 0 | 8.0 | 1.5 | 3.6 | 0.0 | 0.0 |
| White Cap | 31 | .80 | 69 | 2.95 | 0.5 | 1 | 21.5 | 1.8 | 3.6 | 1.5 | 0.5 |
| University No. 3 | 32 | 1.10 | 68 | 3.21 | 0 | 0 | 13.0 | 1.5 | 3.4 | 3.5 | 0.0 |
| Average | 25 | .89 | 75 | 3.05 | 0 | 0 | 11.1 | 2.1 | 3.6 | 3.6 | 0.5 |

TABLE 9.—*Summary of the relationships between the shedding of pollen, silking, and fertilization of corn. 1914, 1915, and 1920.*

| | 1914 | 1915 | 1920 | Av. |
|---|---|---|---|---|
| | *Days* | *Days* | *Days* | *Days* |
| Av. number of days after tassel is visible until— | | | | |
| a. Shedding of pollen begins | 5.2 | 7.0 | 6.9 | 6.4 |
| b. Tassel is entirely out | 5.7 | 5.8 | 7.5 | 6.3 |
| c. Silks first show | 7.8 | 8.3 | 8.9 | 8.3 |
| d. Pollen is shed at maximum rate | 8.2 | 10.8 | 10.4 | 9.8 |
| e. Silks attain maximum length | 9.9 | 10.5 | 11.8 | 10.7 |
| f. Silks show fertilization | 11.6 | 11.7 | 12.7 | 12.0 |
| g. Tassel ceases to shed pollen | 11.1 | 13.2 | 13.9 | 12.7 |
| Av. number of days after pollen begins to shed until— | | | | |
| a. Silks first appear | 2.6 | 1.3 | 2.0 | 2.0 |
| b. Pollen is shed at maximum rate | 3.0 | 3.8 | 3.5 | 3.4 |
| c. Silks show fertilization | 6.4 | 4.7 | 5.8 | 5.6 |
| d. Pollen ceases to shed | 5.9 | 6.2 | 7.0 | 6.4 |
| Av. maximum length attained by silks (inches) | 2.3 | 2.4 | 3.4 | 2.7 |
| Av. length of pollination period for variety in which— | | | | |
| 4 per cent or more plants shed pollen (days) | 12.5 | 13.8 | ...... | 13.1 |
| 12 per cent or more plants shed pollen (days) | 9.5 | 10.4 | ...... | 10.0 |

Fourteen varieties were observed and averaged for the years 1914 and 1915; and nine varieties were observed and averaged for 1920.

In 1914, 1,498 normally developed plants were observed for pollination relationship and averaged; in 1915, 1,606 plants were so observed; and in 1920, 67 such plants were observed.

the pollen which fertilizes the corn falls upon the silks during a three-day period centering upon the maximum shedding of pollen by the same plant. Seasonal climatic conditions influence the time elapsing between the various flowering stages of the corn plant. Favorable conditions at the time of the flowering period, as existed in 1915, caused the silks to appear 1.3 days earlier in relation to the initial shedding of pollen than was the case in the somewhat drier year of 1914. Unfavorable conditions tend to delay the development of the ears more than that of the tassels. Under adverse conditions, the extension of the pollination period for a cornfield by the variability of its individual plants is an important factor in reducing the number of otherwise imperfectly fertilized ears.

As an average for the two years 1914 and 1915, the average duration of shedding pollen by the individual plant was 6.0 days. The silks first appeared 1.9 days after pollen was being shed, and fertilization first became apparent by the characteristic change in appearance of silks 3.6 days later, or 0.6 of a day before the shedding of pollen ceased. The pollen was being shed at the maximum rate 2.1 days before fertilization was apparent by the change in appearance of the silks. Allowing 2.5 days for the fertilization to become manifest on the silks, it appears that the fertilizing pollen fell upon the silks within a day of the time when pollen was dropping at its maximum rate.

TABLE 10.—*Condition of silks at stated intervals after pollination. Hogue's Yellow Dent corn, 1921.*

| Hours after applying pollen at 5 P. M. | Condition of exposed portion of silks | | | | | |
|---|---|---|---|---|---|---|
| | General slight yellowish discoloration | Few silks darkly discolored | 20 per cent of silks darkly discolored | 50 per cent of silks darkly discolored | 75 per cent of silks darkly discolored | 100 per ct. of silks darkly discolored |
| | *Per cent of plants in condition indicated* | | | | | |
| 20 | 3 | 0 | 0 | 0 | 0 | 0 |
| 24 | 25 | 0 | 0 | 0 | 0 | 0 |
| 36 | 26 | 38 | 2 | 11 | 0 | 0 |
| 42 | 17 | 13 | 20 | 15 | 2 | 0 |
| 48 | 14 | 12 | 47 | 15 | 8 | 0 |
| 60 | 9 | 10 | 51 | 12 | 18 | 0 |
| 67 | 3 | 10 | 38 | 27 | 19 | 3 |
| 72 | ...... | 3 | 28 | 42 | 22 | 5 |
| 91 | ...... | ...... | 4 | 21 | 22 | 53 |
| 98 | ...... | ...... | 1 | 6 | 18 | 75 |
| 114 | ...... | ...... | ...... | 1 | 9 | 90 |
| 120 | ...... | ...... | ...... | ...... | 2 | 98 |
| 138 | ...... | ...... | ...... | ...... | ...... | 100 |

The data for columns 1 to 20 of Tables 6 and 7 are based entirely upon those plants which produced both silks and pollen. Plants with sterile tassels or barren of ears, as indicated in columns 21 and 22, were omitted in the other tabulations. During the two years, 3.6 per cent of all the plants for the fourteen varieties proved to be barren of ears and 0.5 per cent had sterile tassels.

While the average pollinating period for individual plants

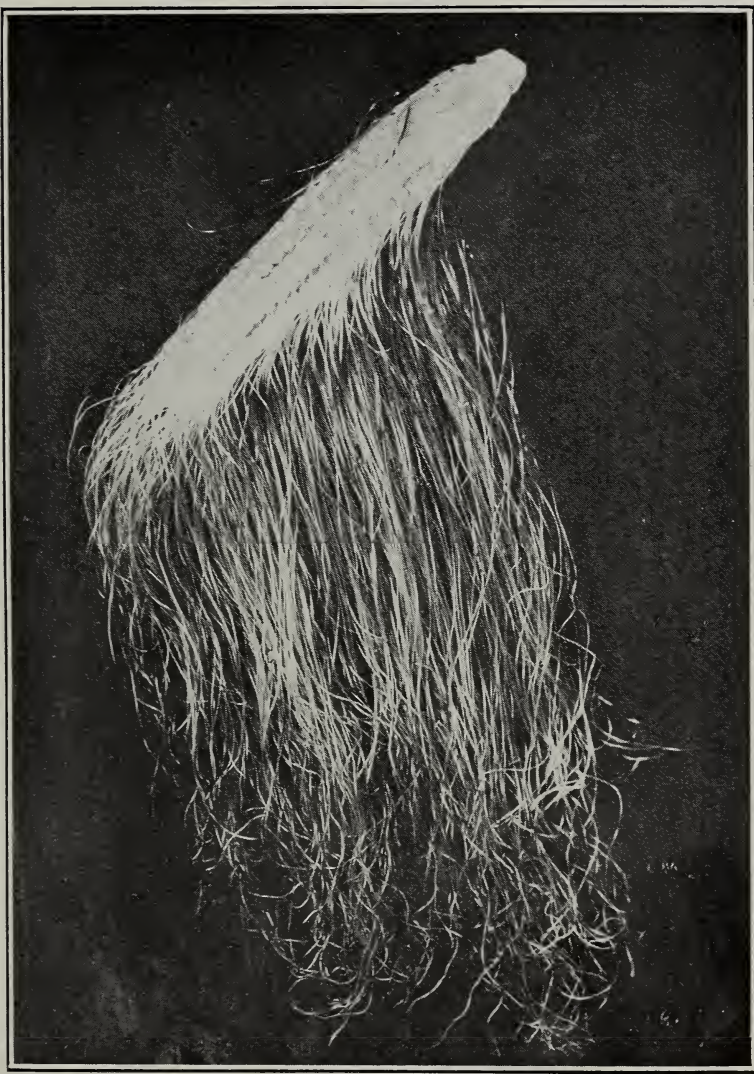


FIG. 5.—An ear of corn at silking time. Every kernel has its own silk and must be fertilized separately. In the process of fertilization, pollen falling on the silk germinates and grows a pollen tube thru the silk to the kernel, to which it conducts the two sperm nuclei. One of these nuclei fuses with the egg nucleus to form the initial embryo nucleus, and the other with the two polar nuclei, forming the initial endosperm nucleus. This entire process has been found to be completed within approximately 24 hours' time. Fertilization is reflected in the discoloration and drying of the silks in from 42 to 72 hours after pollination.

was only 6.0 days, the spread of time between the initial and final shedding of pollen by different plants within the variety equaled 13.1 days. This is due to a number of causes, including strain differences, delayed development, and soil inequalities. The average spread of time for the various varieties in which 12 per cent or more of the plants were shedding pollen equaled 9.9 days.

As a grand average for the three years, 1914, 1915, and 1920, the entire pollination period for a plant was 6.3 days. The silk first appeared two days after the dropping of the pollen began. Pollen was shed at the maximum rate 3.4 days after it began, which is practically midway in the pollinating period of the plant. The silks showed fertilization 5.6 days after the pollen began dropping, which is practically a day before it ceased. This suggests that the average plant in the average year is shedding pollen at approximately the maximum rate at the time when its ear is pollinated, thus providing ample opportunity for self-fertilization. The average length of time in these three years during which cornfields shed their pollen was 13.1 days, and 12 per cent or more of the plants in these fields shed pollen for a period of ten days.

## AMOUNT OF SELF-FERTILIZATION OCCURRING NORMALLY IN A CORNFIELD

In the year 1915, 40 plants of Nebraska White Prize corn were grown, distributed systematically 60 hills apart in a field of pure Hogue's Yellow Dent corn. Both varieties had identical flowering periods. The per cent of self-fertilization occurring in the Nebraska White Prize corn could be determined after maturity by the per cent of kernels on the Nebraska White Prize ears which were pure white. As a result of xenia the kernels fertilized by other plants were yellow. Upon maturity all of the kernels produced by the Nebraska White Prize plants were separated into four groups: (1) Those distinctly showing a yellow cast, which were unquestionably cross-fertilized; (2) those which were pure white and without a doubt self-fertilized; (3) those which showed only a very faint yellowish tinge and were doubtful as to purity; and (4) those kernels which had very light yellow caps and whose verification was desired.

In the following year, 1916, the last three groups were planted in the field and their pure or hybrid nature established by inbreeding 50 plants of each. (Table 11.) By this test the 1.05 per cent apparently pure white kernels were reduced to 0.7 per cent pure white. All of the kernels in the somewhat doubtful groups (3 and 4) proved to be hybrid. Thus it was established that only 0.7 per cent of the kernels of the Nebraska White Prize corn were self-fertilized. Natural field pollination under our conditions appears to be very effective in preventing self-fertilization.

TABLE 11.—*Amount of self-fertilization occurring with Nebraska White Prize corn plants grown scatteringly in a field of Hogue's Yellow Dent corn.*[1] *1915.*

| Classification of kernels | Per cent kernels based on eye separation | Per cent kernels after verifying those doubtful by planting and inbreeding |
|---|---|---|
| | *Per cent* | *Per cent* |
| Total kernels harvested | 100.00 | ..... |
| Distinctly yellow (hybrid) | 90.40 | ..... |
| White or faintly yellow— | | |
| Apparently pure white | 1.05 | 0.70 |
| Apparently hybrid | 3.80 | 3.80 |
| Doubtful kernels proved hybrid | 4.70 | 4.70 |
| Verified per cent of self-fertilization | | 0.70 |

[1]The initial flowering period of both varieties fell on the same dates.

#### EFFECT UPON SEED VALUE OF PREVENTING THE NORMAL AMOUNT OF SELF-FERTILIZATION OCCURRING IN A FIELD OF CORN

During the eight years 1912 to 1917 and 1920 and 1921, a comparative yield test was made of Nebraska White Prize seed corn which had been produced on detasseled plants as opposed to seed from plants not having the tassels removed. In the seed plat, planted to ordinary wind fertilized corn, 8 or more alternating rows were detasseled each year, and the 100 best developed ears were saved from both the detasseled and the undetasseled rows to furnish seed for the following year's yield test. The test plats consisted of single rows 16 rods in length, and were replicated from 6 to 12 times each year. The air-dry yields were based upon the first fifty hills, in each row, containing 3 plants and surrounded by a normal stand. The results are given in Table 12.

As an average for the eight years, the seed harvested from the detasseled rows yielded 48.6 bushels per acre, compared with 48.3 bushels for the seed from the normal rows. It is evident from these data that the amount of self-fertilization which

TABLE 12.—*Effect of detasseling upon the seed value of corn (Nebraska White Prize). Eight years, 1912-1917 and 1920-1921.*

| Seed from | Yield of grain per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| (1) | *Bushels* (2) | *Bushels* (3) | *Bushels* (4) | *Bushels* (5) | *Bushels* (6) | *Bushels* (7) | *Bushels* (8) | *Bushels* (9) | *Bushels* (10) |
| 1. Plants detasseled | 51.6 | 8.1 | 51.8 | 72.9 | 34.9 | 50.6 | 54.0 | 65.0 | 48.6 |
| 2. Plants not detasseled | 54.4 | 8.6 | 52.8 | 69.2 | 33.3 | 50.8 | 51.0 | 66.3 | 48.3 |
| Replications | 10 | 10 | 12 | 12 | 8 | 8 | 6 | 6 | |

| Seed from | Summary of plant characteristics during 6 years, 1914-1917 and 1920 and 1921 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tasseling | Date ripe | Lodging | Two-eared stalks per 100 plants | Barren plants per 100 | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (11) | *Inches* (12) | (13) | (14) | *Per cent* (15) | (16) | (17) | (18) | *Per cent* (19) | *Per cent* (20) |
| 1 | 101 | 49 | 8/1 | 9/22 | 27 | 4 | 4 | 13 | 5.4 | 82.0 |
| 2 | 101 | 48 | 8/1 | 9/22 | 28 | 6 | 4 | 13 | 5.5 | 81.9 |

actually occurs under our ordinary field conditions is negligible and that no material advantage results from selecting seed from detasseled rows and thereby assuring the prevention of all self-fertilization.

Incidentally the yields were determined separately for the detasseled and not detasseled rows in the seed plat for the purpose of determining the immediate effect of detasseling upon the current crop. As an average for the eight years (Table 13), the plats from which all of the tassels were removed yielded 43.6 bushels per acre as compared with 42.9 bushels for the normal corn. The tassels were removed at their first appearance by means of an upward pull which disjointed them without molesting the leaves.

TABLE 13.—*Immediate effect of detasseling upon the current grain yield of the detasseled plants. (Nebraska White Prize.) Eight years, 1912-1917 and 1920-1921.*

| Treatment | Yield of grain per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) | *Bu.* (9) | *Bu.* (10) |
| Detasseled........ | 51.6 | 10.9 | 38.2 | 68.1 | 39.9 | 41.5 | 43.4 | 55.1 | 43.6 |
| Not detasseled..... | 54.4 | 10.1 | 38.0 | 71.7 | 35.0 | 37.9 | 43.6 | 52.3 | 42.9 |
| Number of plats averaged........ | 8 | 18 | 19 | 8 | 8 | 8 | 8 | 8 | |

## ELEMENTAL STRAINS IN CORN AND THEIR HYBRIDIZATION

### SIGNIFICANCE OF ELEMENTAL STRAINS

An ordinary commercial variety of corn is very complex in its inheritance. We may think of such a variety as having for its basis a large number of elemental strains or "pure lines" which differ from each other in some more or less important structural or physiological characteristic. These elemental strains do not occur in the variety as a mere mechanical mixture, but rather as natural hybrids due to chance wind pollination. The characteristics transmitted by these elemental strains to their hybrid offspring is in accordance with the principles of Mendelian inheritance. They are represented in the germ plasm (chromosomes of the reproductive cells) in the form of Mendelian factors or units of inheritance. All inheritance is transmitted thru the chromosomes, of which field corn is believed to have uniformly ten in each egg or sperm cell. Upon hybridization these factors mingle and remain together in all the vegetative cells until shortly before the formation of eggs and sperms when they are segregated as units or groups, forming new combinations, part of which were derived from each of the parent plants.

In commercial varieties, these units of heredity undergo chance rearrangement at each fertilization and practically no

1 2 3 4

FIG. 6.—Effect of inbreeding and hybridizing Hogue's Yellow Dent corn. No. 1, typical Hogue's Yellow Dent plant. Nos. 2 and 4, typical elemental strains or pure line plants produced from Hogue's Yellow Dent (No. 1) by six years' continuous self-fertilization. No. 3, first generation hybrid plant grown from seed produced on No. 2 fertilized with pollen from No. 4.

plants occur in the simplicity of an elemental strain. However, thru controlled and repeated self-fertilization this simplicity of gametic constitution may be achieved, in which the Mendelian factors derived from the male and female parent are alike and all eggs and sperms produced by the offspring will have nuclei which carry the same Mendelian factors. This purified condition of the germ plasm, in which all zygotes, i. e., eggs and sperms, are alike, is called homozygous as opposed to the hybrid or heterozygous condition where two unlike zygotes have united and where many different kinds of zygotes may be formed by segregation of the factors derived from the parents.

The elemental strains differ in such visible physical and physiological characters as height of stalk, diameter of stalk, leaf area, leaf width, erectness of leaves, suckering tendency, brace root development, lodge resistance, firing of leaves, firing of tassels, sterility of tassels, barrenness of ears, stalk and leaf color, grain color, cob color, silk color, anther color, tassel conformation, shank development, ear type, kernel type, grain yield, disease resistance, and earliness of maturity.

Many heritable variations and gradations of these and ... hybrid

PLEASE CORRECT

Nebraska Research Bulletin 20, page 41, lines 3, 5, and 6,

y striking out the word "zygotes" and substituting "gametes".

ingly, the greater will be the ... conditions of some identical factors of inheritance from both parents uniting in the process of fertilization. Whenever these identical factors represent growth or vigor or production characters in the offspring, then there is likelihood of reduction in the size, vigor, and production of the individual offspring so constituted.

When all of the growth factors in both parents are identical, as in an artificially reduced "pure line," a marked degree of reduction in vigor, growth, and production results. Since there is variation in the degree of growth, vigor, or production represented in the corresponding Mendelian factors, much variation occurs in the vigor and productiveness of the different distinct elemental strains. In turn, when certain pairs of elemental strains are hybridized by controlled fertilization, their lines of immediate first generation offspring will differ from each other in vigor, growth, and production, in accordance with the effect

all eggs and sperms produced by the offspring will have nuclei which carry the same Mendelian factors. This purified condition of the germ plasm, in which all zygotes, i. e., eggs and sperms, are alike, is called homozygous as opposed to the hybrid or heterozygous condition where two unlike zygotes have united and where many different kinds of zygotes may be formed by segregation of the factors derived from the parents.

The elemental strains differ in such visible physical and physiological characters as height of stalk, diameter of stalk, leaf area, leaf width, erectness of leaves, suckering tendency, brace root development, lodge resistance, firing of leaves, firing of tassels, sterility of tassels, barrenness of ears, stalk and leaf color, grain color, cob color, silk color, anther color, tassel conformation, shank development, ear type, kernel type, grain yield, disease resistance, and earliness of maturity.

Many heritable variations and gradations of these and other plant characteristics are found in innumerable hybrid combinations in an ordinary corn variety. The particular chance combination of factors or groups of factors upon fertilization of the egg determines the exact nature of many of the individual plant characters as well as of the complete assemblage of characters comprising the plant in its entirety.

The more closely any variety, or individual corn grower's subvariety, has been selected for trueness to plant or ear type, thru prolonged continuous selection, the fewer will be the number of elemental strains represented in its composition. Accordingly, the greater will be the likelihood under ordinary field conditions of some identical factors of inheritance from both parents uniting in the process of fertilization. Whenever these identical factors represent growth or vigor or production characters in the offspring, then there is likelihood of reduction in the size, vigor, and production of the individual offspring so constituted.

When all of the growth factors in both parents are identical, as in an artificially reduced "pure line," a marked degree of reduction in vigor, growth, and production results. Since there is variation in the degree of growth, vigor, or production represented in the corresponding Mendelian factors, much variation occurs in the vigor and productiveness of the different distinct elemental strains. In turn, when certain pairs of elemental strains are hybridized by controlled fertilization, their lines of immediate first generation offspring will differ from each other in vigor, growth, and production, in accordance with the effect produced by the particular combination of Mendelian factors in each hybrid.

Tho perhaps possible, no elemental strain of corn has yet been found by the Nebraska Experiment Station, or to our knowledge has been reported elsewhere, which is as vigorous or productive as the original variety from which it was derived by repeated self-fertilization. On the other hand, a large range of degrees of productivity is found in first generation hybrids between various elemental strains, ranging from no increase to a somewhat greater productivity than that of the original variety. Our results and those of a number of other investigators would seem to justify more extended investigation of the practical possibilities of wholesale elimination of undesirable Mendelian factors and the recombination of those factors which result in superior production. Methods and results along this line at the Nebraska Experiment Station are as follows:

FIG. 7.—Covering tassels and ear shoots with paper bags preparatory to artificial self-fertilization. This is normal Hogue's Yellow Dent corn which has never been self-fertilized and may be compared for size with corn of the same variety in figure 8 which has undergone six years of inbreeding and is growing in the same field. Corn in both illustrations is full grown and at the same stage of development.

### PRODUCTION OF ELEMENTAL STRAINS

Two standard eastern Nebraska varieties of corn were used, Hogue's Yellow Dent and Nebraska White Prize. Inbreeding work with the former variety began in 1908 and with the latter in 1912. Ear-to-row strains were used as the foundation stock.

### TECHNIQUE OF ARTIFICIAL POLLINATION

The procedure in self-fertilization is to pollinate the silks of an ear with pollen produced by the tassel of the same plant. To accomplish this without contamination by foreign pollen, good quality manilla paper bags are inverted over the tassel and tied at its base a few days before the pollen is expected to be used, which usually is about the time when the tassel begins to shed pollen. This frequently is facilitated by removing the upper leaf. The enclosing of leaves in the bag is avoided, as the moisture accompanying transpiration may cause deterioration of the pollen. Whenever the ear shoot has made considerable growth, but a few days before the silks emerge, a paper bag

FIG. 8.—Inbreeding and crossbreeding pure lines of Hogue's Yellow Dent corn. The corn in this illustration may be compared for size with the original Hogue's Yellow Dent corn in figure 7, from which it was derived by six years of inbreeding.

FIG. 9.—The artificial corn breeding plats at the left contain 140 distinct inbred strains of Hogue's Yellow Dent and Nebraska White Prize corn. The corn to the right is standard Hogue's Yellow Dent.

is placed over the ear and closely tied with cord at its base. This excludes foreign pollen, which might otherwise fertilize the ear. The ears may be pollinated as soon as the silks are fully out. The presence of silks can usually be felt by the operator thru the bag. The presence of pollen in the bag over the tassel can readily be heard if the bag is given a gentle shaking. Transfer of the pollen to the silk is effected as follows: The operator loosens the cord holding the bag over the ear; he then moistens his hands in 10 per cent alcohol, to sterilize any foreign pollen which may be on them. The bag containing pollen is next removed from the tassel by a quick lateral movement, which avoids spilling the contents, and then the ear bag is carefully raised and the opening of the pollen bag inserted under it and over the ear, slipped down, and tied at its base. In placing the bag over the ear, it is desirable so to handle it that the pollen will remain in the bottom part of the bag, which may be well shaken after it has been tied, so as to insure pollination. As the ear grows in size, it becomes necessary to loosen the twine at its base once or twice. The bag should in no case be removed for

FIG. 10.—Elemental strains of Hogue's Yellow Dent corn after six years of inbreeding. The almost absolute uniformity of plants within each of the strains is suggested in the picture. Many such distinct strains form the foundation of an ordinary corn variety, in which they occur in hybrid combinations.

several weeks, until all possible danger of chance fertilization of belated silks is past. The source of pollen is indicated with hardware black pencil, on the bag, which serves for temporary identification. As soon after pollination as is convenient, fully marked identification tags are tied to each ear. Rain is sometimes a very disturbing element and may necessitate the renewal of bags over the tassels. Very satisfactory modifications of the above procedure are possible.

## LIFE OF POLLEN

In controlled pollination it is desirable to know how long pollen will retain viability after being shed. It is necessary that any foreign pollen which may have lodged upon the tassel at the time of covering should have lost its viability before the pollen is used in fertilization. For the purpose of approximating the life of pollen, the following tests were made: One hundred ear shoots of Hogue's Yellow Dent corn were bagged to exclude pollen. A quantity of pollen was shaken into a bag from a large number of plants. This was immediately stored in a dry building of 75°-85° F. At intervals of 10, 24, 30, 34, 38, 51,

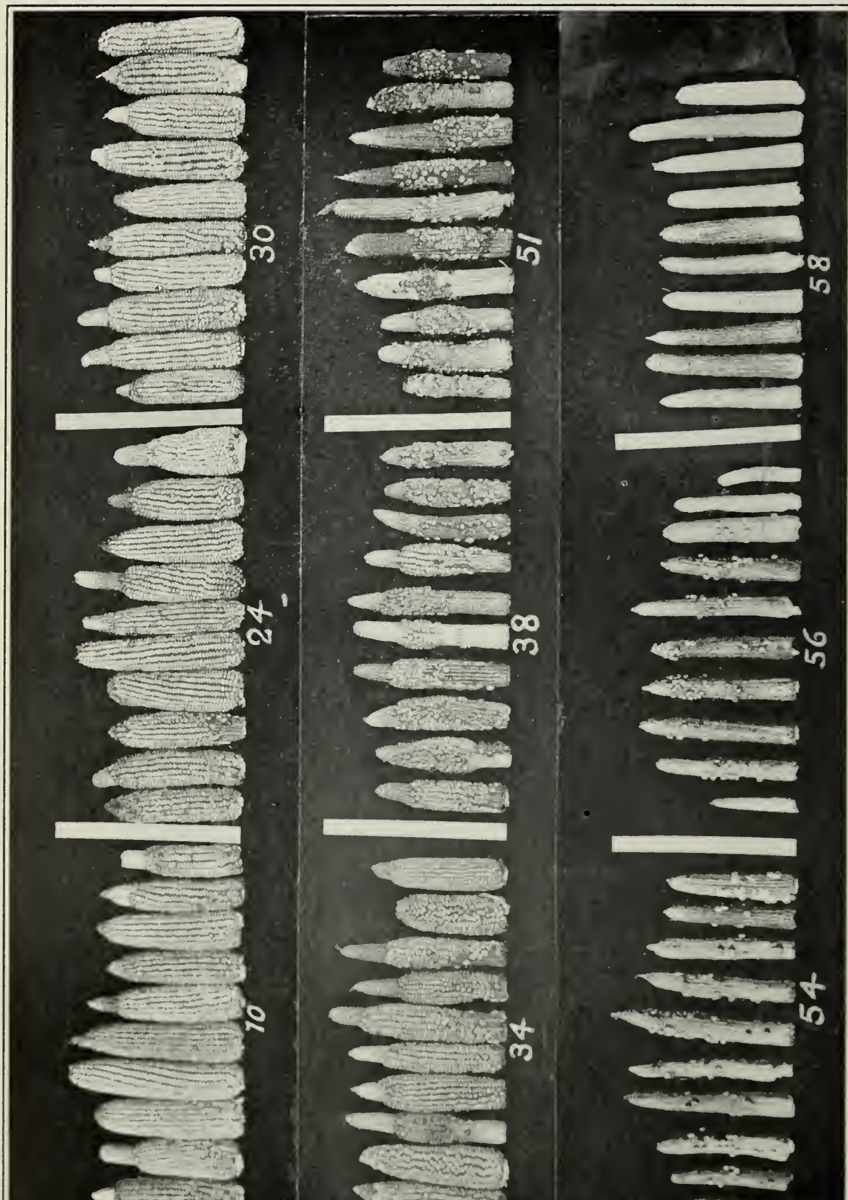



FIG. 11.—Life of pollen. The number of hours elapsing under rather favorable conditions between the time of gathering and the time of applying pollen is shown by the figures beneath each group of ten ears. The life of pollen varies under different conditions, commonly being of shorter duration in the field than is here indicated.

54, 56, and 58 hours after collecting the pollen, ten of the covered ears, having abundant silk development, were fertilized with this pollen. The relative viability of pollen at various ages is illustrated by the number of kernels fertilized on the ears shown in figure No. 11. Fertilization was very poor at the end of 51 hours and failed after 58 hours.

In 1920, fresh pollen was collected at 7 A. M. from 40 tassels and was well mixed. This was immediately divided into 10 paper bags which were tied to the tops of corn plants in the cornfield, where they remained until used. The temperature range was from 75° F. to 100° F. and the mean relative humidity ranged from 30 to 70 per cent. Ears pollinated with this pollen 10 and 15 hours after it was collected showed good fertilization; but the pollen had practically lost its viability at the end of 24 hours. Thus it may be inferred that pollen kept under such intermediate conditions will have lost its viability at the end of 20 to 60 hours after shedding.

### LIFE OF SILKS

The life of the unfertilized silk is seldom a problem in experiments involving the artificial fertilization of corn. Control tests have indicated that silks are receptive to pollination before they have emerged from the husk, and for a period of two weeks thereafter. The earliest effective application of pollen in some instances necessitated opening the husks three or four inches to reach the silks. In other cases of delayed yet effective pollination silks were exposed for a length of twelve inches. Silks continue to grow in length for some time if pollen is withheld. Such silks may be cut off to a short length and yet be successfully pollinated. In controlled fertilization experiments which necessitate covering the young ears, it is important to keep them covered for some time after applying the pollen, in order to avoid the chance pollination of late receptive silks.

Dr. E. C. Miller of the Kansas Agricultural Experiment Station has found by means of histological studies that fertilization of the kernel is effected within a period of about 24 hours after applying pollen to the silk. Thru similar studies, Dr. Paul Weatherwax of the University of Georgia estimates the lapse of time between pollination and fecundation at about twenty-five hours. Germination of the pollen on the silk is rather rapid. In our tests regarding this, the tip ends of the ear shoots were sterilized in alcohol six hours after pollination, and were cut off a short distance below the end of the husks in order to completely remove the portion of the silks to which the pollen had been applied. The ears were kept covered to exclude further pollination. Almost perfect fertilization of the ears resulted, indicating rapid development of the pollen tube. Following fertilization, the silk shrivels up at its base, thus cutting off further sap supply. Thereupon the silk withers and dies, the first reliable external evidence of which is observed on the silks in from forty to seventy hours after pollination.

## HOGUE'S YELLOW DENT (CLASS IX) PURE LINES AND HYBRIDS

### PURE LINES

These pure lines were derived from the 1907 progeny of the four highest yielding ear-to-row strains determined in a two-year (1906-1907) test with 204 individual ears of Hogue's Yellow Dent corn. These four ear-to-row strains were assigned the stock numbers 5, 6, 15, and 17. Three well-developed ears were selected from each of these four strains and planted individually in small partially isolated increase plats, in 1908, constituting twelve inbred strains. Beginning with 1909, single ears from each of the strains were planted in adjacent rows for controlled self-fertilization. In 1911 four of the inbred strains had become sterile and another was lost in 1915. Figure 12 shows representative plants of the eight surviving strains in 1915. The plant to the left is typical of the original variety, while the others from left to right are strains Nos. 1, 2, 4, 5, 8, 9, 10, 12. (Table No. 14.) Typical ears borne by the strains in 1916 are shown in figure 13.

Table No. 14 gives the comparative yields and plant characters (1916) for seven strains, and for the original Hogue's Yellow Dent. Considerable variation is seen to exist in the productivity of different strains, tho the best one yielded only 41 per cent as much as the original. Comparing the average of the seven inbred strains with the original Hogue's Yellow Dent corn: (1) The date of tasseling was one day earlier; (2) the date of ripening was three days earlier; (3) the stalk height was 63 per cent; (4) the ear height was 53 per cent; (5) the leaf area was 56 per cent; and (6) the grain yield was 27 per cent as large. Yield tests of the individual strains have not been made in other years, tho they have been compared in composite with the original each year, beginning with 1911. The annual composite results are included in Table 25 on page 72. During the years 1911, 1912, 1913, 1914, 1915, 1916, and 1917 the pure lines yielded respectively 47, 35, 13, 23, 34, 28, and 30 per cent as much grain per acre as the original corn.

In 1914, after five years of selfing, these strains had apparently all attained the pure elemental state, since their progeny

TABLE 14.—*Comparison of pure lines of Hogue's Yellow Dent corn with the original. 1916.*

| Strain No. | Stock | Date tassel-ing | Date ripe | Ear height | Stalk height | Leaf area per plant | Suckers per 100 plants | Barren plants per 100 | 2-eared stalks per 100 plants | Lodg-ing | Shrink-age of ear corn | Per cent shelled corn | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | *Feet* (5) | *Feet* (6) | *Sq. in.* (7) | (8) | (9) | (10) | *Per ct.* (11) | *Per cent* (12) | *Per cent* (13) | *Bu.* (14) |
| 1 | 5 | 7/22 | 9/18 | 1.5 | 3.8 | 649 | 4 | 1 | 6 | 12 | 2.1 | 77.6 | 14.5 |
| 2 | 5 | 7/22 | 9/18 | 1.5 | 3.8 | 796 | 12 | 1 | 4 | 1 | 1.6 | 77.1 | 8.0 |
| 4 | 6 | 7/21 | 9/18 | 1.6 | 3.7 | 632 | 10 | 14 | 2 | 1 | 3.1 | 73.0 | 2.3 |
| 5 | 6 | 7/23 | 9/17 | 1.8 | 4.5 | 745 | 4 | 8 | 0 | 95 | 5.4 | 56.1 | 3.1 |
| 8 | 15 | 7/23 | 9/17 | 1.8 | 4.4 | 651 | 2 | 1 | 5 | 9 | 1.2 | 85.0 | 10.8 |
| 10 | 17 | 7/23 | 9/17 | 1.7 | 4.5 | 687 | 9 | 12 | 6 | 18 | 1.3 | 84.9 | 15.4 |
| 12 | 17 | 7/23 | 9/13 | 1.8 | 4.6 | 700 | 1 | 1 | 1 | 12 | 2.1 | 77.4 | 14.8 |
| Average | ...... | 7/22 | 9/17 | 1.6 | 4.1 | 694 | 6 | 5 | 3 | 21 | 2.4 | 75.8 | 9.8 |
| Original | ...... | 7/23 | 9/20 | 3.0 | 6.5 | 1,244 | 48 | 8 | 2 | 49 | 2.8 | 81.0 | 37.5 |

These data have been corrected according to check plats of the original Hogue's Yellow Dent corn so as to be comparable with the data for hybrids of these pure lines reported in Table 16.

appeared to be uniform in all characteristics. Further proof of this pure (homozygous) condition was had in 1916. Several ears of each strain were fertilized with pollen from sister plants of the same strain in 1915. These were planted in 1916 in comparison with the self-fertilized seed. The sister bred corn was no more vigorous than the inbred and could not be distinguished from it. This lack of increased vigor following sister breeding is evidence of purity as to Mendelian factors. All plants of each strain appeared to have identical germ plasm and all plants were similar except as affected by slight environmental differences.


Strain No. Orig. 1 2 4 5 8 9 10 12

Fig. 12.—Typical plant of Hogue's Yellow Dent corn at left. At right, typical plants of eight distinct pure lines of the same variety after six years of self-fertilization. When used in hybridization, each strain transmits some unique characters to its hybrid offspring. The comparative growth and grain yields for these strains in 1916 are given in Table 14. Corn photographed in 1915.

### HYBRIDS

Where many elemental strains are being grown in close proximity, hybridization between them must be effected by means of artificial control in order to avoid contamination. This is accomplished by transferring the pollen of one strain to the ear of another strain in the same manner as has been described on page 43 for the production of pure lines. When the resultant seed is planted, the first generation ($F_1$) hybrid plants

Strain No.
Orig. 8 2 5 1 4 10 12

FIG. 13.—Typical ear of Hogue's Yellow Dent corn at left. At right, typical ears of seven distinct pure lines of the same variety after six years of self-fertilization. The yields for these strains in 1916 are given in Table 14, and were respectively: Original, 37.5 bu.; 8, 10.8 bu.; 2, 8.0 bu.; 5, 3.1 bu.; 1, 14.5 bu.; 4, 2.3 bu.; 10, 15.4 bu.; and 12, 14.8 bu. per acre.

are produced. In figure 14 are shown representative plants of each of ten different $F_1$ hybrid combinations among the elemental strains shown in figure 12. Many other combinations of these seven strains have been grown and all showed increased vigor except the cross between strains 8 and 10. These two strains, altho originating from entirely different stock, do not differ materially in any visible character except in color of the midrib of the leaf and leaf sheath. Strain No. 10 has an orange-colored midrib, while No. 8 has a green midrib. It is likely that they are nearly identical in the Mendelian factors associated with vigor of growth. No extensive detailed study has been made of the Mendelian behavior of the various plant characters. However, the crooked stalk of strain 5 (fig. 12) is dominant in all of its $F_1$ hybrids (hybrids Nos. 12×5 and 10×5, fig. 14), and in the second generation ($F_2$) it breaks up in the normal $F_2$ ratio. The orange midrib of strain No. 10 is recessive in its $F_1$

Male parent: 12 1 10 10 2 2 12 10 5 5
Female parent: 4 4 8 9 8 12 10 2 12 10

Fig. 14.—Typical plant of Hogue's Yellow Dent corn at left and typical plants of ten first generation hybrids between some of the inbred strains shown in figure 12. The numbers below the plants show which of the strains in figure 12 were crossed. The grain yields of eight of these hybrids are given in Table 15 for four years in comparison with the original Hogue's Yellow Dent. Photograph taken in 1915.

hybrids, which break up in the simple Mendelian ratios in later generations. For example, comparing the first and second generations of the hybrid No. 2×10 (Table 16), all of the first generation plants had green midribs; while out of a total of 351 second generation hybrid plants observed, 78 had orange and 273 green colored midribs. This amounts to an actual 22 per cent orange colored midribs, whereas the theoretical number for a simple unit character should be 25 per cent.

Only eight $F_1$ hybrids between elemental strains reported

TABLE 15.—*Comparison of first generation hybrids of Hogue's Yellow Dent corn pure lines with the original variety. 1913, 1915, 1916, and 1917.*[1]

| Pure lines crossed | Date tassel-ing | Date ripe | Ear height | Stalk height | Suckers per 100 plants | Barren plants per 100 | 2-eared stalks per 100 plants | Lodg-ing | Leaf area per plant | Shrink-age of ear corn | Shelling per cent | Bushels per acre of shelled corn | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 1913 | 1915 | 1916 | 1917 | 2-year average 1915-'16 | 4-year average |
| (1) | (2) | (3) | *Feet* (4) | *Feet* (5) | (6) | (7) | (8) | *Per cent* (9) | *Sq. in.* (10) | *Per cent* (11) | *Per cent* (12) | *Bu.* (13) | *Bu.* (14) | *Bu.* (15) | *Bu.* (16) | *Bu.* (17) | *Bu.* (18) |
| 4 × 12.... | 7/23 | 9/19 | 2.8 | 6.5 | 41 | 1 | 23 | 23 | 900 | 2.3 | 83.1 | 22.0 | 61.9 | 38.8 | 60.6 | 50.3 | 45.8 |
| 4 × 1..... | 7/23 | 9 19 | 2.7 | 6.3 | 68 | 2 | 35 | 10 | 1,003 | 2.5 | 85.2 | 26.8 | 64.8 | 53.2 | 41.6 | 59.0 | 46.6 |
| 12 × 5..... | 7/26 | 9/23 | 3.2 | 7.5 | 0 | 1 | 28 | 39 | 1,112 | 4.8 | 81.5 | 22.8 | 69.5 | 44.6 | 48.5 | 57.0 | 46.4 |
| 8 × 2..... | 7/26 | 9/22 | 3.0 | 7.1 | 72 | 2 | 41 | 8 | 968 | 5.2 | 90.2 | 20.1 | 71.3 | 66.2 | 51.9 | 68.7 | 52.4 |
| 12 × 2..... | 7/27 | 9/23 | 3.3 | 7.3 | 27 | 2 | 40 | 9 | 1,070 | 4.2 | 87.2 | 21.9 | 73.6 | 58.0 | 59.4 | 65.8 | 53.2 |
| 10 × 12.... | 7/25 | 9/21 | 3.1 | 7.3 | 4 | 0 | 37 | 29 | 925 | 3.9 | 86.6 | 22.7 | 57.9 | 51.5 | 53.6 | 54.7 | 46.4 |
| 10 × 5..... | 7/27 | 9/22 | 3.2 | 7.1 | 2 | 5 | 31 | 56 | 1,104 | 4.9 | 86.9 | 24.2 | 61.0 | 43.3 | 51.0 | 52.1 | 44.9 |
| 2 × 10.... | 7/26 | 9/23 | 3.2 | 7.5 | 72 | 0 | 41 | 18 | 996 | 3.2 | 90.1 | 25.6 | 75.4 | 58.2 | 45.2 | 66.8 | 51.1 |
| Average.... | ...... | 9/21 | 3.1 | 7.1 | 36 | 2 | 34 | 24 | 1,010 | 3.9 | 86.3 | 23.3 | 66.9 | 51.7 | 51.5 | 59.3 | 48.3 |
| Original.... | 7/28 | 9/23 | 3.3 | 7.5 | 60 | 4 | 25 | 29 | 1,236 | 7.3 | 83.1 | 11.4 | 73.1 | 34.5 | 46.0 | 53.8 | 41.2 |

[1]Seed was too limited for a yield test of the individual crosses in 1914, due to the drouth in 1913. All data except yields are the average for 1915 and 1916 only. Most of the records were not kept in 1913 and 1917.

in Table 14 have been grown continuously thru a period of four years, 1913-1917. The results with these are shown in Table 15. As a four-year average for the eight hybrids, the yield of the original corn was exceeded by 17 per cent, while the highest yielding combination (12x2) yielded 29 per cent more grain than the original variety. In this connection attention may be called to the fact that the original Hogue's Yellow Dent has never been subjected to any degree of close breeding and is one of the highest yielding varieties ever grown at the Experiment Station. Detailed notes were taken for some of the plant characters in addition to the yield during 1915 and 1916. Compared with the original the eight hybrids ripened two days earlier on an average, were four inches shorter, and had 24 suckers and 2 barren stalks fewer per 100 plants. The leaf area was 13 per cent smaller, the shelling percentage 4 per cent higher, and the grain yield 10 per cent greater.

FIG. 15.—A field of mature $F_1$ hybrids between pure lines of Hogue's Yellow Dent (Class IX). The center row and second row to the right show the inherited tendency to lodge imparted by pure line No. 5. See Table 14.

A COMPARISON OF FIRST, SECOND, AND THIRD GENERATION PURE LINE HYBRIDS

In 1915 several $F_1$ plants in each of the eight combinations shown in Table 16 were fertilized with composite pollen of 15 sister plants, in order to produce seed for second generation ($F_2$) hybrid plants to be tested in 1916. In 1916, $F_2$ hybrid seed was again produced in the same manner, and third generation ($F_3$) hybrid seed was similarly produced from $F_2$ plants. First generation hybrid seed was produced anew each year, for comparison. The comparative 1916 results for the individual first and second generation hybrids are shown in Table 16, in contrast with the average results for the pure lines and the original corn. The original corn yielded 37.5 bushels per acre; the seven pure lines averaged 9.8 bushels; the eight first generation hybrids averaged 51.7 bushels; and the second generation hybrids 25.1 bushels per acre. Thus the $F_1$ crop yielded 138 per cent as much, the $F_2$ crop 67 per cent as much, and the pure lines 26 per cent as much as the original variety from which they were produced.

The increased degree of homozygosity due to Mendelian segregation and recombination of parental factors would account for the reduction in yield of the second generation plants, which is nearly in accordance with expectancy in a hybrid population in which the factors represented were all derived from two homozygous individuals.

In 1917, $F_1$, $F_2$, and $F_3$ pure line hybrids were available for comparison. (Table 17.) The original seed yielded 46 bushels, the $F_1$ averaged 51.5 bushels, the $F_2$ 29.4 bushels, and the $F_3$ 25.6 bushels per acre. This extreme reduction in yield of the $F_2$ and $F_3$ crop below the yields of the $F_1$ and the original variety is evidence to show that, in any application of the principles of corn improvement thru crossing two pure lines, it is essential to avoid selecting seed from the hybrid progeny. An experiment is under way in which seed of a large number of elemental strains are mixed to be grown thereafter as a variety without further controlled inbreeding and hybridization. By mixing a large number of strains, the chance of union of like gametes is reduced and when enough strains are used will become small, as in ordinary commercial varieties. At the same time, advantage would be taken of the process of weeding out inferior strains thru inbreeding.

The two years' results with $F_1$ and $F_2$ crop are summarized in Table 18 and show respective yields of 52.2 and 27.8 bushels per acre in comparison with 41.7 bushels for the original corn.

TABLE 16.—*Comparison of first and second generation hybrids of pure lines of Hogue's Yellow Dent corn with the original variety. 1916.*

| Description | Date tassel-ing | Date ripe | Ear height | Stalk height | Leaf area per plant | Suckers per 100 plants | Barren plants per 100 | Two-eared stalks per 100 plants | Lodging | Shrinkage of ear corn | Shelling per cent | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Feet* | *Feet* | *Sq. in.* | | | | *Per cent* | *Per cent* | *Per cent* | *Bushels* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| 4 × 12 $F_1$ | 7/18 | 9/18 | 3.0 | 6.0 | 879 | 38 | 5 | 1 | 38 | 1.5 | 80.0 | 38.8 |
| $F_2$ | 7/18 | 9/16 | 2.7 | 5.7 | 813 | 17 | 12 | 2 | 9 | 1.6 | 75.6 | 21.6 |
| Difference | 0 | —2 | —0.3 | —0.3 | —66 | —21 | +7 | +1 | —29 | +0.1 | +4.4 | —17.2 |
| 4 × 1 $F_1$ | 7/17 | 9/16 | 2.7 | 5.9 | 1,027 | 82 | 4 | 1 | 16 | 2.3 | 84.3 | 53.2 |
| $F_2$ | 7/16 | 9/15 | 2.7 | 5.7 | 946 | 60 | 12 | 5 | 7 | 1.7 | 79.6 | 31.4 |
| Difference | —1 | —1 | 0.0 | —0.2 | —81 | —22 | +8 | +4 | —9 | —0.6 | —4.7 | —21.8 |
| 12 × 5 $F_1$ | 7/20 | 9/20 | 3.2 | 6.7 | 1,151 | 1 | 2 | 0 | 52 | 2.6 | 80.8 | 44.6 |
| $F_2$ | 7/19 | 9/16 | 3.0 | 6.2 | 980 | 3 | 15 | 0 | 47 | 3.5 | 67.5 | 15.9 |
| Difference | —1 | —4 | —0.2 | —0.5 | —171 | +2 | +13 | 0 | —5 | +0.9 | —13.3 | —28.7 |
| 8 × 2 $F_1$ | 7/19 | 9/18 | 2.7 | 6.5 | 1,008 | 72 | 2 | 0 | 11 | 2.6 | 90.6 | 66.2 |
| $F_2$ | 7/25 | 9/21 | 2.6 | 4.7 | 979 | 41 | 5 | 6 | 42 | 2.9 | 87.3 | 38.3 |
| Difference | +6 | +3 | —0.1 | —1.8 | —29 | —31 | +3 | +6 | +31 | +0.3 | —3.3 | —27.9 |
| 12 × 2 $F_1$ | 7/20 | 9/20 | 3.5 | 6.7 | 1,031 | 38 | 2 | 2 | 8 | 2.2 | 87.2 | 58 |
| $F_2$ | 7/20 | 9/15 | 2.7 | 4.7 | 916 | 23 | 5 | 7 | 23 | 3.2 | 80.8 | 28 |
| Difference | 0 | —5 | —0.8 | —2.0 | —115 | —15 | +3 | +5 | +15 | +1.0 | —6.4 | —30 |
| 10 × 12 $F_1$ | 7/17 | 9/15 | 3.2 | 6.7 | 930 | 3 | 1 | 1 | 54 | 2.3 | 85.6 | 51.5 |
| $F_2$ | 7/19 | 9/15 | 2.5 | 5.7 | 933 | 1 | 8 | 1 | 79 | 2.3 | 79.6 | 24.1 |
| Difference | +2 | 0 | —0.7 | —1.0 | +3 | —2 | +7 | 0 | +25 | 0 | —6.0 | —27.4 |
| 10 × 5 $F_1$ | 7/22 | 9/20 | 3.3 | 6.3 | 1,185 | 1 | 5 | 1 | 92 | 2.5 | 86.0 | 43.3 |
| $F_2$ | 7/22 | 9/15 | 2.5 | 5.7 | 1,098 | 0 | 13 | 1 | 82 | 4.1 | 79.1 | 17.2 |
| Difference | 0 | —5 | —0.8 | —0.6 | —87 | —1 | +8 | 0 | —10 | +1.6 | —6.9 | —26.1 |
| 2 × 10 $F_1$ | 7/21 | 9/21 | 3.2 | 7.0 | 995 | 98 | 5 | 1 | 10 | 2.1 | 89.8 | 58.2 |
| $F_2$ | 7/23 | 9/15 | 3.2 | 6.0 | 926 | 38 | 11 | 3 | 72 | 2.5 | 86.6 | 24.0 |
| Difference | +2 | —6 | 0 | —1.0 | —69 | —60 | +6 | +2 | +62 | +0.4 | —3.2 | —34.2 |
| Average $F_1$ | 7/19 | 9/18 | 3.1 | 6.5 | 1,026 | 42 | 3 | 1 | 35 | 2.3 | 85.5 | 51.7 |
| Average $F_2$ | 7/20 | 9/16 | 2.7 | 5.5 | 949 | 23 | 10 | 3 | 45 | 2.7 | 79.5 | 25.1 |
| Original | 7/23 | 9/20 | 3.0 | 6.5 | 1,244 | 48 | 8 | 2 | 49 | 2.8 | 81.0 | 37.5 |
| Average of pure lines | 7/23 | 9/16 | 1.7 | 4.2 | 708 | 6 | 6 | 3 | 20 | 2.3 | 76.0 | 10.3 |

[1]Data for pure line parents compiled from Table 14 by including each in the average as often as it occurs in the hybrids.

The $F_2$ hybrids were compared directly with the original corn, and their yields are here corrected to check plat yields, to be comparable with the yield of the other corn.

**Table 17.**—*Comparison of first, second, and third generation hybrids of pure lines of Hogue's Yellow Dent corn with the original variety. 1917.*

| Description | | Date tasseling | Date ripe | Ear height | Stalk height | Suckers per 100 plants | Barren plants per 100 | Two-eared stalks per 100 plants | Lodging | Shrinkage of ear corn | Shelling per cent | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Feet* | *Feet* | | | | *Per cent* | *Per cent* | *Per cent* | *Bushels* |
| (1) | | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| 4 × 12 | $F_1$ | 8/6 | 10/2 | 3.2 | 7.2 | 9 | 0 | 4 | 7 | 3.8 | 85.0 | 60.6 |
| | $F_2$ | 8/5 | 10/1 | 3.0 | 5.0 | 2 | 0 | 5 | 33 | 6.7 | 83.5 | 32.0 |
| | $F_3$ | 8/2 | 10/1 | 2.0 | 4.7 | 3 | 4 | 12 | 27 | 5.3 | 83.0 | 22.3 |
| 4 × 1 | $F_1$ | 8/5 | 9/28 | 3.2 | 6.0 | 12 | 6 | 36 | 13 | 2.3 | 81.4 | 41.6 |
| | $F_2$ | 8/4 | 9/29 | 3.0 | 5.5 | 6 | 1 | 39 | 29 | 8.7 | 80.8 | 26.4 |
| | $F_3$ | 8/1 | 9/29 | 2.2 | 4.5 | 3 | 13 | 18 | 9 | 4.4 | 77.9 | 20.0 |
| 12 × 5 | $F_1$ | 8/5 | 10/1 | 3.5 | 6.5 | 2 | 3 | 23 | 40 | 6.8 | 81.4 | 48.5 |
| | $F_2$ | 8/3 | 9/28 | 3.0 | 5.7 | 2 | 1 | 7 | 57 | 6.7 | 78.8 | 22.8 |
| | $F_3$ | 8/3 | 9/28 | 2.5 | 5.2 | 0 | 5 | 1 | 56 | 6.6 | 75.9 | 19.3 |
| 8 × 2 | $F_1$ | 8/6 | 10/2 | 3.5 | 6.6 | 3 | 0 | 1 | 16 | 6.6 | 88.4 | 51.9 |
| | $F_2$ | 8/5 | 10/3 | 3.0 | 6.2 | 2 | 2 | 3 | 38 | 8.7 | 88.3 | 30.0 |
| | $F_3$ | 8/4 | 10/2 | 2.7 | 5.2 | 6 | 1 | 5 | 52 | 8.9 | 84.8 | 27.2 |
| 12 × 2 | $F_1$ | 8/4 | 10/1 | 3.4 | 7.0 | 5 | 2 | 16 | 22 | 6.9 | 86.3 | 59.4 |
| | $F_2$ | 8/4 | 10/2 | 3.0 | 5.5 | 0 | 4 | 9 | 46 | 7.0 | 85.5 | 32.1 |
| | $F_3$ | 8/3 | 9/29 | 2.7 | 5.2 | 2 | 3 | 4 | 41 | 5.4 | 85.6 | 32.7 |
| 10 × 12 | $F_1$ | 8/5 | 10/1 | 3.7 | 7.0 | 11 | 0 | 35 | 10 | 6.0 | 78.7 | [illegible]3.6 |
| | $F_2$ | 8/4 | 10/1 | 3.0 | 5.5 | 2 | 1 | 12 | 58 | 3.0 | 85.6 | 29.9 |
| | $F_3$ | 8/3 | 9/30 | 2.7 | 5.0 | 4 | 2 | 2 | 62 | 3.1 | 85.0 | 28.3 |
| *8 × 10 | $F_1$ | 8/6 | 10/1 | 3.0 | 6.0 | 2 | 7 | 4 | 35 | 12.3 | 80.7 | 16.4 |
| | $F_2$ | 8/7 | 10/2 | 2.0 | 5.0 | 3 | 0 | 11 | 26 | 7.4 | 84.1 | 18.0 |
| | $F_3$ | 8/7 | 10/2 | 2.2 | 4.7 | 0 | 2 | 10 | 44 | 10.0 | 83.3 | 21.2 |
| 2 × 10 | $F_1$ | 8/6 | 10/3 | 3.2 | 7.0 | 5 | 3 | 13 | 20 | 4.7 | 88.4 | 45.2 |
| | $F_2$ | 8/4 | 10/2 | 3.2 | 6.5 | 5 | 2 | 11 | 37 | 2.1 | 89.1 | 32.7 |
| | $F_3$ | 8/4 | 10/1 | 2.7 | 5.5 | 1 | 1 | 3 | 37 | 5.1 | 88.6 | 29.3 |
| Average $F_1$ | | 8/5 | 10/1 | 3.4 | 6.8 | 7 | 2 | 18 | 18 | 5.3 | 84.2 | 51.5 |
| Average $F_2$ | | 8/4 | 10/1 | 3.0 | 5.7 | 3 | 2 | 12 | 43 | 6.1 | 84.5 | 29.4 |
| Average $F_3$ | | 8/3 | 9/30 | 2.5 | 5.0 | 3 | 4 | 6 | 41 | 5.5 | 83.0 | 25.6 |
| Original | | 8/5 | 10/1 | 3.5 | 6.7 | 9 | 6 | 3 | 22 | 7.9 | 83.2 | 46.0 |

*The 8 × 10 was omitted from the averages because of its uncharacteristic hybrid behavior.

The three generations of corn were each compared directly with the original corn, which was used in check plats. In this table the second and third generations have been corrected according to check plats in order to make them comparable with the $F_1$ generation.

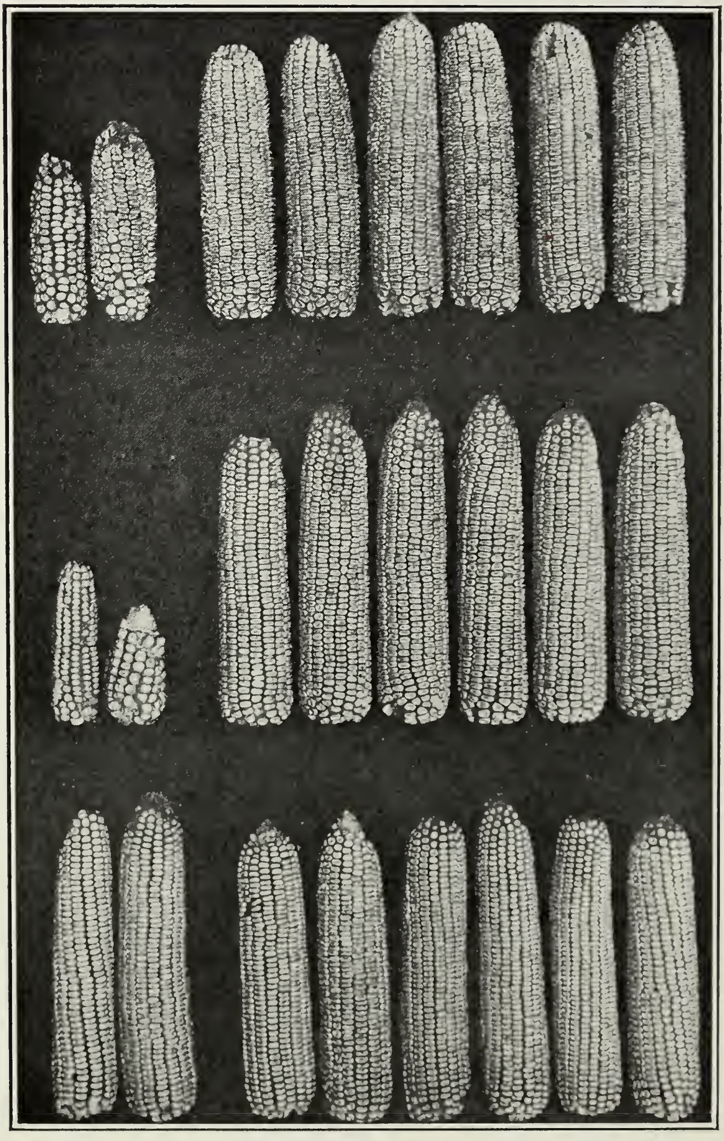


FIG. 16.—Representative ears showing effects of prolonged inbreeding followed by crossing of the homozygous pure lines. Lower row: Original commercial seed at left and progeny at right. Upper two rows: Inbred parents at left and first generation hybrid progeny at right.

TABLE 18.—*Summary of first and second generation hybrids of pure lines of Hogue's Yellow Dent corn. 1916-1917.*

| Pure lines crossed | Yield per acre (bushels) | | | | | |
|---|---|---|---|---|---|---|
| | First generation | | Second generation | | 2-year average | |
| | 1916 | 1917 | 1916 | 1917 | $F_1$ | $F_2$ |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 4 × 12 | 38.8 | 60.6 | 21.6 | 32.0 | 49.7 | 26.8 |
| 4 × 1 | 53.2 | 41.6 | 31.4 | 26.4 | 47.4 | 28.9 |
| 12 × 5 | 44.6 | 48.5 | 15.9 | 22.8 | 46.5 | 19.3 |
| 8 × 2 | 66.2 | 51.9 | 38.3 | 30.0 | 59.0 | 34.1 |
| 12 × 2 | 58.0 | 59.4 | 28.0 | 32.1 | 58.7 | 30.0 |
| 10 × 12 | 51.5 | 53.6 | 24.1 | 29.9 | 52.5 | 27.0 |
| 2 × 10 | 58.2 | 45.2 | 24.0 | 32.7 | 51.7 | 28.3 |
| Average | 52.9 | 51.5 | 26.2 | 29.4 | 52.2 | 27.8 |
| Original | 37.5 | 46.0 | 37.5 | 46.0 | 41.7 | 41.7 |

## HOGUE'S YELLOW DENT "LEAF AREA" PURE LINES AND HYBRIDS

### ORIGINAL STOCK

The origin of these selections dates back to 1905. In that year a large number of ordinary wind fertilized Hogue's Yellow Dent corn plants were measured individually for leaf area and for dry matter. The ratio of leaf area (in square inches) to dry matter (in grams) was calculated as a basis for type selection. The ears from two plants having a low ratio of leaf area per gram dry matter served as the foundation for "low leaf area" selections, while the ears from two plants having a high ratio of leaf area per gram dry matter formed the foundation for the "high leaf area" selection. The four ears were planted individually in ear-to-row plats in 1906 and a number of individual plants of their respective types selected from the progeny for planting ear-to-row plats in 1907. During 1907, 1908, and 1909, the "low leaf area" selections were planted in one isolated group of ear-to-row plats while the "high leaf area" selections were grown in another isolated group. This permitted free pollination between the strains selected for their respective types but avoided cross-pollination between the high and the low leaf area selections. In 1909, after three years' continuous selection respectively for high and low ratio of leaf area to dry matter,

TABLE 19.—*Description of the "high leaf area" and the "low leaf area" selections in 1909 from which the pure line "leaf area" strains recorded in Table 20 were derived by selfing during five successive years.*

| Pure lines derived from 1909 stock No. | Foundation stock number, 1909 | Description of foundation "leaf area" selections, 1909 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Date ripe | Height of stalk | Height of ear | Weight of stover | Weight of ear | Total weight | Leaf area per plant | Leaf area per gram dry weight |
| | | | *Inches* | *Inches* | *Grams* | *Grams* | *Grams* | *Sq. in.* | *Sq. in.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| "HIGH LEAF AREA" SELECTIONS | | | | | | | | | |
| 721, 743 | 94 | 9/20 | 113 | 54 | 268.9 | 264.9 | 533.8 | 1,541 | 2.89 |
| 722 | 921 | 9/21 | 112 | 55 | 216.9 | 255.3 | 472.2 | 1,471 | 3.12 |
| 725 | 93 | 9/21 | 109 | 50 | 221.3 | 265.5 | 486.8 | 1,450 | 2.98 |
| 726 | 92 | 9/20 | 111 | 52 | 246.9 | 271.6 | 518.5 | 1,561 | 3.01 |
| 728 | 91 | 9/20 | 112 | 53 | 253.5 | 257.1 | 510.6 | 1,448 | 2.83 |
| 741 | 98 | 9/20 | 115 | 47 | 245.6 | 313.0 | 558.6 | 1,407 | 2.52 |
| 746 | 97 | 9/19 | 114 | 52 | 254.9 | 312.9 | 568.0 | 1,561 | 2.75 |
| Average | ........... | 9/20 | 112 | 52 | 244.0 | 277.2 | 521.2 | 1,491 | 2.87 |
| "LOW LEAF AREA" SELECTIONS | | | | | | | | | |
| 730 | 925 | 9/17 | 110 | 40 | 206.5 | 247.7 | 454.2 | 1,049 | 2.31 |
| 731, 752, 753 | 924 | 9/16 | 112 | 46 | 232.6 | 276.8 | 509.4 | 1,207 | 2.37 |
| 732, 733, 734, 748 | 940 | 9/14 | 110 | 44 | 206.2 | 293.5 | 499.7 | 1,178 | 2.36 |
| 751, 735 | 938 | 9/13 | 106 | 43 | 213.6 | 278.1 | 491.7 | 1,147 | 2.38 |
| 736 | 937 | 9/14 | 114 | 44 | 218.4 | 285.2 | 503.6 | 1,174 | 2.33 |
| 737 | 933 | 9/14 | 108 | 45 | 246.1 | 286.8 | 532.9 | 1,240 | 2.37 |
| 738, 739 | 936 | 9/13 | 110 | 48 | 194.9 | 255.6 | 450.5 | 1,154 | 2.56 |
| 754 | 923 | 9/16 | 112 | 53 | 234.7 | 257.9 | 492.6 | 1,197 | 2.43 |
| 755, 756 | 942 | 9/15 | 106 | 44 | 247.2 | 275.8 | 523.0 | 1,073 | 2.05 |
| Average | ........... | 9/15 | 110 | 45 | 222.2 | 273.0 | 495.2 | 1,157 | 2.35 |

these selections tended strongly to come true to type, tho there was still considerable variation between the individual plants. The comparative growth characteristics of these different selections before inbreeding is shown for 1909 in Table 19.

Comparing the average of the low leaf area selections with the average of the high leaf area selections, the former had 82 per cent as much leaf area per gram dry matter, 77 per cent as much actual leaf area, 95 per cent as much total dry matter, 99 per cent as great ear weight, grew two inches shorter, and matured five days earlier. These comparisons were all based on individual measurements of ten representative plants for each strain. In addition to the above differences, a very distinct difference in ear type had unconsciously been developed for the two general groups. The low leaf area selection had a more slender ear, with shallower and flintier kernel, than the original variety. The high leaf area selections, on the other hand, were characterized by a somewhat larger ear circumference and a deeper and rougher kernel.

### INBRED STRAINS

During the six years 1909-1915 (omitting 1913), these 8 high and 17 low leaf area strains were subjected to continuous self-fertilization. The comparative growth at the end of this period of reduction to elemental strains is shown in Table 20, which gives the averages for the two years 1915-1916. Comparing the average of the low leaf area pure lines with the average of the high leaf area pure lines, the former had 84 per cent as much leaf area per gram dry matter, 76 per cent as much actual leaf area, 94 per cent as much total dry matter, 125 per cent as great ear weight, grew 2 inches taller, and matured 5 days earlier.

In the more important characteristics, practically the same relationships obtained between the two groups of pure lines as existed before self-fertilization. However, a great reduction in plant size and productivity had resulted from the continuous self-fertilization.

### HYBRIDS BETWEEN LEAF AREA PURE LINES

During 1915 and 1916 a comparative yield test was made of (1) 18 $F_1$ hybrids between low leaf area pure lines, (2) 4 $F_1$ hybrids between high leaf area pure lines, (3) 7 $F_1$ hybrids between high and low leaf area pure lines, and (4) original Hogue's Yellow Dent corn. The results are given in Table No. 21.

TABLE 20.—*Plant characters for leaf area inbreds. Average for two years, 1915-1916.*

| Pure line No. | 1909 stock number | 1905 family number | Date tasseling | Date ripe | Height ear | Height stalk | Dry weight stover | Dry weight ears | Total dry weight plant | Leaf area per stalk | Leaf area per gram dry matter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Feet* | *Feet* | *Grams* | *Grams* | *Grams* | *Sq. in.* | *Sq. in.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| HIGH LEAF AREA INBRED STRAINS | | | | | | | | | | | |
| 721 | 94 | 56 | 8/1 | 9/25 | 2.4 | 5.2 | 124.9 | 29.7 | 154.6 | 695 | 4.49 |
| 722 | 921 | 56 | 8/5 | 9/27 | 2.9 | 6.0 | 116.0 | 41.3 | 157.3 | 1,006 | 6.40 |
| 725 | 93 | 56 | 8/8 | 9/28 | 2.4 | 5.3 | 107.2 | 44.5 | 151.7 | 682 | 4.49 |
| 726 | 92 | 56 | 8/9 | 9/28 | 2.4 | 5.0 | 138.1 | 41.6 | 179.7 | 993 | 5.53 |
| 728 | 91 | 56 | 8/7 | 9/28 | 2.3 | 4.3 | 132.3 | 25.2 | 157.5 | 821 | 5.21 |
| 741 | 98 | 5113 | 8/8 | 9/28 | 2.6 | 5.4 | 163.6 | 38.0 | 201.6 | 831 | 4.12 |
| 743 | 94 | 56 | 8/7 | 9/28 | 2.4 | 5.2 | 112.7 | 47.2 | 159.9 | 781 | 4.88 |
| 746 | 97 | 5113 | 8/7 | 9/28 | 2.0 | 4.4 | 138.5 | 66.6 | 205.1 | 804 | 3.92 |
| Average | | | 8/7 | 9/28 | 2.4 | 5.1 | 129.2 | 41.8 | 170.9 | 827 | 4.88 |
| LOW LEAF AREA INBRED STRAINS | | | | | | | | | | | |
| 730 | 925 | 5123 | 7/30 | 9/24 | 2.0 | 5.3 | 85.8 | 54.2 | 140.0 | 555 | 3.96 |
| 731 | 924 | 5123 | 7/30 | 9/24 | 2.7 | 6.1 | 69.5 | 84.7 | 154.2 | 724 | 4.69 |
| 732 | 940 | 5132 | 8/2 | 9/26 | 2.5 | 5.4 | 112.8 | 20.8 | 133.6 | 687 | 5.14 |
| 733 | 940 | 5132 | 7/30 | 9/23 | 2.8 | 5.0 | 97.8 | 18.4 | 116.2 | 614 | 5.28 |
| 734 | 940 | 5132 | 8/1 | 9/23 | 2.7 | 5.6 | 90.5 | 35.4 | 125.9 | 698 | 5.54 |
| 735 | 938 | 5132 | 8/1 | 9/24 | 2.7 | 5.7 | 109.5 | 80.6 | 190.1 | 715 | 3.76 |
| 736 | 937 | 5132 | 7/28 | 9/21 | 2.2 | 5.3 | 109.3 | 54.3 | 163.6 | 576 | 3.52 |
| 737 | 933 | 5132 | 7/30 | 9/21 | 3.1 | 6.5 | 132.5 | 64.0 | 196.5 | 692 | 3.52 |
| 738 | 936 | 5182 | 7/28 | 9/21 | 3.0 | 4.2 | 105.0 | 9.3 | 114.3 | 707 | 6.18 |
| 739 | 936 | 5132 | 7/29 | 9/21 | 2.1 | 4.8 | 100.3 | 34.2 | 134.5 | 547 | 4.07 |
| 748 | 940 | 5132 | 7/28 | 9/21 | 2.9 | 5.7 | 144.3 | 42.4 | 186.7 | 658 | 3.52 |
| 751 | 938 | 5132 | 7/30 | 9/23 | 2.6 | 5.0 | 105.6 | 55.7 | 161.3 | 451 | 2.80 |
| 752 | 924 | 5132 | 7/29 | 9/23 | 2.7 | 6.3 | 147.4 | 56.2 | 203.6 | 856 | 4.20 |
| 753 | 924 | 5132 | 7/25 | 9/21 | 2.5 | 4.5 | 94.6 | 59.8 | 154.4 | 556 | 3.60 |
| 754 | 923 | 5132 | 7/31 | 9/25 | 1.9 | 4.5 | 110.4 | 109.3 | 219.7 | 559 | 2.54 |
| 755 | 942 | 5132 | 7/30 | 9/24 | 2.6 | 5.0 | 137.4 | 77.0 | 214.4 | 634 | 2.96 |
| 756 | 942 | 5132 | 7/26 | 9/22 | 2.6 | 6.0 | 96.3 | 29.4 | 125.7 | 511 | 4.07 |
| Average | | | 7/29 | 9/23 | 2.6 | 5.3 | 108.8 | 52.1 | 160.9 | 632 | 4.08 |
| Original | | | 7/28 | 9/25 | 3.5 | 7.9 | 237.1 | 312.4 | 549.5 | 1,256 | 2.29 |

[1]Measurements were not made for the original corn grown directly in connection with these pure lines. Therefore the data for the original corn, obtained under similar conditions in comparison with the hybrids between these pure lines and recorded in Table 21, are given here.

Comparing the averages of the low leaf area pure line hybrids with the average high leaf area pure line hybrids, the former had 82 per cent as much leaf area per gram dry matter, 82 per cent as much actual leaf area, 99 per cent as much total dry matter, 107 per cent as great ear weight, stalk height 6 inches taller, and matured 3 days earlier. The same two rather distinct ear types prevailed for the two groups that were noted for them in 1909, before any inbreeding had taken place. All of the plant and ear characters appeared uniform for each hybrid, except for some slight variations due to environmental differences.

TABLE 21.—*Comparison of first generation hybrids of pure lines of Hogue's Yellow Dent high leaf area and low leaf area selections with the original variety. Two-year average, 1915 and 1916.*

| Description | Date tasseling | Date ripe | Ear height | Stalk height | Suckers per 100 plants | Barren plants per 100 | 2-eared stalks per 100 plants | Lodging | Weight stover per plant | Weight ear per plant | Total plant weight | Leaf area per plant | Leaf area per gram dry matter | Shrinkage of ear corn | Shelling per cent | Yield per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Feet* | *Feet* | | | | *Per cent* | *Grams* | *Grams* | *Grams* | *Sq. in.* | *Sq. in.* | *Per cent* | *Per cent* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| HYBRIDS OF LOW LEAF AREA PURE LINES | | | | | | | | | | | | | | | | |
| 731 × 736 F₁ | 7/29 | 9/25 | 4.0 | 8.0 | 48 | 4 | 25 | 49 | 245.0 | 360.0 | 605.0 | 1,059 | 1.75 | 4.0 | 85.1 | 57.9 |
| 738 × 736 F₁ | 7/27 | 9/24 | 3.7 | 7.8 | 51 | 1 | 25 | 35 | 171.3 | 296.5 | 467.8 | 852 | 1.82 | 3.2 | 83.4 | 54.9 |
| 734 × 732 F₁ | 8/1 | 9/26 | 2.6 | 6.4 | 3 | 5 | 48 | 5 | 173.7 | 168.3 | 342.0 | 950 | 2.78 | 6.4 | 83.7 | 31.8 |
| 751 × 738 F₁ | 7/26 | 9/25 | 3.4 | 7.8 | 34 | 2 | 29 | 3 | 237.9 | 350.7 | 588.6 | 1,088 | 1.85 | 4.9 | 84.1 | 66.2 |
| 736 × 754 F₁ | 7/27 | 9/25 | 3.2 | 7.5 | 62 | 1 | 52 | 21 | 196.9 | 378.6 | 575.5 | 969 | 1.68 | 6.7 | 84.0 | 72.1 |
| 731 × 732 F₁ | 7/28 | 9/25 | 3.8 | 8.2 | 3 | 1 | 41 | 29 | 220.2 | 408.6 | 628.8 | 1,210 | 1.92 | 6.1 | 84.0 | 65.8 |
| 748 × 731 F₁ | 7/26 | 9/25 | 3.7 | 7.9 | 4 | 3 | 9 | 43 | 209.0 | 242.0 | 451.0 | 1,051 | 2.34 | 7.6 | 84.5 | 44.8 |
| 738 × 731 F₁ | 7/27 | 9/26 | 3.5 | 7.8 | 8 | 1 | 38 | 21 | 291.4 | 325.6 | 617.0 | 1,289 | 2.09 | 6.4 | 82.6 | 63.2 |
| 756 × 730 F₁ | 7/28 | 9/25 | 3.5 | 8.2 | 56 | 5 | 11 | 5 | 244.8 | 327.2 | 572.0 | 987 | 1.72 | 4.2 | 79.0 | 51.9 |
| 737 × 754 F₁ | 7/27 | 9/25 | 3.4 | 8.1 | 80 | 4 | 34 | 48 | 187.3 | 320.0 | 507.3 | 968 | 1.91 | 5.6 | 82.7 | 65.5 |
| 735 × 756 F₁ | 7/28 | 9/25 | 4.0 | 8.3 | 49 | 2 | 45 | 21 | 213.2 | 282.9 | 496.1 | 1,130 | 2.28 | 7.2 | 85.6 | 71.8 |
| 731 × 734 F₁ | 7/29 | 9/26 | 4.1 | 8.2 | 16 | 1 | 33 | 21 | 259.7 | 375.0 | 634.7 | 1,367 | 2.15 | 6.5 | 83.6 | 65.4 |
| 738 × 735 F₁ | 7/24 | 9/24 | 3.9 | 8.0 | 17 | 3 | 40 | 41 | 211.2 | 290.0 | 501.2 | 1,138 | 2.27 | 8.0 | 86.9 | 70.4 |
| 733 × 753 F₁ | 7/25 | 9/24 | 3.2 | 6.7 | 42 | 5 | 30 | 59 | 178.4 | 298.3 | 476.7 | 928 | 1.95 | 7.6 | 82.7 | 52.4 |
| 755 × 754 F₁ | 7/29 | 9/25 | 3.8 | 7.6 | 10 | 0 | 43 | 47 | 191.0 | 284.9 | 475.9 | 1,118 | 2.35 | 8.2 | 85.2 | 64.7 |
| 731 × 739 F₁ | 7/27 | 9/25 | 3.5 | 8.1 | 61 | 0 | 30 | 30 | 204.6 | 324.4 | 529.0 | 943 | 1.78 | 6.3 | 84.0 | 72.8 |
| 738 × 752 F₁ | 7/25 | 9/24 | 3.9 | 8.1 | 46 | 2 | 42 | 49 | 239.0 | 378.5 | 617.5 | 1,151 | 1.86 | 6.6 | 84.8 | 64.5 |
| 754 × 738 F₁ | 7/27 | 9/25 | 3.7 | 8.1 | 17 | 5 | 8 | 33 | 221.7 | 342.0 | 563.7 | 1,117 | 1.98 | 7.2 | 86.1 | 74.1 |
| Average... | 7/27 | 9/25 | 3.6 | 7.8 | 34 | 2.5 | 32 | 31 | 216.4 | 319.6 | 536.0 | 1,073 | 2.02 | 6.2 | 84.0 | 61.7 |
| HYBRIDS OF HIGH LEAF AREA PURE LINES | | | | | | | | | | | | | | | | |
| 743 × 746 F₁ | 7/31 | 9/28 | 3.7 | 7.3 | 11 | 2 | 39 | 5 | 247.5 | 309.0 | 556.5 | 1,268 | 2.28 | 8.6 | 78.4 | 68.9 |
| 743 × 722 F₁ | 7/30 | 9/23 | 3.3 | 6.6 | 8 | 2 | 24 | 22 | 208.8 | 236.7 | 445.5 | 1,240 | 2.80 | 6.4 | 80.1 | 54.0 |
| 726 × 741 F₁ | 7/31 | 9/28 | 3.5 | 7.7 | 22 | 1 | 24 | 47 | 262.0 | 348.5 | 610.5 | 1,324 | 2.17 | 10.8 | 65.9 | 40.7 |
| 728 × 746 F₁ | 7/31 | 9/23 | 3.4 | 7.2 | 26 | 2 | 40 | 7 | 246.0 | 302.0 | 548.0 | 1,402 | 2.56 | 6.9 | 81.2 | 58.8 |
| Average... | 7/31 | 9/23 | 3.5 | 7.2 | 17 | 2 | 32 | 20 | 241.1 | 299.0 | 540.1 | 1,311 | 2.45 | 8.2 | 76.4 | 55.6 |
| HYBRIDS OF LOW LEAF AREA BY HIGH LEAF AREA PURE LINES | | | | | | | | | | | | | | | | |
| 741 × 752 F₁ | 7/30 | 9/26 | 2.7 | 7.3 | 17 | 2 | 32 | 57 | 241.0 | 314.8 | 555.8 | 986 | 1.77 | 9.5 | 78.7 | 51.5 |
| 728 × 737 F₁ | 7/29 | 9/26 | 3.4 | 7.2 | 20 | 6 | 36 | 31 | 152.7 | 294.9 | 447.6 | 1,273 | 2.84 | 4.3 | 81.6 | 55.3 |
| 721 × 732 F₁ | 7/27 | 9/25 | 3.6 | 7.8 | 17 | 1 | 8 | 12 | 287.2 | 342.0 | 629.2 | 1,246 | 1.98 | 7.1 | 82.3 | 62.3 |
| 725 × 734 F₁ | 7/30 | 9/26 | 3.6 | 8.0 | 7 | 1 | 49 | 8 | 306.2 | 367.2 | 673.4 | 1,520 | 2.26 | 6.6 | 81.6 | 63.4 |
| 728 × 732 F₁ | 7/28 | 9/25 | 3.8 | 7.6 | 8 | 1 | 51 | 32 | 238.5 | 296.0 | 534.5 | 1,376 | 2.57 | 5.0 | 82.6 | 66.3 |
| 722 × 732 F₁ | 7/30 | 9/26 | 3.5 | 7.9 | 3 | 1 | 39 | 32 | 304.7 | 314.7 | 619.4 | 1,358 | 2.19 | 8.0 | 82.3 | 54.9 |
| 722 × 751 F₁ | 7/26 | 9/25 | 3.3 | 7.4 | 17 | 1 | 14 | 17 | 222.7 | 299.2 | 521.9 | 1,219 | 2.33 | 4.7 | 81.3 | 60.7 |
| Average... | 7/29 | 9/26 | 3.4 | 7.6 | 13 | 2 | 33 | 27 | 250.4 | 318.4 | 568.8 | 1,283 | 2.28 | 6.4 | 81.5 | 59.2 |
| Original..... | 7/28 | 9/25 | 3.5 | 7.9 | 63.7 | 2 | 30 | 50.2 | 237.1 | 312.4 | 549.5 | 1,256 | 2.29 | 8.3 | 84.1 | 55.1 |

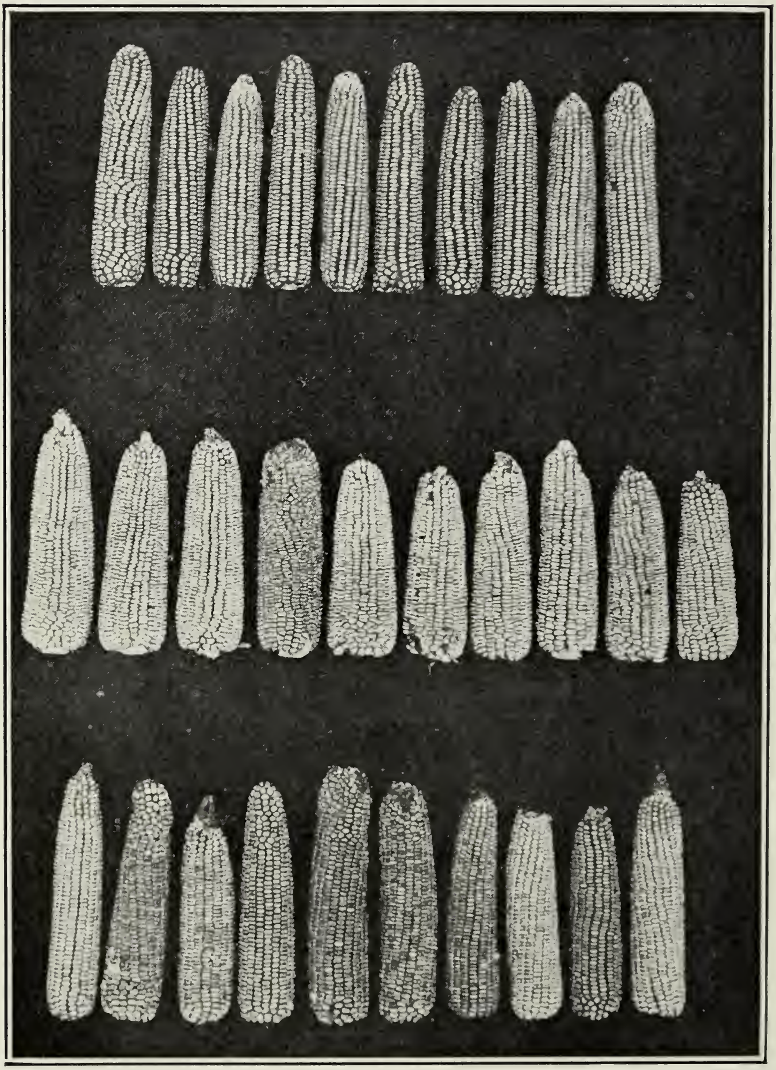


FIG. 17.—Upper, middle, and lower rows respectively: (1) Ears from ten successive plants of an $F_1$ cross between two "low leaf area" pure lines; (2) ears from ten successive plants of an $F_1$ cross between two "high leaf area" pure lines; (3) ears from ten successive plants of the original ordinary Hogue's Yellow Dent. (Table 21.)

It is interesting to note that the principal character, viz, ratio of leaf area to dry matter, showed an identical difference for the two groups in all three conditions—before inbreeding, after inbreeding, and after crossing. The plant and ear types, which had been fairly well fixed by ordinary plant selection within a variety, were carried over thru the inbreeding period for five years and retained in the $F_1$ pure line hybrids.

The $F_1$ hybrids between low leaf and high leaf area pure lines were intermediate in their ratio of leaf area to dry weight and also in ear type. Considerable variation occurred between different hybrids in yield of grain per acre, but as an average the hybrids were considerably more productive than the original. The yields of the low leaf hybrids, high leaf hybrids, low by high leaf hybrids, and the original averaged respectively 61.7, 55.6, 59.2, and 55.1 bushels. This is a 12 per cent greater yield for the average of the low leaf pure line hybrids compared with the original variety, while the highest yielding individual hybrid yielded 34 per cent more.

### RELATION BETWEEN VIGOR OF PURE LINE PARENTS AND PRODUCTIVITY OF FIRST GENERATION HYBRIDS

There has been much speculation regarding the relation between the vigor of the pure lines and of their hybrid progeny. The general concensus of opinion among students of this problem would seem to support the theory that those elemental strains which undergo the least reduction from inbreeding are likely to produce the most productive hybrid offspring when crossed.

The observations at this Station bearing upon this point may be of interest, altho they are hardly of sufficient extent to warrant conclusions. The yields of eight $F_1$ hybrids and their inbred parents are given for 1916 in Table 22. The average yield of the four hybrids in each of which the lowest yielding parent yielded not to exceed 3.1 bushels per acre was 45.0 bushels. In comparison, the average yield of the four hybrids in none of which the lowest yielding parent produced less than 8.0 bushels was 58.5 bushels per acre.

The average superiority in grain yield of the inbred parents of the second group over those of the first group was 34 per cent. In comparison, the average superiority in grain yield of the $F_1$ hybrids of the second group was 30 per cent over the $F_1$ hybrids of the first group.

In Table 23 are compiled the average yield per acre during two years for eighteen $F_1$ low leaf area hybrids and the average

TABLE 22.—*Comparison of first generation hybrids and their pure line parents; Hogue's Yellow Dent corn, (Class IX). 1916.*

| Hybrid | Stalk height | | | | Yield, grain per acre | | | |
|---|---|---|---|---|---|---|---|---|
| | Hybrids | | Parents | | Hybrids | | Parents | |
| | $F_1$ | $F_2$ | Female | Male | $F_1$ | $F_2$ | Female | Male |
| | *Feet* | *Feet* | *Feet* | *Feet* | *Bu.* | *Bu.* | *Bu.* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| 4 × 12.... | 6.0 | 5.7 | 3.7 | 4.6 | 38.8 | 21.6 | 2.3 | 14.8 |
| 4 × 1..... | 5.9 | 5.7 | 3.7 | 3.8 | 53.2 | 31.4 | 2.3 | 14.5 |
| 12 × 5..... | 6.7 | 6.2 | 4.6 | 4.5 | 44.6 | 15.9 | 14.8 | 3.1 |
| 10 × 5..... | 6.3 | 5.7 | 4.5 | 4.5 | 43.3 | 17.2 | 15.4 | 3.1 |
| Average.... | 6.2 | 5.8 | 4.1 | 4.3 | 45.0 | 21.5 | 8.7 | 8.9 |
| 8 × 2..... | 6.5 | 4.7 | 4.4 | 3.8 | 66.2 | 38.3 | 10.8 | 8.0 |
| 12 × 2..... | 6.7 | 4.7 | 4.6 | 3.8 | 58.0 | 28.0 | 14.8 | 8.0 |
| 10 × 12.... | 6.7 | 5.7 | 4.5 | 4.6 | 51.5 | 24.1 | 15.4 | 14.8 |
| 2 × 10.... | 7.0 | 6.0 | 3.8 | 4.5 | 58.2 | 24.0 | 8.0 | 15.4 |
| Average.... | 6.7 | 5.3 | 4.3 | 4.2 | 58.5 | 28.6 | 12.2 | 11.5 |
| Original.... | 6.5 | 6.5 | 6.5 | 6.5 | 37.5 | 37.5 | 37.5 | 37.5 |

These data are compiled from Tables 14 and 16.

individual plant and ear weights of their inbred parents. The hybrids are grouped into the five highest, eight intermediate, and five lowest, yielding hybrids. The respective average yields of these three hybrid groups were 72.2, 64.1, and 47.2 bushels per acre, which is equivalent to the relative yields of 100, 89, and 65 per cent. The corresponding relative ear weights of the inbred parents of the three groups were 100, 86, and 65, while the respective relative total plant weights were 100, 97, and 86 per cent.

There appears to be some general correlation between productivity of the pure line parents and that of their hybrid offspring. Exceptions to this general relation occur.

It is doubtful if maximum increased vigor as indicated by plant size is necessarily the vigor character to be striven for. Some of the most productive hybrids which this Station has produced are shorter growing and have a smaller vegetative development than the original corn from which they came.

TABLE 23.—*Comparison of first generation hybrids and their pure line parents. Hogue's Yellow Dent low leaf area strains. Two-year average, 1915 and 1916.*

| Hybrid | Hybrid yield per acre | Moisture free weights of inbred parents | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ear weight | | | Total plant weight | | |
| | | Female | Male | Average | Female | Male | Average |
| | *Bushels* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| FIVE HIGHEST YIELDING HYBRIDS | | | | | | | |
| 736 × 754...... | 72.1 | 54.3 | 109.3 | 81.8 | 163.6 | 219.7 | 191.6 |
| 735 × 736...... | 71.8 | 80.6 | 54.3 | 67.4 | 190.1 | 163.6 | 176.8 |
| 738 × 735...... | 70.4 | 9.3 | 80.6 | 44.9 | 114.0 | 190.1 | 152.0 |
| 731 × 739...... | 72.8 | 84.7 | 34.2 | 59.4 | 154.2 | 134.5 | 144.3 |
| 754 × 738...... | 74.1 | 109.3 | 9.3 | 59.3 | 219.7 | 114.0 | 166.8 |
| Average........ | 72.2 | 67.6 | 57.5 | 62.6 | 168.3 | 164.4 | 166.3 |
| HYBRIDS INTERMEDIATE IN YIELD | | | | | | | |
| 731 × 736...... | 57.9 | 84.7 | 54.3 | 70.0 | 154.2 | 163.6 | 158.9 |
| 751 × 738...... | 66.2 | 55.7 | 9.3 | 32.5 | 161.3 | 114.2 | 137.7 |
| 731 × 732...... | 65.8 | 84.7 | 20.8 | 52.7 | 154.2 | 133.6 | 143.9 |
| 738 × 734...... | 63.2 | 9.3 | 35.4 | 22.3 | 114.2 | 125.9 | 120.0 |
| 737 × 754...... | 65.5 | 64.0 | 109.3 | 66.6 | 196.5 | 219.7 | 208.1 |
| 731 × 734...... | 65.4 | 84.7 | 35.4 | 60.0 | 154.2 | 125.9 | 140.0 |
| 755 × 754...... | 64.7 | 77.0 | 109.3 | 93.1 | 214.4 | 219.7 | 217.0 |
| 738 × 752...... | 64.5 | 9.3 | 56.2 | 32.7 | 114.2 | 203.6 | 158.9 |
| Average........ | 64.1 | 58.7 | 53.7 | 53.7 | 157.9 | 163.3 | 160.6 |
| FIVE LOWEST YIELDING HYBRIDS | | | | | | | |
| 738 × 736...... | 54.9 | 9.3 | 54.3 | 31.8 | 114.2 | 163.6 | 138.9 |
| 734 × 732...... | 31.8 | 35.4 | 20.8 | 28.1 | 125.9 | 133.6 | 129.7 |
| 748 × 731...... | 44.8 | 42.4 | 84.7 | 63.5 | 186.7 | 154.2 | 170.4 |
| 756 × 730...... | 51.9 | 29.4 | 54.2 | 41.8 | 125.7 | 140.0 | 132.8 |
| 733 × 753...... | 52.4 | 18.4 | 59.8 | 39.1 | 116.2 | 154.4 | 135.3 |
| Average........ | 47.2 | 27.0 | 54.8 | 40.9 | 133.7 | 149.2 | 141.4 |

These data are compiled from Tables 20 and 21.

### RATE OF GROWTH OF FIRST GENERATION HYBRIDS BETWEEN PURE LINES

The mature kernels of inbred corn (pure lines) commonly weigh less than those of the original heterozygous corn from which they are derived. Cross-fertilized kernels borne on these pure line plants weigh on an average only about ten per cent heavier than selfed kernels. It has been suggested that first generation hybrids of pure lines are at a disad-

TABLE 24.—*Rate of growth of standard Hogue's Yellow Dent corn, pure line strains, and first generation hybrids between pure lines. 1921.*

| Description | Age of plant[1] | Total plant height | Stem height | Length of tassel[2] | No. of leaves exposed | Leaf area per plant | Green plant weight | Length of largest ear |
|---|---|---|---|---|---|---|---|---|
| | *Days* | *Inches* | *Inches* | *Inches* | | *Sq. in.* | *Grams* | *Inches* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| DEVELOPMENT BY JUNE 16 | | | | | | | | |
| Pure lines.. | 14 | 5 | ....... | ....... | 6 | 28 | 5 | ....... |
| Hybrids $F_1$. | 14 | 9 | ....... | ....... | 7 | 83 | 15 | ....... |
| Original.... | 14 | 9 | ....... | ....... | 7 | 85 | 16 | ....... |
| DEVELOPMENT BY JUNE 23 | | | | | | | | |
| Pure lines.. | 21 | 11 | 1.3 | 0.0 | 8 | 89 | 27 | ....... |
| Hybrids $F_1$. | 21 | 18 | 2.8 | 0.1 | 9 | 212 | 82 | ....... |
| Original.... | 21 | 18 | 2.5 | 0.0 | 9 | 216 | 90 | ....... |
| DEVELOPMENT BY JUNE 30 | | | | | | | | |
| Pure lines.. | 28 | 17 | 4.8 | 0.36 | 10 | 259 | 121 | ....... |
| Hybrids $F_1$. | 28 | 27 | 10.4 | 0.36 | 13 | 517 | 290 | ....... |
| Original.... | 28 | 28 | 8.0 | 0.48 | 12 | 500 | 259 | ....... |
| DEVELOPMENT BY JULY 7 | | | | | | | | |
| Pure lines.. | 35 | 25 | 11.0 | 1.4 | 13 | 436 | 265 | 0.06 |
| Hybrids $F_1$. | 35 | 39 | 21.2 | 4.5 | 15 | 751 | 524 | 0.13 |
| Original.... | 35 | 42 | 22.7 | 7.0 | 14 | 739 | 505 | 0.14 |
| DEVELOPMENT BY JULY 14 | | | | | | | | |
| Pure lines.. | 42 | 37 | 21.1 | 7.8 | 14 | 657 | 513 | 0.21 |
| Hybrids $F_1$. | 42 | 53 | 42.0 | 16.2 | 15 | 1,224 | 1,034 | 0.84 |
| Original.... | 42 | 50 | 44.0 | 17.0 | 15 | 1,235 | 1,059 | 0.93 |
| DEVELOPMENT BY JULY 21 | | | | | | | | |
| Pure lines.. | 49 | 58 | 40.0 | 16.0 | 14 | 705 | 655 | 1.3 |
| Hybrids $F_1$. | 49 | 82 | 66.0 | 23.0 | 15 | 1,200 | 1,191 | 4.2 |
| Original.... | 49 | 84 | 71.0 | 25.0 | 15 | 1,245 | 1,300 | 4.6 |
| FULL GROWN CORN AUGUST 9 | | | | | | | | |
| Pure lines.. | 68 | 79 | 79 | 18 | 14 | 731 | ....... | 4.2 |
| Hybrids $F_1$. | 68 | 99 | 99 | 24 | 15 | 1,204 | ....... | 8.6 |
| Original.... | 68 | 100 | 100 | 27 | 15 | 1,260 | ....... | 8.7 |

[1]Age of plant begins with day the corn came up.

[2]The tassel includes the stem between the last node and the first tassel branch.

vantage in their early growth because of the reduced kernel size upon which the seedling plant draws for its early nourishment. To overcome this, the substitution of double crossed seed has been suggested in which two unrelated $F_1$ hybrids are crossed. The hereditary constitution of the resultant kernel is as complex as for the $F_1$ hybrid and yet the kernels are normal in size. The data in Table 24 record the rate of growth and general early development in 1921 of standard Hogue's Yellow Dent corn having kernels of normal size, with the average results from a number of pure lines which had been inbred for ten years. and with eight vigorous $F_1$ hybrids between these pure lines. The results suggest that the size of the $F_1$ hybrid kernel may, in some cases at least, be sufficient to supply ample nourishment for the young plant under normal soil and climatic conditions at time of planting.

## DEGREES OF INBREEDING

There are various degrees of kinship between the ovules of the ear and the pollen grains which fertilize them. The past discussion has indicated that a large number of distinct elemental strains with independently inherited Mendelian characters are the basis for an ordinary corn variety, and that broad fertilization to avoid the pairing of identical Mendelian factors is desirable. Investigation has been made to determine the effect of intermediate degrees of close breeding. Two separate experiments have been conducted, one beginning in 1909 with Hogue's Yellow Dent corn and one in 1912 with Nebraska White Prize. Beginning with ear-to-row strains, the following degrees of relationship between source of ovule and pollen have been studied:

1. *Self-fertilization*, in which the seed has been continued each year with a single ear of corn, fertilized by pollen from the same plant.

2. *Close breeding* within an ear-to-row strain, in which the seed has been continued each year with a single ear of corn, fertilized with pollen from a single sister plant of the same strain.

3[a]. *Narrow breeding* within an ear-to-row strain, in which the seed has been continued each year with a single ear of corn, fertilized with composite pollen from 15 sister plants of the same strain.

3[b]. *Narrow breeding* within an ear-to-row strain, in which the seed has been continued each year with ears in composite from 15 sister plants, all fertilized with pollen from a single sister plant of the same strain. Class 3[a] and 3[b] represent the same degree, but are the reciprocal of each other. Class 3[a] has probably actually had somewhat broader breeding than 3[b], because the full number of ears for continuing 3[b] has not always materialized, thereby lowering the relative number of plants represented in the continuation of the strain.

4. *Broad breeding* within an ear-to-row strain, in which the seed is continued each year with a composite of ears from 15 plants, fertilized with composite pollen from 15 sister plants of the same strain.

5. *Crossbreeding* between ear-to-row strains, in which several strains are planted in alternating rows and cross-fertilized by detasseling part of them, seed being selected from the detasseled rows.

6. *Ordinary wind fertilization* within a commercial variety, in which the seed is continued each year with a composite sample of a large number of well-developed ears.

7. *Crossing of varieties*, in which two commercial varieties are planted each year in alternating plats, one of which is detasseled to furnish the hybrid seed.

### DEGREES OF INBREEDING, HOGUE'S YELLOW DENT CORN

Five of these degrees of inbreeding, which have just been described, viz, No. 1, 3[a], 4, 5, and 6, have been continuously carried on with Hogue's Yellow Dent corn since 1909. Classes 1 and 3[a] were begun in 1909 with each of three ear-to-row strains, selected from each of four high yielding strains, having their origin in an ear-to-row test begun in 1906. The original strains are the same as those described on page 48 as the foundation stock of Hogue's Yellow Dent pure lines. Classes 4 and 5 originated in 1909 from the four highest yielding individual ear-to-row strains selected in 1903. Class 6 merely represents the original wind fertilized variety, seed of which was obtained each year prior to 1910 from R. Hogue, living at a distance of 30 miles from the Station. Since 1910 it has been continued annually in large seed plats at the Nebraska Experiment Station.

The yields have been determined for the various strains of any one degree in composite, rather than individually. Seven years' results are given in Table 25. The five degrees of inbreeding—1, 3[a], 4, 5, and 6—yielded respectively 16.8, 42.2, 49.2, 54.0, and 53.1 bushels per acre. Every degree narrower than that of crossing between ear-to-row strains resulted in a reduction of yield. The more nearly the fertilization approached self-fertilization, the greater the reduction.

Class No. 6 5 4 3a 1

FIG. 18.—Degrees of inbreeding with Hogue's Yellow Dent corn in 1915. From right to left: (1) Inbreeding; (3a) narrow breeding; (4) broad breeding; (5) natural crossing; (6) original wind fertilized Hogue's Yellow Dent. See Table 25 for seven years' results for these different degrees.

#### DEGREES OF INBREEDING, NEBRASKA WHITE PRIZE CORN

All the different degrees of inbreeding were carried out with Nebraska White Prize corn. This is a standard full-season, eastern Nebraska variety. The eight highest yielding ear-to-row strains as determined in a two-year (1911-1912) ear-to-row test with 200 ears were subjected to each of the degrees of inbreeding thruout this period. In the comparative yield test for the various degrees, the eight strains of each were grown in composite. The specialized breeding began in each case in 1912. Examination of the five years' results given in Table 26 discloses that the closer the breeding the lower the yield. It would appear that in the production of seed corn any practice should be avoided which might result in any degree of close breeding.

TABLE 25.—*Narrow versus broad fertilization in corn. Hogue's Yellow Dent. Seven years, 1911-1917.*

| Class No. | Description | Yield per acre | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | Av. |
| | (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) | *Bu.* (9) |
| 1 | Inbreeding (single ear self-fertilized) | 19.8 | 17.2 | 1.1 | 14.4 | 27.0 | 19.8 | 18.5 | 16.8 |
| 3a | Narrow breeding (single ear fertilized with composite pollen from sister plants) | 38.8 | 44.9 | 6.2 | 47.7 | 61.7 | 57.2 | 38.6 | 42.2 |
| 4 | Broad breeding (composite ears fertilized with composite pollen from sister plants) | 40.9 | 54.3 | 8.0 | 58.3 | 77.3 | 60.0 | 45.8 | 49.2 |
| 5 | Natural crossing (between ear-to-row strains) | 40.8 | 53.3 | 7.8 | 65.0 | 84.1 | 69.4 | 57.3 | 53.9 |
| 6 | Original wind fertilized corn | 41.8 | 49.6 | 8.5 | 63.1 | 79.5 | 71.7 | 57.4 | 53.1 |
| | Number of replications | 4 | 4 | 4 | 4 | 7 | 4 | 4 | |

SUMMARY OF PLANT CHARACTERISTICS. AVERAGE FOR FOUR YEARS, 1914-1917

| Class No. | Description | Stalk height | Ear height | Date tasseling | Date ripe | Leaf area per plant | Lodging | 2-eared stalks per 100 plants | Barren plants per 100 | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | *In.* (10) | *In.* (11) | (12) | (13) | *Sq. in.* (14) | *Per ct.* (15) | (16) | (17) | (18) | *Per cent* (19) | *Per cent* (20) |
| 1 | Inbreeding | 69 | 31 | 8/1 | 9/22 | 640 | 27 | 29 | 8 | 5 | 6.8 | 83.3 |
| 3a | Narrow breeding | 82 | 42 | 7/29 | 9/20 | 933 | 19 | 11 | 3 | 17 | 7.6 | 85.8 |
| 4 | Broad breeding | 91 | 46 | 7/28 | 9/22 | 1,208 | 18 | 15 | 2 | 12 | 9.1 | 84.9 |
| 5 | Natural crossing | 94 | 47 | 7/28 | 9/22 | 1,226 | 21 | 15 | 2 | 25 | 8.3 | 84.9 |
| 6 | Original wind fertilized | 92 | 48 | 7/29 | 9/22 | 1,220 | 22 | 14 | 2 | 28 | 10.3 | 84.6 |

TABLE 26.—*Narrow versus broad fertilization in corn. Nebraska White Prize. Five years, 1915 to 1917 and 1920 to 1921.*

| Class No. | Degree of inbreeding—seed continued by: | Yield of grain per acre | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| (1) | (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) |
| 1 | Inbreeding (single ear self-fertilized) | 33.3 | 33.0 | 15.4 | 11.0 | 18.6 | 22.3 |
| 2 | Close breeding (single ear fertilized with pollen from single sister plant) | 63.1 | 49.9 | 27.6 | 30.8 | 42.3 | 42.7 |
| 3*a* | Narrow breeding (single ear fertilized with composite pollen from sister plants) | 58.0 | 58.2 | 36.8 | 38.4 | 53.0 | 48.9 |
| 3*b* | Narrow breeding (composite ears fertilized with pollen from single sister plant) | 60.0 | 55.4 | 30.8 | 33.4 | 44.4 | 44.8 |
| Av. 3*a*, 3*b* | Narrow breeding (average of classes 3*a* and 3*b*) | 59.0 | 56.8 | 33.8 | 35.9 | 48.7 | 46.8 |
| 4 | Broad breeding (composite ears fertilized with composite pollen from sister plants) | 56.5 | 62.1 | 38.9 | 38.9 | 60.3 | 51.3 |
| 5 | Natural crossing (between ear-to-row strains) | 73.7 | 74.1 | 47.9 | 59.1 | 69.4 | 64.8 |
| 6 | Natural crossing (between varieties—Nebraska White Prize × Hogue's) | 77.9 | 70.2 | 50.7 | 52.8 | 68.6 | 64.0 |
| 7 | Original Nebraska White Prize (wind pollinated) | 75.5 | 73.8 | 48.2 | 52.4 | 68.6 | 63.7 |
| | Number of replications | 4 | 3 | 3 | 3 | 3 | |

| Class No. | Summary of plant characteristics. Average for period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tasseling | Date ripe | Lodging | Two-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (9) | *Inches* (10) | (11) | (12) | *Per cent* (13) | (14) | (15) | (16) | *Per cent* (17) | *Per cent* (18) |
| 1 | 87 | 40 | 8/5 | 9/23 | 27 | 12 | 80 | 7 | 14.0 | 76.6 |
| 2 | 94 | 43 | 8/5 | 9/22 | 26 | 8 | 91 | 11 | 14.0 | 80.5 |
| 3*a* | 97 | 50 | 8/4 | 9/22 | 25 | 10 | 97 | 12 | 13.0 | 80.2 |
| 3*b* | 97 | 48 | 8/4 | 9/23 | 25 | 12 | 93 | 16 | 13.8 | 81.6 |
| Av. 3*a*, 3*b* | 97 | 49 | 8/4 | 9/22 | 25 | 11 | 95 | 14 | 13.4 | 80.9 |
| 4 | 98 | 50 | 8/4 | 9/23 | 27 | 10 | 99 | 16 | 13.0 | 81.1 |
| 5 | 101 | 51 | 8/3 | 9/23 | 28 | 11 | 99 | 16 | 10.8 | 82.2 |
| 6 | 100 | 50 | 8/1 | 9/22 | 31 | 13 | 104 | 20 | 8.0 | 83.1 |
| 7 | 101 | 50 | 8/3 | 9/22 | 28 | 12 | 104 | 18 | 10.0 | 82.9 |

Each yield for classes Nos. 1 to 5 is for eight independent strains tested for yield in composite.

## CROSSING VARIETIES

An investigation was carried on with 14 varieties during four years, 1914-1917, to determine what effect the crossing of varieties might have upon the yield of dent corn. A description of the growth habits of the varieties used will be found in Table 27. The varieties used were so selected as to include a wide diversity of growth characteristics. Thirteen hybrids and their parents were tested each year. Their male parent was Hogue's Yellow Dent corn, thruout, while the female parent was different in each case. The $F_1$ hybrid seed was produced by planting rows of the varieties to serve as the female parents between rows of the Hogue's Yellow Dent. All varieties except Hogue's were kept detasseled, in order to insure their cross-fertilization with Hogue's Yellow Dent. The date of planting the different varieties, for hybridizing, was so adjusted that their flowering period would coincide with that of the Hogue's Yellow Dent.

Fig. 19.—Corn to left of man, Hogue's Yellow Dent; to the right, Minnesota No. 13. Note the difference in plant height and vegetative development. To be compared with figure 20. (Table 27.)

Second and third generation hybrids were produced by artificially close breeding a number of ears in the $F_1$ and $F_2$ generations respectively with composite pollen from a number of plants.

### RESULTS WITH FIRST GENERATION VARIETY HYBRIDS

Table 28 reports the yields for the four separate years, as well as the average for the period. The difference in yield between the first generation hybrids and their two parents has been calculated. None of the variety crosses showed an increased yield above the better of the two parents. As an average for all the hybrids, the yield was 1.6 bushels lower than the mean for both parents, and four bushels lower than for the best parents. Table 29 summarizes briefly for a number of plant characters the average deviation of all hybrids from the parents individually, as well as from their average. These re-

FIG. 20.—To be compared with figure 19. Corn to left of man, Hogue's Yellow Dent; to the right, first generation hybrid between Hogue's Yellow Dent and Minnesota No. 13. Note the intermediate character of the cross. (Table 27.)

TABLE 27.—*Comparison of first generation corn variety hybrids and their parents. Four-year average, 1914-1917.*

| Description | Date tasseling | Date ripe | Stalk height | Ear height | Suckers per 100 plants | Ears per 100 plants | 2-eared stalks per 100 plants | Shrinkage of ear corn | Shelling per cent | Yield per acre | Deviation of hybrid from parent average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | *In.* (4) | *In.* (5) | (6) | (7) | (8) | *Per cent* (9) | *Per cent* (10) | *Bu.* (11) | *Bushels* (12) |
| Hogue's Yellow Dent ♂ | 8/1 | 9/23 | 88 | 43 | 24 | 84 | 4 | 10.19 | 84.0 | 45.2 | |
| Reid's Yellow Dent ♀ | 8/1 | 9/23 | 85 | 44 | 17 | 87 | 5 | 7.63 | 85.1 | 44.9 | |
| Reid's Yellow Dent × Hogue's Yellow Dent $F_1$ | 8/1 | 9/23 | 90 | 43 | 22 | 88 | 5 | 10.68 | 84.7 | 45.0 | 0.0 |
| Iowa Gold Mine ♀ | 7/29 | 9/24 | 86 | 42 | 13 | 78 | 4 | 7.58 | 84.9 | 39.1 | |
| Iowa Gold Mine × Hogue's Yellow Dent $F_1$ | 7/30 | 9/23 | 88 | 43 | 22 | 84 | 4 | 9.16 | 84.3 | 43.1 | +1.0 |
| Leaming ♀ | 7/29 | 9/23 | 87 | 43 | 13 | 80 | 3 | 8.46 | 82.8 | 43.1 | |
| Leaming × Hogue's Yellow Dent $F_1$ | 7/31 | 9/23 | 90 | 44 | 16 | 82 | 3 | 8.23 | 83.7 | 42.1 | —2.0 |
| Calico ♀ | 8/4 | 9/28 | 86 | 43 | 13 | 81 | 3 | 7.40 | 82.4 | 43.3 | |
| Calico × Hogue's Yellow Dent $F_1$ | 8/3 | 9/25 | 89 | 45 | 19 | 81 | 4 | 13.39 | 82.8 | 40.9 | —3.3 |
| Bloody Butcher ♀ | 8/5 | 9/28 | 88 | 41 | 12 | 81 | 2 | 8.34 | 82.1 | 42.7 | |
| Bloody Butcher × Hogue's Yellow Dent $F_1$ | 8/4 | 9/27 | 91 | 43 | 18 | 84 | 2 | 12.32 | 82.4 | 39.1 | —4.8 |
| Boone County White ♀ | 8/7 | 9/29 | 91 | 41 | 5 | 78 | 3 | 19.26 | 80.7 | 35.6 | |
| Boone County White × Hogue's Yellow Dent $F_1$ | 8/5 | 9/27 | 92 | 42 | 11 | 80 | 3 | 13.18 | 81.8 | 36.6 | —3.8 |
| St. Charles White ♀ | 7/30 | 9/22 | 82 | 39 | 2 | 82 | 1 | 7.92 | 84.3 | 40.1 | |
| St. Charles White × Hogue's Yellow Dent $F_1$ | 7/31 | 9/24 | 86 | 40 | 6 | 86 | 2 | 8.43 | 83.6 | 42.8 | +0.2 |
| Iowa Silver Mine ♀ | 8/1 | 9/25 | 83 | 40 | 10 | 80 | 2 | 9.44 | 82.2 | 39.3 | |
| Iowa Silver Mine × Hogue's Yellow Dent $F_1$ | 8/1 | 9/26 | 88 | 42 | 14 | 81 | 3 | 9.49 | 82.6 | 40.5 | —1.7 |
| Nebraska White Prize ♀ | 8/4 | 9/27 | 91 | 46 | 9 | 83 | 3 | 11.81 | 83.2 | 42.5 | |
| Nebraska White Prize × Hogue's Yellow Dent $F_1$ | 8/2 | 9/26 | 91 | 46 | 13 | 83 | 4 | 9.94 | 83.1 | 40.9 | —2.9 |
| University No. 3 ♀ | 7/29 | 9/21 | 78 | 40 | 11 | 81 | 1 | 8.85 | 82.7 | 43.0 | |
| University No. 3 × Hogue's Yellow Dent $F_1$ | 7/30 | 9/21 | 81 | 41 | 16 | 82 | 2 | 10.35 | 83.5 | 42.9 | —1.2 |
| White Cap ♀ | 7/28 | 9/21 | 78 | 41 | 5 | 86 | 3 | 4.96 | 83.9 | 37.1 | |
| White Cap × Hogue's Yellow Dent $F_1$ | 7/30 | 9/22 | 81 | 42 | 14 | 85 | 3 | 7.47 | 84.1 | 41.2 | 0.0 |
| Pride of the North ♀ | 7/26 | 9/14 | 78 | 38 | 14 | 90 | 8 | 5.08 | 82.0 | 40.1 | |
| Pride of the North × Hogue's Yellow Dent $F_1$ | 7/30 | 9/23 | 83 | 42 | 15 | 85 | 4 | 7.83 | 85.8 | 38.6 | —4.0 |
| Minnesota No. 13 ♀ | 7/22 | 9/10 | 68 | 35 | 4 | 86 | 2 | 3.98 | 81.9 | 35.7 | |
| Minnesota No. 13 × Hogue's Yellow Dent $F_1$ | 7/28 | 9/17 | 79 | 39 | 9 | 82 | 2 | 6.09 | 82.7 | 42.3 | +1.9 |

All tests were in duplicate each year except Hogue's Yellow Dent, which was replicated fourteen times among the other plats.
♂ Male parent. ♀ Female parent.

TABLE 28.—*Yields of first generation corn variety hybrids and their parents during four years, 1914-1917.*

| Description | Annual yield per acre | | | | Average for the four years | Average yield per acre for four years | | | | Average deviation of hybrid from | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1914 | 1915 | 1916 | 1917 | | Male parent | Female parent | Av. both parents | $F_1$ hybrid | Male parent | Female parent | Av. both parents |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) | *Bu.* (9) | *Bu.* (10) | *Bu.* (11) | *Bu.* (12) | *Bu.* (13) |
| Hogue's Yellow Dent ♂ | 56.4 | 42.0 | 51.6 | 30.7 | 45.2 | | | | | | | |
| Reid's Yellow Dent ♀ | 51.8 | 53.2 | 44.4 | 30.3 | 44.9 | | | | | | | |
| Reid's Yellow Dent × Hogue's Yellow Dent $F_1$ | 60.7 | 47.1 | 41.6 | 30.5 | 45.0 | 45.2 | 44.9 | 45.0 | 45.0 | —0.2 | +0.1 | 0.0 |
| Iowa Gold Mine ♀ | 44.9 | 46.8 | 42.4 | 22.4 | 39.1 | | | | | | | |
| Iowa Gold Mine × Hogue's Yellow Dent $F_1$ | 54.3 | 49.1 | 41.9 | 27.1 | 43.1 | 45.2 | 39.1 | 42.1 | 43.1 | —2.1 | +4.0 | +1.0 |
| Leaming ♀ | 55.4 | 48.5 | 43.6 | 25.1 | 43.1 | | | | | | | |
| Leaming × Hogue's Yellow Dent $F_1$ | 49.4 | 48.7 | 39.7 | 30.6 | 42.1 | 45.2 | 43.1 | 44.1 | 42.1 | —3.1 | —1.0 | —2.0 |
| Calicc ♀ | 54.3 | 48.0 | 43.5 | 27.3 | 43.3 | | | | | | | |
| Calico × Hogue's Yellow Dent $F_1$ | 53.4 | 38.4 | 44.3 | 27.6 | 40.9 | 45.2 | 43.3 | 44.2 | 40.9 | —4.3 | —2.4 | —3.3 |
| Bloody Butcher ♀ | 52.9 | 43.3 | 48.2 | 26.5 | 42.7 | | | | | | | |
| Bloody Butcher × Hogue's Yellow Dent $F_1$ | 54.7 | 31.1 | 44.6 | 26.0 | 39.1 | 45.2 | 42.7 | 43.9 | 39.1 | —6.1 | —3.6 | —4.8 |
| Boone County White ♀ | 42.4 | 26.0 | 51.0 | 23.0 | 35.6 | | | | | | | |
| Boone County White × Hogue's Yellow Dent $F_1$ | 39.5 | 35.5 | 43.0 | 28.5 | 36.6 | 45.2 | 35.6 | 40.4 | 36.6 | —8.6 | +1.0 | —3.8 |
| St. Charles White ♀ | 50.7 | 43.4 | 40.8 | 25.5 | 40.1 | | | | | | | |
| St. Charles White × Hogue's Yellow Dent $F_1$ | 54.3 | 43.2 | 43.5 | 30.4 | 42.8 | 45.2 | 40.1 | 42.6 | 42.8 | —2.4 | +2.7 | +0.2 |
| Iowa Silver Mine ♀ | 45.4 | 42.3 | 41.6 | 27.8 | 39.3 | | | | | | | |
| Iowa Silver Mine × Hogue's Yellow Dent $F_1$ | 45.9 | 47.6 | 39.8 | 28.8 | 40.5 | 45.2 | 39.3 | 42.2 | 40.5 | —4.7 | +1.2 | —1.7 |
| Nebraska White Prize ♀ | 59.2 | 35.6 | 51.9 | 23.4 | 42.5 | | | | | | | |
| Nebraska White Prize × Hogue's Yellow Dent $F_1$ | 51.3 | 38.0 | 48.3 | 25.9 | 40.9 | 45.2 | 42.5 | 43.8 | 40.9 | —4.3 | —1.6 | —2.9 |
| University No. 3 ♀ | 53.1 | 44.5 | 46.2 | 28.2 | 43.0 | | | | | | | |
| University No. 3 × Hogue's Yellow Dent $F_1$ | 52.7 | 45.9 | 46.9 | 26.0 | 42.9 | 45.2 | 43.0 | 44.1 | 42.9 | —2.3 | —0.1 | —1.2 |
| White Cap ♀ | 49.6 | 42.2 | 36.3 | 20.2 | 37.1 | | | | | | | |
| White Cap × Hogue's Yellow Dent $F_1$ | 53.1 | 40.2 | 47.2 | 24.2 | 41.2 | 45.2 | 37.1 | 41.1 | 41.2 | —4.0 | +4.1 | 0.0 |
| Pride of the North ♀ | 45.9 | 48.7 | 44.8 | 20.9 | 40.1 | | | | | | | |
| Pride of the North × Hogue's Yellow Dent $F_1$ | 41.5 | 44.8 | 45.9 | 22.3 | 38.6 | 45.2 | 40.1 | 42.6 | 38.6 | —6.6 | —1.5 | —4.0 |
| Minnesota No. 13 ♀ | 49.2 | 48.9 | 32.6 | 12.0 | 35.7 | | | | | | | |
| Minnesota No. 13 × Hogue's Yellow Dent $F_1$ | 52.4 | 51.8 | 46.6 | 18.6 | 42.3 | 45.2 | 35.7 | 40.4 | 42.3 | —2.9 | +6.6 | +1.9 |
| Average | | | | | | 45.2 | 40.5 | 42.8 | 41.2 | —4.0 | +0.7 | —1.6 |

Yield tests were in duplicate each year except that there were fourteen plats of Hogue's Yellow Dent.
♂ Male Parent. ♀ Female Parent.

sults suggest that farmers in general would not increase their corn yields by exchanging seed with neighbors for the purpose of crossing with their own variety, except where seed selection has been so restricted that a measurable degree of close breeding has resulted.

TABLE 29.—*Summary showing comparison of $F_1$ hybrids and their parents. Average for thirteen hybrids for four years, 1914-1917.*

| | Average of female parent | Average of male parent | Average of both parents | Average of hybrids | Deviation of hybrids from: Average of both parents | Deviation of hybrids from: Highest yielding parent |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Date tasseling | 7/30 | 8/1 | 7/31 | 8/1 | +1 | 0.0 |
| Date ripe | 9/23 | 9/23 | 9/23 | 9/24 | +1 | +1.0 |
| Days to maturity | 53.8 | 53.0 | 53.4 | 53.9 | +0.5 | +0.9 |
| Stalk height, inches | 83.1 | 88.0 | 85.5 | 86.8 | +1.3 | —1.2 |
| Ear height, inches | 41.0 | 43.0 | 42.0 | 42.4 | +0.4 | —0.6 |
| Suckers per 100 plants | 10.0 | 24.0 | 17.0 | 15.0 | —2 | —9.0 |
| Lodged per 100 plants | 13.8 | 15.0 | 14.4 | 15.4 | +1 | +0.4 |
| Ears per 100 plants | 82.5 | 84.0 | 83.2 | 83.3 | +0.1 | —0.7 |
| Two-eared plants, per 100 | 3.0 | 4.0 | 3.5 | 3.0 | —0.5 | —1.0 |
| Shrinkage, per cent | 8.5 | 10.2 | 9.3 | 9.7 | +0.3 | —0.5 |
| Shelled corn, per cent | 83.0 | 84.0 | 83.5 | 85.0 | +1.5 | +1.0 |
| Yield per acre, bushels | 40.5 | 45.2 | 42.8 | 41.2 | —1.6 | —4.0 |

## FIRST, SECOND, AND THIRD GENERATIONS OF VARIETY HYBRIDS COMPARED

The comparative yields of the first and second generations of the variety hybrids are given in Table 30 for a three-year period, 1915-1917. Comparative yields for the first, second, and third generation hybrids are also given for the two-year period 1916-1917. The second and third generation crops did not deviate on an average more than 1.5 bushels from the $F_1$ hybrid, with the slight difference in favor of the later generations. Allowing this amount of difference for experimental error, we might conclude that the later generations of a variety cross tend to yield as well as the first generation.

This is strikingly different from the results with pure line hybrids, where greatly reduced yields resulted from planting second or third generation seed, (see chart 2). This difference in behavior between pure line hybrids and variety hybrids in

TABLE 30.—*Comparison of first, second, and third generation variety hybrids with the parent averages. 1915-1917.*

| Description | Yield per acre: 3-year average, 1915-1917: $F_1$ | $F_2$ | Both parents | 2-year average, 1916-1917: $F_1$ | $F_2$ | $F_3$ | Both parents |
|---|---|---|---|---|---|---|---|
| | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Reid's × Hogue's | 39.7 | 40.1 | 42.0 | 36.0 | 37.1 | 35.5 | 39.3 |
| Iowa Gold Mine × Hogue's | 39.4 | 35.9 | 39.4 | 34.5 | 34.3 | 35.6 | 36.2 |
| Leaming × Hogue's | 39.7 | 43.3 | 40.1 | 35.1 | 40.3 | 39.3 | 37.5 |
| Calico × Hogue's | 36.8 | 40.0 | 40.4 | 35.9 | 39.4 | 36.6 | 38.5 |
| Bloody Butcher × Hogue's | 33.9 | 35.9 | 39.8 | 35.3 | 33.5 | 30.3 | 38.3 |
| U. S. S. Brush × Hogue's | 35.7 | 38.7 | 36.8 | 35.7 | 38.3 | 37.6 | 38.1 |
| St. Charles White × Hogue's | 39.0 | 40.7 | 39.7 | 36.9 | 37.3 | 36.9 | 38.2 |
| Iowa Silver Mine × Hogue's | 38.7 | 40.3 | 40.0 | 34.3 | 39.7 | 36.9 | 38.9 |
| Nebraska White Prize × Hogue's | 37.4 | 37.3 | 39.0 | 37.1 | 35.4 | 39.7 | 39.1 |
| Pride of the North × Hogue's | 37.7 | 38.6 | 39.6 | 34.1 | 38.9 | 38.3 | 36.8 |
| Minnesota No. 13 × Hogue's | 39.0 | 36.2 | 36.7 | 32.6 | 31.3 | 28.7 | 32.3 |
| White Cap × Hogue's | 37.2 | 40.7 | 37.6 | 35.7 | 36.7 | 34.7 | 35.3 |
| University No. 3 × Hogue's | 39.6 | 40.0 | 39.9 | 36.4 | 37.3 | 30.3 | 38.2 |
| General average | 38.0 | 39.1 | 39.3 | 35.3 | 36.8 | 35.4 | 37.4 |

these later generations may be accounted for by the difference in the number of elemental strains represented in their basic composition. There is a cardinal difference between the behavior of second and later generations of pure line hybrids and that of variety hybrids. In these experiments the $F_2$ and $F_3$ variety hybrids and pure line hybrids were produced by close breeding a number of ears in the $F_1$ and $F_2$ generations respectively, with composite pollen from a number of plants. In regard to Mendelian factors, this corresponded to broad fertilization in the case of the former, and self-fertilization in the latter. The second generation seed was equivalent to composite seed as picked by a farmer from promiscuously pollinated fields of corn planted to first generation hybrids. Second and later generations lack the plant uniformity possessed by the first generation.

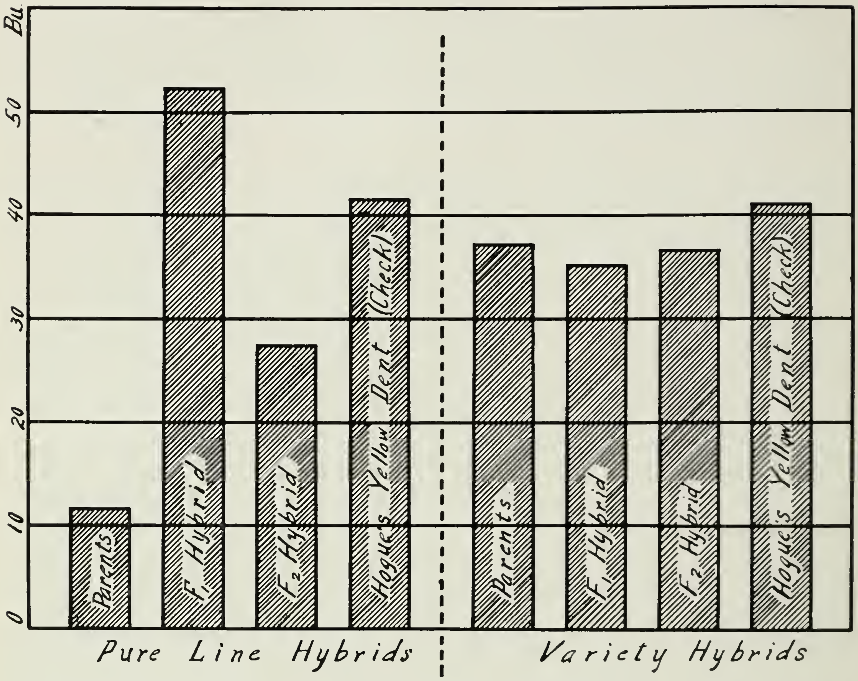



CHART 2.—Comparative effects of the crossing of pure lines (inbred) versus the crossing of commercial varieties. Average yields of grain per acre for seven pure line hybrids at left and thirteen variety hybrids at right. Data taken from Tables 14, 18, 25, 28, and 30 averaged for two years, 1916 and 1917. The 1917 yields for inbred parents are for composite planting and are taken from Table 25.

## IMMEDIATE EFFECT OF FOREIGN POLLEN ON KERNEL WEIGHT

The study of the immediate effect of foreign pollen upon the weight of the corn kernel has aroused much interest. It is well known that the embryo of a kernel of corn is the direct product of the union of the male and female gametes. The embryo is a rudimentary corn plant and is just as homozygous or heterozygous as is the plant which it produces when planted. As the result of double fecundation in corn, its endosperm development is also subject to the influence of both gametes. The color and type of endosperm are very readily influenced by the immediate effect of foreign pollen, which gives rise to the well-known phenomenon of xenia.

Under what conditions and to what extent the kernel weight is influenced by the degree of kinship between pollen and ovules is not so well understood. It has been suggested by other investigators (1) that variety tests as commonly conducted, permitting promiscuous pollination between neighboring varieties, are unreliable because of the immediate effect of foreign pollen upon the yield and (2) that farmers may increase their yields by planting a mixture of varieties so that cross-pollination will occur. The theory upon which these statements are based is that the developing corn kernel receives an immediate stimulus thru being fertilized by foreign pollen. On this subject the following tests have been made at the Nebraska Experiment Station.

### METHODS OF DETERMINATION

Since the effect of foreign pollen is confined to the individual kernels so fertilized, a direct comparison of hybrid and pure kernels on the same mature ear is possible. Pure, in this case, refers to kernels fertilized by pollen of the same variety, and hybrid refers to those fertilized by another variety. For experimental purposes, varieties are used which differ in endosperm color, so that the two sorts of kernels may be distinguished by the phenomenon of xenia.

This mixture of pure and hybrid kernels of known parentage may be produced either by planting two varieties in close proximity, thereby permitting natural mixing of pollen, or by artificially collecting, mixing, and applying the pollen to receptive silks which have been previously covered to avoid chance fertilization.

The method of comparing the weights of pure and hybrid kernels on the same ear has been commonly employed by other investigators and has been used in these investigations. The number and location of the hybrid kernels upon the ear is more or less a matter of chance. On some ears they are uniformly scattered thru the ear (fig. 21); on others they will tend to be localized in certain portions of the ear. Since the kernels usually become systematically smaller with an approach toward the tip of the ear, it is apparent that precautions must be taken to avoid experimental errors easily resulting from place effect on the ear. Pure and hybrid kernels should, for comparison, be removed in adjacent pairs. Thus the hybrid kernel should be taken for the test only when there is an adjacent pure kernel in the same row, which may also be removed. If a high degree of accuracy is desired, equal numbers of pure kernels should be taken from the butt and tip sides of the hybrid kernels used. This will overcome the systematic reduction in kernel size toward the ear tip which is associated with the natural tapering of the ear.

In a test with four varieties, the average reduction in kernel weight from butt to tip was one per cent for each successive kernel.

In an endeavor to determine the effect of foreign pollen

TABLE 31.—*Illustrating the method of determining the immediate effect of foreign pollen upon kernel size by comparing the hybrid kernels with all pure kernels on an ear of corn versus the method of comparing them in adjacent pairs. 1921.*

| Ear No. | Hybrid kernels mostly located at | Pure and hybrid kernels compared only in pairs | | | |
|---|---|---|---|---|---|
| | | No. of kernels of each sort | Weight of 100 kernels | | Ratio of hybrid to pure |
| | | | Pure | Hybrid | |
| | | | *Grams* | *Grams* | *Per cent* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 1 | Tip of ear | 174 | 18.45 | 18.40 | 99.73 |
| 2 | Middle of ear | 72 | 26.89 | 26.94 | 100.19 |
| 3 | Butt of ear | 204 | 19.98 | 20.36 | 101.90 |
| 4 | Generally distributed | 153 | 33.25 | 33.63 | 101.14 |

| Ear No. | All hybrid kernels on ear contrasted with all pure kernels | | | | |
|---|---|---|---|---|---|
| | No. of kernels of each sort | | Weight of 100 kernels | | Ratio of hybrid to pure |
| | Pure | Hybrid | Pure | Hybrid | |
| | | | *Grams* | *Grams* | *Per cent* |
| (1) | (7) | (8) | (9) | (10) | (11) |
| 1 | 591 | 276 | 24.72 | 18.15 | 73.42 |
| 2 | 418 | 328 | 26.67 | 27.21 | 102.02 |
| 3 | 342 | 574 | 19.22 | 21.51 | 111.91 |
| 4 | 548 | 173 | 33.91 | 33.61 | 99.12 |

These ears were selected from a field of Hogue's Yellow Dent corn partly fertilized with pollen from a neighboring field of Nebraska White Prize corn. (See fig. 21.)

upon kernel weight, a large number of ears should be used to overcome variation in the degree of reaction to cross-pollination by individual ears. The method of comparing pure and hybrid kernels in pairs has been found far superior at this Station (Table 31) to that of contrasting hybrid kernels with all the pure kernels grown on the same ear.

In the case of two varieties: (1) When the hybrid kernels were largely localized on the tip third portion of the ear and all were compared as to average kernel weight with all the pure kernels on the ear, the average weight of hybrid kernels was 26.58 per cent less than that of the pure kernels; whereas, when removed in pairs the hybrid kernels weighed only 0.27 per cent less than the pure. (2) When the hybrid kernels were largely localized on the butt third of the ear, their weight exceeded that of the pure kernels by 11.91 per cent when compared by the former method, and by only 1.90 per cent when taken in pairs. (3) When the hybrid kernels were largely localized on the middle third of the ear, the hybrid kernels outweighed the pure by 2.02 per cent when the former method was used and by only 0.19 per cent when taken out in pairs. (4) When the hybrid kernels were quite generally distributed thru the ear, their average weight was 0.88 per cent less than that of the pure when compared by the former method and 1.14 per cent more when removed in pairs. When all the hybrid kernels were contrasted with all the pure kernels on each ear, the variation in weight, for all ears, of the hybrid kernels was from 26.58 per cent less to 11.91 per cent more than that of the pure; and when the kernels were removed from each ear in pairs, the extreme range of variation in weight of the hybrid kernels for the various ears used was from 0.27 per cent less to 1.90 per cent more than the pure.

### RESULTS WITH VARIETIES

During five years (Table 32) a large number of ordinary Hogue's Yellow Dent ears were selected which had been grown near a field of Nebraska White Prize corn and were therefore subject to partial cross-fertilization. The hybrid and pure kernels were removed in pairs only and the two groups compared for weight. The results for different years were slightly variable, ranging from 1.8 per cent increase for hybrid kernels in 1914 to 0.7 per cent reduction for hybrid kernels in 1917 and 1920. As an average for the five years, the 38,017 hybrid kernels weighed 0.32 per cent heavier than the 38,017 pure kernels.

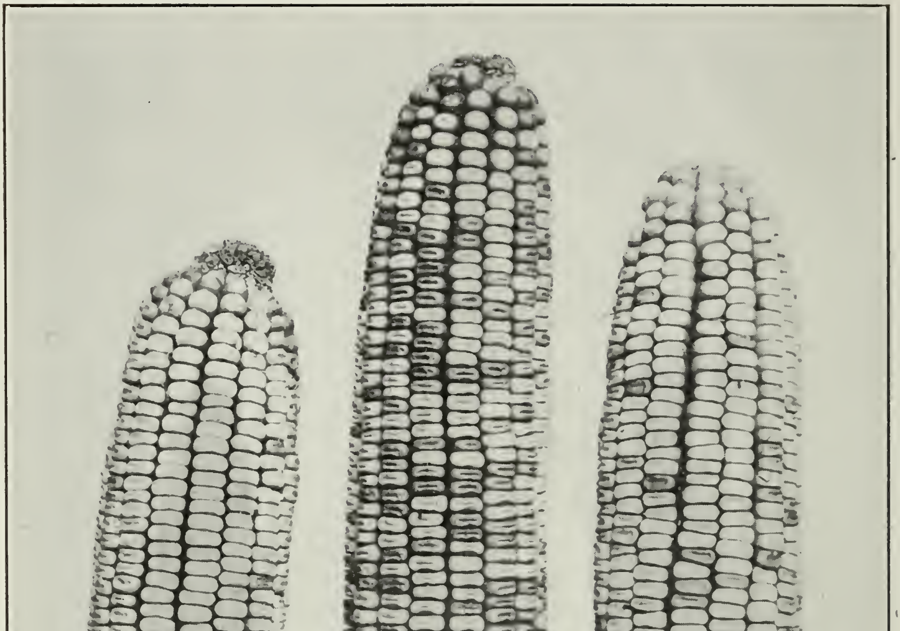


FIG. 21.—Ears of Hogue's Yellow Dent corn partially fertilized by Nebraska White Prize. The pure and hybrid kernels may easily be separated, because of xenia, in a study of the immediate effect of foreign pollen on kernel weight. These ears illustrate the possibility of experimental error in such studies resulting from place effect in the unequal distribution of pure and hybrid kernels thruout the ear. This place effect may be largely overcome by comparing such kernels in adjacent pairs only.

TABLE 32.—*Immediate effect of foreign pollen upon kernel weight of an ordinary variety of dent corn. Five years, 1914-1917 and 1920.*

| Year | Kind of kernels | Number of kernels in test | Weight of 1000 kernels (moisture free) | | Difference in weight of 1000 kernels | |
|---|---|---|---|---|---|---|
| | | | Actual | Relative | | |
| | | | *Grams* | *Per cent* | *Grams* | *Per cent* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1914.... | Pure....... | 5,000 | 307.8 | 100.0 | | |
| | Hybrid..... | 5,000 | 313.4 | 101.8 | +5.6 | +1.8 |
| 1915.... | Pure....... | 10,177 | 246.1 | 100.0 | | |
| | Hybrid..... | 10,177 | 249.3 | 101.3 | +3.2 | +1.3 |
| 1916.... | Pure....... | 9,405 | 272.0 | 100.0 | | |
| | Hybrid..... | 9.405 | 271.5 | 99.8 | —0.5 | —0.2 |
| 1917.... | Pure....... | 8,435 | 281.7 | 100.0 | | |
| | Hybrid..... | 8,435 | 279.8 | 99.3 | —1.9 | —0.7 |
| 1920.... | Pure....... | 5,000 | 259.6 | 100.0 | | |
| | Hybrid..... | 5,000 | 257.8 | 99.3 | —1.8 | —0.7 |

As a five-year average, the hybrid kernels weighed 0.32 per cent more than the pure.

The hybrid kernels were Hogue's Yellow Dent fertilized by Nebraska White Prize corn.

The pure kernels were Hogue's Yellow Dent.

This is equal to one bushel increase in every 312 bushels hybrid grain. The data suggest that the gametes which unite to produce the kernels within an ordinary variety of dent corn are already so unrelated that the vigor which they impart is only very slightly exceeded by introducing foreign Mendelian factors thru the pollen of another dent variety. This conclusion is further substantiated by the data for 1921 with miscellaneous varieties, in Table 33. As an average for five varieties fertilized in part by foreign pollen, the hybrid kernels weighed 0.42 per cent heavier than the pure kernels.

### RESULTS WITH PURE LINES AND VARIETIES COMPARED

In 1921 the immediate effect of foreign pollen on kernel weight was determined for the following combinations: (1) Pure line (inbred) Hogue's Yellow Dent ears fertilized by a mixture of pollen from pure line sister plants and from Nebraska White Prize pure lines. (2) Pure line Nebraska White Prize ears fertilized by a mixture of pollen from pure line sister

TABLE 33.—*Immediate effect of foreign pollen upon kernel weight of five ordinary varieties of dent corn. 1921.*

| Ear No. | Number of kernels of each sort | Weight of 100 kernels | | | |
|---|---|---|---|---|---|
| | | Actual | | Relative | |
| | | Pure | Hybrid | Pure | Hybrid |
| | | *Grams* | *Grams* | *Per cent* | *Per cent* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| MARTENS' WHITE DENT PARTLY FERTILIZED BY MINNESOTA NO. 13 | | | | | |
| 1........ | 89 | 27.68 | 28.00 | 100 | 101.16 |
| 2........ | 72 | 27.79 | 28.13 | 100 | 101.22 |
| 3........ | 70 | 27.63 | 28.03 | 100 | 101.45 |
| Average........ | | | | 100 | 101.27 |
| MINNESOTA NO. 13 PARTLY FERTILIZED BY MARTENS' WHITE DENT | | | | | |
| 1........ | 29 | 18.20 | 18.10 | 100 | 99.45 |
| 2........ | 24 | 36.15 | 35.88 | 100 | 99.25 |
| 3........ | 35 | 27.43 | 27.52 | 100 | 100.33 |
| Average........ | | | | 100 | 99.68 |
| BOONE COUNTY WHITE PARTLY FERTILIZED BY REID'S YELLOW DENT | | | | | |
| 1........ | 101 | 25.08 | 24.40 | 100 | 97.29 |
| 2........ | 91 | 27.80 | 27.68 | 100 | 99.57 |
| 3........ | 198 | 29.96 | 29.47 | 100 | 98.36 |
| Average........ | | | | 100 | 98.41 |
| REID'S YELLOW DENT PARTLY FERTILIZED BY COMMERCIAL WHITE | | | | | |
| 1........ | 117 | 33.36 | 33.95 | 100 | 101.77 |
| 2........ | 95 | 33.37 | 33.86 | 100 | 101.47 |
| 3........ | 146 | 32.88 | 32.29 | 100 | 98.21 |
| Average........ | | | | 100 | 100.48 |
| HOGUE'S YELLOW DENT PARTLY FERTILIZED BY COMMERCIAL WHITE | | | | | |
| 1........ | 36 | 20.33 | 20.56 | 100 | 101.13 |
| 2........ | 44 | 36.73 | 36.68 | 100 | 99.86 |
| 3........ | 75 | 28.65 | 29.01 | 100 | 101.26 |
| Average........ | | | | 100 | 100.75 |
| Average for all varieties........ | | | | 100 | 100.12 |

plants and from Hogue's Yellow Dent pure lines. (3) Pure line Hogue's Yellow Dent ears fertilized by a mixture of pollen from pure line sister plants and from standard Nebraska White

Prize. (4) Pure line Nebraska White Prize ears fertilized by a mixture of pollen from pure line sister plants and from standard Hogue's Yellow Dent. (5) Ordinary standard Hogue's Yellow Dent ears fertilized by a mixture of pollen from the same variety and from Nebraska White Prize pure lines. (6) Standard Nebraska White Prize ears fertilized by a mixture from the same variety and from Hogue's Yellow Dent pure lines. (7) Hogue's Yellow Dent ears fertilized by a mixture of pollen from the same variety and from standard Nebraska White Prize. (8) Standard Nebraska White Prize ears fertilized by a mixture of pollen from the same variety and from standard Hogue's Yellow Dent.

The number of ears available for the pure line combinations is so small that the increase in weight due to foreign pollen may not be typical in exact degree, tho the general indication is correct. The results are given in Table 34 and are summarized together with other 1921 data in Table 35.

Hybrid kernels on Hogue's Yellow Dent pure line ears fertilized with pollen from Nebraska White Prize pure lines weighed 16.15 per cent heavier than the pure kernels.

Hybrid kernels on Nebraska White Prize pure line ears fertilized with pollen from Hogue's Yellow Dent pure lines weighed 10.87 per cent heavier than the pure kernels.

Hybrid kernels on Hogue's Yellow Dent pure line ears fertilized with pollen from the ordinary commercial variety of Nebraska White Prize corn weighed 6.97 per cent heavier than the pure kernels.

Hybrid kernels on Nebraska White Prize pure line ears which had been fertilized with pollen from standard Hogue's Yellow Dent weighed 10.65 per cent heavier than the pure kernels.

Hybrid kernels on ordinary commercial Hogue's Yellow Dent ears fertilized by Nebraska White Prize pure lines weighed 0.73 per cent less than the pure kernels.

Hybrid kernels on ordinary commercial Nebraska White Prize ears fertilized by Hogue's Yellow Dent pure lines weighed 0.64 per cent heavier than the pure kernels.

Hybrid kernels on ordinary commercial Hogue's Yellow Dent ears fertilized by ordinary commercial Nebraska White Prize weighed 1.09 per cent heavier than the pure kernels.

Hybrid kernels on ordinary commercial Nebraska White Prize ears fertilized by ordinary commercial Hogue's Yellow Dent weighed 0.10 per cent less than pure kernels.

TABLE 34.—*Immediate effect of foreign pollen upon kernel weight of inbred pure lines versus original varieties. 1921.*

| Ear No. | Number of kernels of each sort | Weight of 100 kernels | | | |
|---|---|---|---|---|---|
| | | Actual | | Relative | |
| | | Pure | Hybrid | Pure | Hybrid |
| | | *Grams* | *Grams* | *Per cent* | *Per cent* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| INBRED NEBRASKA WHITE PRIZE PARTLY FERTILIZED BY INBRED HOGUE'S YELLOW DENT | | | | | |
| 1 | 71 | 29.24 | 31.99 | 100 | 109.40 |
| 2 | 86 | 25.48 | 28.31 | 100 | 111.11 |
| 3 | 41 | 27.20 | 30.73 | 100 | 112.98 |
| 4 | 68 | 28.92 | 31.79 | 100 | 109.92 |
| 5 | 109 | 25.96 | 29.17 | 100 | 112.37 |
| 6 | 39 | 29.84 | 32.91 | 100 | 110.29 |
| 7 | 35 | 23.72 | 26.92 | 100 | 113.49 |
| 8 | 52 | 30.23 | 31.68 | 100 | 104.80 |
| 9 | 30 | 18.17 | 20.88 | 100 | 114.91 |
| 10 | 116 | 19.03 | 20.83 | 100 | 109.46 |
| Average | | | | | 110.87 |
| INBRED NEBRASKA WHITE PRIZE PARTLY FERTILIZED BY STANDARD HOGUE'S YELLOW DENT | | | | | |
| 1 | 51 | 13.63 | 14.24 | 100 | 104.48 |
| 2 | 17 | 14.30 | 14.52 | 100 | 101.54 |
| 3 | 11 | 9.06 | 10.19 | 100 | 112.47 |
| 4 | 24 | 16.14 | 16.87 | 100 | 104.52 |
| 5 | 21 | 9.84 | 11.44 | 100 | 116.26 |
| 6 | 11 | 9.14 | 10.63 | 100 | 116.30 |
| 7 | 43 | 19.87 | 20.91 | 100 | 105.23 |
| 8 | 8 | 10.67 | 11.72 | 100 | 109.84 |
| 9 | 14 | 8.61 | 9.96 | 100 | 115.68 |
| 10 | 19 | 9.69 | 11.63 | 100 | 120.14 |
| Average | | | | | 110.65 |
| STANDARD NEBRASKA WHITE PRIZE PARTLY FERTILIZED BY INBRED HOGUE'S YELLOW DENT | | | | | |
| 1 | 33 | 36.24 | 36.08 | 100 | 99.56 |
| 2 | 13 | 29.42 | 30.11 | 100 | 102.35 |
| 3 | 44 | 25.20 | 25.49 | 100 | 101.15 |
| 4 | 105 | 19.59 | 19.46 | 100 | 99.34 |
| 5 | 89 | 21.65 | 21.59 | 100 | 99.72 |
| 6 | 26 | 26.69 | 27.29 | 100 | 102.25 |
| 7 | 11 | 33.86 | 34.32 | 100 | 101.36 |
| 8 | 87 | 25.06 | 24.90 | 100 | 99.36 |
| Average | | | | | 100.64 |
| STANDARD NEBRASKA WHITE PRIZE PARTLY FERTILIZED BY STANDARD HOGUE'S YELLOW DENT | | | | | |
| 1 | 117 | 19.37 | 18.88 | 100 | 97.47 |
| 2 | 103 | 23.30 | 23.15 | 100 | 99.36 |
| 3 | 122 | 15.64 | 15.72 | 100 | 100.51 |
| 4 | 64 | 18.85 | 19.37 | 100 | 102.76 |
| 5 | 86 | 19.91 | 19.18 | 100 | 96.33 |
| 6 | 22 | 24.09 | 24.66 | 100 | 102.37 |
| 7 | 117 | 15.93 | 15.81 | 100 | 99.25 |
| 8 | 73 | 30.84 | 30.97 | 100 | 100.42 |
| 9 | 69 | 25.41 | 25.55 | 100 | 100.55 |
| 10 | 25 | 28.80 | 28.48 | 100 | 98.89 |
| 11 | 127 | 26.91 | 26.78 | 100 | 99.52 |
| 12 | 60 | 17.57 | 17.82 | 100 | 101.42 |
| Average | | | | | 99.90 |

TABLE 34 CONCLUDED.—*Immediate effect of foreign pollen upon kernel weight of inbred pure lines versus original varieties. 1921.*

| Ear No. | Number of kernels of each sort | Weight of 100 kernels | | | |
|---|---|---|---|---|---|
| | | Actual | | Relative | |
| | | Pure | Hybrid | Pure | Hybrid |
| | | *Grams* | *Grams* | *Per cent* | *Per cent* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| INBRED HOGUE'S YELLOW DENT PARTLY FERTILIZED BY INBRED NEBRASKA WHITE PRIZE | | | | | |
| 1 | 9 | 21.94 | 25.47 | 100 | 116.09 |
| 2 | 7 | 26.05 | 29.98 | 100 | 115.09 |
| 3 | 7 | 23.94 | 26.84 | 100 | 112.11 |
| 4 | 8 | 21.37 | 25.90 | 100 | 121.20 |
| 5 | 12 | 21.17 | 24.61 | 100 | 116.25 |
| Average | | | | | 116.15 |
| INBRED HOGUE'S YELLOW DENT PARTLY FERTILIZED BY STANDARD NEBRASKA WHITE PRIZE | | | | | |
| 1 | 15 | 23.98 | 24.79 | 100 | 103.38 |
| 2 | 52 | 16.80 | 19.14 | 100 | 113.93 |
| 3 | 35 | 20.60 | 22.07 | 100 | 107.14 |
| 4 | 18 | 21.07 | 21.49 | 100 | 101.99 |
| 5 | 47 | 22.49 | 24.38 | 100 | 108.40 |
| Average | | | | | 106.97 |
| STANDARD HOGUE'S YELLOW DENT PARTLY FERTILIZED BY INBRED NEBRASKA WHITE PRIZE | | | | | |
| 1 | 8 | 14.44 | 14.34 | 100 | 99.31 |
| 2 | 130 | 30.19 | 30.10 | 100 | 99.70 |
| 3 | 86 | 25.78 | 26.03 | 100 | 100.97 |
| 4 | 37 | 36.69 | 35.62 | 100 | 97.08 |
| Average | | | | | 99.27 |
| STANDARD HOGUE'S YELLOW DENT PARTLY FERTILIZED BY STANDARD NEBRASKA WHITE PRIZE | | | | | |
| 1 | 229 | 27.62 | 27.98 | 100 | 101.30 |
| 2 | 137 | 25.73 | 25.80 | 100 | 100.27 |
| 3 | 125 | 29.52 | 30.08 | 100 | 101.90 |
| 4 | 271 | 27.99 | 28.62 | 100 | 102.25 |
| 5 | 216 | 26.87 | 27.43 | 100 | 102.08 |
| 6 | 192 | 26.90 | 27.58 | 100 | 102.53 |
| 7 | 191 | 34.82 | 35.08 | 100 | 100.75 |
| 8 | 242 | 24.26 | 24.34 | 100 | 100.33 |
| 9 | 246 | 22.07 | 22.12 | 100 | 100.23 |
| 10 | 216 | 23.45 | 23.56 | 100 | 100.47 |
| 11 | 164 | 20.73 | 20.78 | 100 | 100.24 |
| 12 | 151 | 22.15 | 22.32 | 100 | 100.77 |
| Average | | | | | 101.09 |

Taking all of the data into consideration, it may be concluded that no material increase in weight results from fertilizing a heterozygous kernel—as in an ordinary dent variety—with foreign pollen. On the other hand, altho there is a considerable variation between different strains, an approximate average increase in kernel weight of about ten per cent may be expected from fertilizing homozygous (pure line) kernels with foreign dent pollen.

TABLE 35.—*Summary showing immediate effect of foreign pollen upon kernel weight of dent corn. 1921.*[1]

| No. of ears av. | Female parent | Male parent | Ratio weight of hybrid kernels to pure |
|---|---|---|---|
| | | | *Per cent* |
| | EARS BORNE ON INBRED PURE LINE PLANTS | | |
| 10 | Inbred Nebraska White Prize | Inbred Hogue's Yellow Dent... | 110.87 |
| 5 | Inbred Hogue's Yellow Dent. | Inbred Nebraska White Prize.. | 116.15 |
| 10 | Inbred Nebraska White Prize | Ordinary Hogue's Yellow Dent. | 110.65 |
| 5 | Inbred Hogue's Yellow Dent. | Ordinary Nebraska White Prize | 106.97 |
| 30 | Average........................................ | | 111.16 |
| | EARS BORNE ON PLANTS OF ORDINARY VARIETIES | | |
| 12 | Nebraska White Prize....... | Hogue's Yellow Dent......... | 99.90 |
| 12 | Hogue's Yellow Dent....... | Nebraska White Prize......... | 101.09 |
| 3 | Martens' White Dent....... | Minnesota No. 13............ | 101.27 |
| 3 | Minnesota No. 13.......... | Martens' White Dent........ | 99.68 |
| 3 | Boone County White....... | Reid's Yellow Dent........... | 98.41 |
| 3 | Reid's Yellow Dent......... | Commercial White............ | 100.48 |
| 3 | Hogue's Yellow Dent....... | Commercial White............ | 100.75 |
| 39 | Average................ | ............................ | 100.22 |
| 8 | Nebraska White Prize....... | Inbred Hogue's Yellow Dent... | 100.64 |
| 4 | Hogue's Yellow Dent....... | Inbred Nebraska White Prize.. | 99.27 |
| 12 | Average........................................ | | 99.95 |

[1]Data compiled from Tables 33 and 34.

Pollen from an unrelated homozygous plant has as much influence upon kernel size as pollen from a heterozygous plant.

Varieties or strains which have undergone very close selection for type or have by some other means been somewhat restricted in the number of Mendelian factors represented in their hereditary constitution might reasonably be expected to respond in a slight degree to foreign pollen.

With broad, wind fertilized varieties, the slight average increase of 0.22 per cent in kernel weight due to foreign pollen can doubtless be accounted for in part by the fact that absolutely none of the hybrid kernels were selfed; while, as has been shown earlier, a small portion, approximately 0.7 per cent, of the kernels in a field were selfed in ordinary wind fertilization.

The studies of the comparative effects of foreign pollen have by no means been exhaustive, and further investigations are suggested. The entire problem is so involved that these data are merely offered as a report of progress.

### RELATIVE EFFECTS OF FOREIGN POLLEN UPON EMBRYO AND ENDOSPERM WEIGHTS OF INBRED CORN

The preceding data indicate so clearly an increase in kernel weight resulting from fertilization of homozygous (inbred) corn with foreign pollen that it becomes a matter of interest to know the relative effect upon the various parts of the kernel. A grain of corn consists of three main portions, (1) the seed coat (pericarp), (2) the endosperm or starchy portion, and (3) the embryo. The seed coat is a portion of the mother plant and can be only indirectly influenced by the character of the pollen.

The separation of the kernels into their component parts was facilitated by soaking them in water for 24 hours. This was preceded by heating at 100° C. to destroy the viability and thereby avoid any growth changes due to supplying moisture. After dissection, the respective portions were rendered moisture free at 105° C. and weighed. Pure line strains of both Hogue's Yellow Dent and Nebraska White Prize reported in Table 34 were used in these tests. A very brief study was also made with ordinary corn of these two varieties for the purpose of general comparison. The results are given in Table 36 and summarized in Table 37 and chart 3.

The manner of obtaining comparable pure and hybrid kernels has been previously described. As an average for the pure lines of both varieties, the immediate effect of foreign pollen was to increase the weight of (1) the kernel 11.09 per cent, (2) the embryo 20.22 per cent, (3) the endosperm 10.39 per cent, and (4) the seed coat 5.36 per cent. In contrast, kernels of ordinary heterozygous corn were not materially influenced in the development of their respective parts by fertilization with foreign pollen.

The ratio of embryo to endosperm weight is nearly the same for the kernels borne on ordinary heterozygous variety plants as for the pure kernels on pure line plants derived by inbreeding. This suggests that the embryo and endosperm reduce to about the same degree as a result of continued self-fertilization. The proportion of embryo to endosperm is somewhat greater in cross-pollinated than in pure kernels borne on pure line plants.

TABLE 36.—*Immediate effect of foreign pollen on the relative development of different parts of the kernels of pure line (inbred) corn (Hogue's Yellow Dent and Nebraska White Prize corn). 1921.*

| Ear No. | Kind of kernels | Number of kernels | Moisture free weights of | | | | Ratio of embryo to endosperm |
|---|---|---|---|---|---|---|---|
| | | | Kernels | Embryos | Endo-sperms | Seed coats | |
| | | | *Grams* | *Grams* | *Grams* | *Grams* | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| INBRED HOGUE'S YELLOW DENT PARTLY FERTILIZED BY NEBRASKA WHITE PRIZE | | | | | | | |
| 1 | Pure...... | 9 | 1.9748 | 0.2232 | 1.6477 | 0.1038 | 0.1355 |
| | Hybrid.... | 9 | 2.2924 | 0.2906 | 1.8879 | 0.1139 | 0.1539 |
| | Ratio..... | ........ | 1.1608 | 1.3020 | 1.1458 | 1.0973 | 1.1358 |
| 2 | Pure...... | 7 | 1.8236 | 0.1826 | 1.5532 | 0.0878 | 0.1176 |
| | Hybrid.... | 7 | 2.0985 | 0.2454 | 1.7605 | 0.0926 | 0.1394 |
| | Ratio..... | ........ | 1.1507 | 1.3439 | 1.1335 | 1.0547 | 1.1854 |
| 3 | Pure...... | 7 | 1.6758 | 0.1741 | 1.4133 | 0.0886 | 0.1232 |
| | Hybrid.... | 7 | 1.8785 | 0.2270 | 1.5593 | 0.0922 | 0.1456 |
| | Ratio..... | ........ | 1.1209 | 1.3038 | 1.1033 | 1.0406 | 1.1818 |
| 4 | Pure...... | 8 | 1.7093 | 0.1801 | 1.4398 | 0.0894 | 0.1251 |
| | Hybrid.... | 8 | 2.0724 | 0.2398 | 1.7326 | 0.1000 | 0.1384 |
| | Ratio..... | ........ | 1.2124 | 1.3315 | 1.2034 | 1.1186 | 1.1063 |
| 5 | Pure...... | 12 | 2.5409 | 0.2726 | 2.1325 | 0.1358 | 0.1278 |
| | Hybrid.... | 12 | 2.9535 | 0.3569 | 2.4478 | 0.1488 | 0.1458 |
| | Ratio..... | ........ | 1.1624 | 1.3092 | 1.1479 | 1.0957 | 1.1408 |
| 6 | Pure...... | 15 | 3.5965 | 0.3523 | 3.0679 | 0.1763 | 0.1148 |
| | Hybrid.... | 15 | 3.7187 | 0.3768 | 3.1554 | 0.1865 | 0.1194 |
| | Ratio..... | ........ | 1.0340 | 1.0695 | 1.0285 | 1.0578 | 1.0401 |
| 7 | Pure...... | 52 | 8.7381 | 0.7834 | 7.5109 | 0.4442 | 0.1043 |
| | Hybrid.... | 52 | 9.9526 | 1.0692 | 8.4028 | 0.4806 | 0.1272 |
| | Ratio..... | ........ | 1.1390 | 1.3648 | 1.1187 | 1.0819 | 1.2196 |
| 8 | Pure...... | 35 | 7.2108 | 0.7035 | 6.1793 | 0.3380 | 0.1138 |
| | Hybrid.... | 35 | 7.7258 | 0.8394 | 6.5221 | 0.3641 | 0.1287 |
| | Ratio..... | ........ | 1.0714 | 1.1932 | 1.0555 | 1.0772 | 1.1309 |
| 9 | Pure...... | 18 | 3.7922 | 0.3820 | 3.2062 | 0.2020 | 0.1191 |
| | Hybrid.... | 18 | 3.8690 | 0.3985 | 3.2614 | 0.2091 | 0.1222 |
| | Ratio..... | ........ | 1.0202 | 1.0432 | 1.0172 | 1.0351 | 1.0260 |
| | Pure...... | 47 | 10.5694 | 1.0506 | 9.0944 | 0.4244 | 0.1155 |
| | Hybrid.... | 47 | 11.4583 | 1.1885 | 9.7763 | 0.4535 | 0.1216 |
| | Ratio............ | | 1.0841 | 1.1313 | 1.0750 | 1.0686 | 1.0528 |
| | Average of ratios.. | | 1.1156 | 1.2392 | 1.1029 | 1.0728 | 1.1219 |

TABLE 36 CONCLUDED.—*Immediate effect of foreign pollen on the relative development of different parts of the kernels of pure line (inbred) corn. 1921.*

| Ear No. | Kind of kernels | Number of kernels | Moisture free weights of | | | | Ratio of embryo to endosperm |
|---|---|---|---|---|---|---|---|
| | | | Kernels | Embryos | Endo-sperms | Seed coats | |
| | | | *Grams* | *Grams* | *Grams* | *Grams* | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| INBRED NEBRASKA WHITE PRIZE PARTLY FERTILIZED BY HOGUE'S YELLOW DENT | | | | | | | |
| 1 | Pure...... | 51 | 6.9526 | 0.8081 | 5.7566 | 0.3879 | 0.1404 |
| | Hybrid.... | 51 | 7.2600 | 0.8250 | 6.0413 | 0.3937 | 0.1366 |
| | Ratio..... | ........ | 1.0442 | 1.0209 | 1.0495 | 1.0150 | 0.9729 |
| 2 | Pure...... | 17 | 2.4316 | 0.2598 | 2.0330 | 0.1388 | 0.1278 |
| | Hybrid.... | 17 | 2.4677 | 0.2688 | 2.0542 | 0.1447 | 0.1309 |
| | Ratio..... | ........ | 1.0148 | 1.0346 | 1.0104 | 1.0425 | 1.0243 |
| 3 | Pure...... | 11 | 0.9971 | 0.1155 | 0.8098 | 0.0718 | 0.1426 |
| | Hybrid.... | 11 | 1.1204 | 0.1371 | 0.9141 | 0.0692 | 0.1500 |
| | Ratio..... | ........ | 1.1237 | 1.1870 | 1.1288 | 0.9638 | 1.0519 |
| 4 | Pure...... | 24 | 3.8747 | 0.4671 | 3.2062 | 0.2014 | 0.1457 |
| | Hybrid.... | 24 | 4.0498 | 0.5010 | 3.3393 | 0.2095 | 0.1500 |
| | Ratio..... | ........ | 1.0452 | 1.0726 | 1.0415 | 1.0402 | 1.0295 |
| 5 | Pure...... | 21 | 2.0656 | 0.1708 | 1.7390 | 0.1558 | 0.0982 |
| | Hybrid.... | 21 | 2.4030 | 0.2227 | 2.0131 | 0.1672 | 0.1106 |
| | Ratio..... | ........ | 1.1633 | 1.3039 | 1.1576 | 1.0732 | 1.1263 |
| 6 | Pure...... | 11 | 1.0054 | 0.1067 | 0.8304 | 0.0683 | 0.1285 |
| | Hybrid.... | 11 | 1.1694 | 0.1439 | 0.9524 | 0.0731 | 0.1511 |
| | Ratio..... | ........ | 1.1631 | 1.3486 | 1.1469 | 1.0703 | 1.1759 |
| 7 | Pure...... | 43 | 8.5430 | 0.9147 | 7.0237 | 0.6046 | 0.1302 |
| | Hybrid.... | 43 | 8.9897 | 1.0200 | 7.3966 | 0.5731 | 0.1379 |
| | Ratio..... | ........ | 1.0523 | 1.1151 | 1.0531 | 0.9479 | 1.0591 |
| 8 | Pure...... | 8 | 0.8534 | 0.0877 | 0.7138 | 0.0519 | 0.1229 |
| | Hybrid.... | 8 | 0.9379 | 0.0912 | 0.7857 | 0.0610 | 0.1161 |
| | Ratio..... | ........ | 1.0990 | 1.0399 | 1.1007 | 1.1753 | 0.9447 |
| 9 | Pure...... | 14 | 1.2050 | 0.1184 | 1.0102 | 0.0764 | 0.1172 |
| | Hybrid.... | 14 | 1.3940 | 0.1488 | 1.1666 | 0.0766 | 0.1276 |
| | Ratio..... | ........ | 1.1568 | 1.2568 | 1.1548 | 1.0026 | 1.0887 |
| 10 | Pure...... | 19 | 1.8400 | 0.1822 | 1.5370 | 0.1208 | 0.1185 |
| | Hybrid.... | 19 | 2.2100 | 0.2320 | 1.8556 | 0.1224 | 0.1250 |
| | Ratio............ | | 1.2011 | 1.2733 | 1.2073 | 1.0132 | 1.0549 |
| | Average of ratios.. | | 1.1063 | 1.1653 | 1.1051 | 1.0344 | 1.0528 |

TABLE 37.—*Summary of immediate effect of foreign pollen on the relative development of different parts of the corn kernel (Hogue's Yellow Dent and Nebraska White Prize). 1921.*

| Ear-bearing parent | Pollen parent | Kind of kernels | No. of ears tested | Relative weights | | | | Ratio of embryo weight to endosperm weight |
|---|---|---|---|---|---|---|---|---|
| | | | | Kernel | Embryo | Endo-sperm | Seed coat | |
| (1) | (2) | (3) | (4) | *Per cent* (5) | *Per cent* (6) | *Per cent* (7) | *Per cent* (8) | (9) |
| EARS BORNE ON PURE LINE (INBRED) PLANTS | | | | | | | | |
| Inbred Hogue's Yellow Dent | Nebraska White Prize | Pure | 10 | 100.00 | 100.00 | 100.00 | 100.00 | .1197 |
| | | Hybrid | 10 | 111.55 | 123.92 | 110.29 | 107.28 | .1342 |
| Inbred Nebraska White Prize | Hogue's Yellow Dent | Pure | 10 | 100.00 | 100.00 | 100.00 | 100.00 | .1272 |
| | | Hybrid | 10 | 110.63 | 116.53 | 110.50 | 103.44 | .1336 |
| Average, both varieties | | Pure | 20 | 100.00 | 100.00 | 100.00 | 100.00 | .1234 |
| | | Hybrid | 20 | 111.09 | 120.22 | 110.39 | 105.36 | .1339 |
| EARS BORNE ON PLANTS OF ORDINARY VARIETIES | | | | | | | | |
| Average of Hogue's Yellow Dent and Nebraska White Prize | | Pure | 4 | 100.00 | 100.00 | 100.00 | 100.00 | .1275 |
| | | Hybrid | 4 | 100.16 | 101.31 | 100.18 | 99.00 | .1295 |

The relatively greater immediate increase in weight of the embryo than of the endosperm upon crossing elemental strains would necessarily seem to be due either to the difference in chromosome relationships within the two parts or else to a difference in their relative nutrition.

The cause of the difference in relative development seems more likely a matter of nutrition. The small leaf area, reduced root development, and sluggish synthetic activities of the inbred plant may result in a somewhat undersupply of plant nutrients. In such event, the full development of the embryo, which is the vital element in reproduction, might be favored at the expense of the endosperm. The endosperm is a mere food supply for the embryo and may be somewhat more heavily drawn upon even at this stage as a result of the stimulated growth of the embryo.

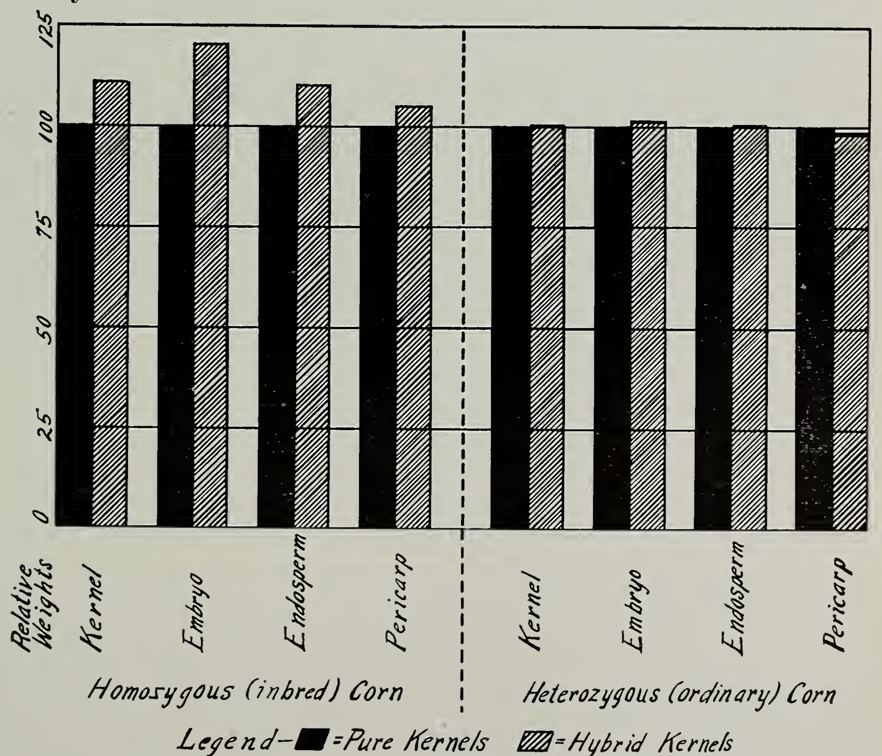



CHART 3.—Immediate effect of crossing upon the kernel development of pure lines (inbred) and ordinary commercial varieties. (In case of the varieties, "pure" kernels refers to those kernels fertilized by pollen of the same variety.) Data taken from Table 37.

## HISTOLOGICAL EFFECTS OF INBREEDING

The hybridization of elemental strains of corn is so commonly attended with marked increase in plant size that it becomes a matter of interest to know how this is related to cell development—the cell being the unit of plant structure.

The data in Table 38, showing the relative number and size of certain histological units, covers seven pure lines and ten $F_1$ hybrids in which all seven pure lines are represented. Histological material was gathered from four representative plants of each pure line or hybrid at about the silking period. The corn had attained its full vegetative development by this time. Material for stalk sectioning was taken midway of the first internode above the ground. Material for leaf study was taken at the widest portion of the main ear leaf midway between the midrib and the margin. In order to overcome the great variability among the different units, a large number of individual counts and measurements were taken for each strain. In the case of stalk sections, fifty independent observations were made for each character under consideration. In case of leaf measurements, this number was increased to 100. All of these microscopic observations were made with unstained material preserved in alcohol.

The data as taken are considered as indicative of the histological differences which occur between pure lines and their hybrids. Plant individuality and limited amount of material may account for some of the irregularity and apparent inconsistencies which occur in a few instances. These are probably fairly well eliminated in the averages for all the pure lines as opposed to the averages for all the hybrids.

Comparing the hybrid with the average of its two parents, (1) the stalk diameter was 46 per cent greater, (2) the total number of fibrovascular bundles in a cross section of the stalk was 45 per cent greater, (3) the number of vascular bundles in one square centimenter of cross section of the stalk was 34 per cent less, which indicates that they are larger in size, (4) the number of bundles occurring along one diameter of a cross section of stalk was 21 per cent greater, (5) the number of bundles along one centimeter of the stalk diameter was 19 per cent less, (6) the actual diameter of vascular bundles was 15 per cent greater, (7) the number of pith cells along one diameter of cross section was 38 per cent greater, (8) the average diameter of one pith cell in stalk was 8 per cent greater, (9) the length of pith cells in the stalk was 10 per cent greater, (10) the leaf

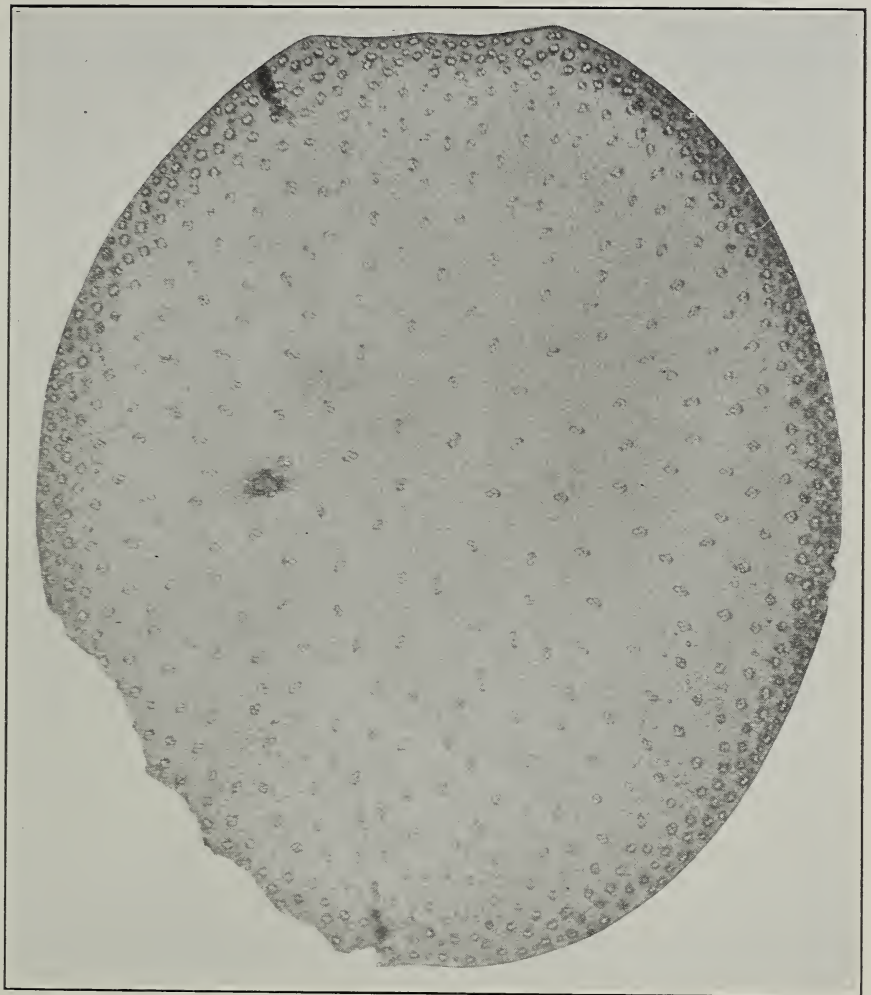


FIG. 22.—Cross section of a full-grown cornstalk near base, showing cellular structure and arrangement of vascular bundles. Enlarged five diameters. The effects of inbreeding and crossing on these and other histological units are given in Table 38.

In cross section of the stalk near base, ten hybrids compared with their pure line parents averaged approximately 117 per cent greater area, 92 per cent more pith cells, 46 per cent more vascular bundles, 8 per cent greater pith cell diameter, and 15 per cent greater bundle diameter.

TABLE 38—*Comparative histological development of elemental strains and their first generation hybrids. Hogue's Yellow Dent corn. 1916.*

| Pure line No. | Stalk: Diameter of stalk | Stalk: No. of bundles in stalk | Stalk: No. of bundles in one sq. cm. | Stalk: No. of bundles in one diameter | Stalk: No. of bundles in one cm. diameter | Stalk: Diameter of bundle | Stalk: No. of pith cells in diameter | Stalk: Diameter of one pith cell | Stalk: Length of pith cell | Leaf: Thickness of leaf | Leaf: Average thickness of upper and lower epidermis | Leaf: No. of vascular bundles in one cm. | Leaf: Average width of epidermal cell, lower and upper epidermis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Mm.* | | | | | *Microns* | | *Microns* | *Microns* | *Microns* | *Microns* | | *Microns* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| 1 | 18.0 | 449 | 174.6 | 5.8 | 3.16 | 309.9 | 154.6 | 105.8 | 154.2 | 193.8 | 29.4 | 67.5 | 36.3 |
| 4 | 16.7 | 404 | 186.7 | 6.0 | 3.60 | 302.2 | 142.5 | 103.1 | 134.9 | 186.7 | 32.2 | 69.7 | 33.3 |
| Average | 17.3 | 426 | 180.6 | 5.9 | 3.38 | 306.0 | 148.5 | 104.4 | 144.5 | 190.2 | 30.8 | 68.6 | 34.8 |
| 4 × 1 $F_1$ | 28.3 | 621 | 100.0 | 7.1 | 2.52 | 392.8 | 196.8 | 129.0 | 158.0 | 207.5 | 33.0 | 62.0 | 40.0 |
| Ratio | 1.617 | 1.458 | 0.554 | 1.203 | 0.746 | 1.284 | 1.325 | 1.236 | 1.093 | 1.091 | 1.071 | 0.904 | 1.149 |
| 1 | 18.0 | 449 | 174.6 | 5.8 | 3.16 | 309.9 | 154.6 | 105.8 | 154.2 | 193.8 | 29.4 | 67.5 | 36.3 |
| 8 | 17.7 | 373 | 161.8 | 4.1 | 2.34 | 279.5 | 145.4 | 111.0 | 162.6 | 208.1 | 33.3 | 78.5 | 33.5 |
| Average | 17.8 | 411 | 168.2 | 4.9 | 2.75 | 294.7 | 150.0 | 108.4 | 158.4 | 200.9 | 31.3 | 73.0 | 34.9 |
| 1 × 8 $F_1$ | 26.4 | 730 | 134.2 | 6.8 | 2.57 | 353.2 | 197.4 | 133.5 | 161.2 | 244.1 | 32.5 | 66.4 | 35.4 |
| Ratio | 1.483 | 1.776 | 0.798 | 1.388 | 0.935 | 1.199 | 1.316 | 1.232 | 1.018 | 1.215 | 1.038 | 0.910 | 1.014 |
| 2 | 18.7 | 543 | 198.4 | 6.2 | 3.34 | 279.9 | 140.3 | 120.5 | 162.4 | 205.5 | 33.6 | 66.3 | 37.3 |
| 10 | 16.1 | 466 | 237.0 | 4.6 | 2.92 | 279.2 | 135.9 | 107.9 | 163.2 | 207.9 | 34.8 | 76.1 | 34.0 |
| Average | 17.4 | 504 | 217.7 | 5.4 | 3.13 | 279.5 | 138.1 | 114.2 | 162.8 | 206.7 | 34.2 | 71.2 | 35.6 |
| 2 × 10 $F_1$ | 27.4 | 772 | 130.7 | 7.1 | 2.57 | 357.2 | 225.3 | 110.6 | 167.3 | 237.4 | 34.5 | 65.8 | 37.1 |
| Ratio | 1.575 | 1.532 | 0.600 | 1.315 | 0.821 | 1.278 | 1.631 | 0.968 | 1.028 | 1.149 | 1.009 | 0.924 | 1.042 |
| 2 | 18.7 | 543 | 198.4 | 6.2 | 3.34 | 279.9 | 140.3 | 120.5 | 162.4 | 205.5 | 33.6 | 66.3 | 37.3 |
| 12 | 24.3 | 629 | 135.7 | 6.2 | 2.55 | 305.4 | 185.7 | 120.9 | 154.5 | 193.7 | 26.9 | 70.6 | 31.0 |
| Average | 21.5 | 586 | 167.0 | 6.2 | 2.94 | 292.6 | 163.0 | 120.7 | 158.4 | 199.6 | 30.2 | 68.4 | 34.1 |
| 12 × 2 $F_1$ | 29.5 | 857 | 125.0 | 7.3 | 2.46 | 343.6 | 223.7 | 120.2 | 182.0 | 242.1 | 31.4 | 60.0 | 37.1 |
| Ratio | 1.372 | 1.462 | 0.749 | 1.177 | 0.837 | 1.174 | 1.372 | 0.996 | 1.149 | 1.213 | 1.040 | 0.877 | 1.088 |
| 4 | 16.7 | 404 | 186.7 | 6.0 | 3.60 | 302.2 | 142.5 | 103.1 | 134.9 | 186.7 | 32.2 | 69.7 | 33.3 |
| 12 | 24.3 | 629 | 135.7 | 6.2 | 2.55 | 305.4 | 185.7 | 120.9 | 154.5 | 193.7 | 26.9 | 70.6 | 31.0 |
| Average | 20.5 | 516 | 161.2 | 6.1 | 3.07 | 303.8 | 164.1 | 112.0 | 144.7 | 190.2 | 29.5 | 70.1 | 32.1 |
| 4 × 12 $F_1$ | 28.3 | 652 | 103.6 | 6.0 | 2.11 | 349.0 | 220.5 | 112.4 | 176.3 | 209.1 | 31.4 | 63.2 | 32.8 |
| Ratio | 1.380 | 1.264 | 0.643 | 0.984 | 0.687 | 1.149 | 1.344 | 1.004 | 1.218 | 1.099 | 1.064 | 0.902 | 1.022 |

TABLE 38 CONCLUDED.—*Comparative histological development of elemental strains and their first generation hybrids. Hogue's Yellow Dent corn. 1916.*

| Pure line No. | Stalk | | | | | | | | | Leaf | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of stalk | No. of bundles in stalk | No. of bundles in one sq. cm. | No. of bundles in one diameter | No. of bundles in one cm. diameter | Diameter of bundle | No. of pith cells in diameter | Diameter of one pith cell | Length of pith cell | Thickness of leaf | Average thickness of upper and lower epidermis | No. of vascular bundles in one cm. | Average width of epidermal cell, lower and upper epidermis |
| | *Mm.* | | | | | *Microns* | | *Microns* | *Microns* | *Microns* | *Microns* | | *Microns* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| 5 | 21.2 | 510 | 145.2 | 5.9 | 2.84 | 327.0 | 177.3 | 108.0 | 191.4 | 209.5 | 28.6 | 62.6 | 34.4 |
| 10 | 16.1 | 466 | 237.0 | 4.6 | 2.92 | 279.3 | 135.8 | 107.9 | 163.2 | 207.9 | 34.8 | 76.1 | 34.0 |
| Average | 18.6 | 488 | 191.1 | 5.2 | 2.88 | 303.1 | 156.5 | 107.9 | 177.3 | 208.7 | 31.7 | 69.3 | 34.2 |
| 10 × 5 $F_1$ | 27.9 | 685 | 112.7 | 6.6 | 2.43 | 319.0 | 229.3 | 110.3 | 220.1 | 230.3 | 32.6 | 67.4 | 34.2 |
| Ratio | 1.500 | 1.404 | 0.590 | 1.269 | 0.844 | 1.052 | 1.465 | 1.022 | 1.241 | 1.103 | 1.028 | 0.973 | 1.000 |
| 5 | 21.2 | 510 | 145.2 | 5.9 | 2.84 | 327.0 | 177.3 | 108.0 | 191.4 | 209.5 | 28.6 | 62.6 | 34.4 |
| 12 | 24.3 | 629 | 135.7 | 6.2 | 2.55 | 305.4 | 185.7 | 120.9 | 154.5 | 193.7 | 26.9 | 70.6 | 31.0 |
| Average | 22.7 | 569 | 140.4 | 6.0 | 2.69 | 316.2 | 181.5 | 114.4 | 172.9 | 201.6 | 27.7 | 66.6 | 32.7 |
| 12 × 5 $F_1$ | 34.1 | 852 | 93.5 | 6.6 | 1.93 | 340.2 | 232.0 | 137.2 | 179.4 | 236.2 | 29.8 | 63.7 | 32.7 |
| Ratio | 1.502 | 1.497 | 0.666 | 1.100 | 0.717 | 1.076 | 1.278 | 1.199 | 1.038 | 1.172 | 1.076 | 0.956 | 1.000 |
| 8 | 17.7 | 373 | 161.8 | 4.1 | 2.34 | 279.5 | 145.4 | 111.0 | 162.6 | 208.1 | 33.3 | 78.5 | 33.5 |
| 10 | 16.1 | 466 | 237.0 | 4.6 | 2.92 | 279.2 | 135.9 | 107.9 | 163.2 | 207.0 | 34.8 | 76.1 | 34.0 |
| Average | 16.9 | 419 | 199.4 | 4.3 | 2.63 | 279.3 | 140.6 | 109.4 | 162.9 | 208.0 | 34.0 | 77.3 | 33.7 |
| 8 × 10 $F_1$ | 23.3 | 560 | 132.2 | 5.0 | 2.16 | 297.6 | 186.0 | 117.4 | 161.6 | 218.5 | 34.0 | 78.1 | 35.3 |
| Ratio | 1.379 | 1.337 | 0.663 | 1.163 | 0.821 | 1.066 | 1.323 | 1.073 | 0.992 | 1.050 | 1.000 | 1.010 | 1.047 |
| 10 | 16.1 | 466 | 237.0 | 4.6 | 2.92 | 279.2 | 135.9 | 107.9 | 163.2 | 207.9 | 34.8 | 76.1 | 34.0 |
| 12 | 24.3 | 629 | 135.7 | 6.2 | 2.55 | 305.4 | 185.7 | 120.9 | 154.5 | 193.7 | 26.9 | 70.6 | 31.0 |
| Average | 20.2 | 547 | 186.3 | 5.4 | 2.73 | 292.3 | 160.8 | 114.4 | 158.8 | 200.8 | 30.8 | 73.3 | 32.5 |
| 10 × 12 $F_1$ | 29.6 | 759 | 111.3 | 6.9 | 2.33 | 328.7 | 237.9 | 113.4 | 194.2 | 222.4 | 31.8 | 70.6 | 33.9 |
| Ratio | 1.465 | 1.388 | 0.597 | 1.278 | 0.854 | 1.125 | 1.480 | 0.991 | 1.223 | 1.108 | 1.032 | 0.963 | 1.043 |
| 12 | 24.3 | 629 | 135.7 | 6.2 | 2.55 | 305.4 | 185.7 | 120.9 | 154.5 | 193.8 | 29.4 | 67.5 | 36.3 |
| 1 | 18.0 | 449 | 174.6 | 5.8 | 3.16 | 309.9 | 154.6 | 105.8 | 154.2 | 193.7 | 26.9 | 70.6 | 31.0 |
| Average | 21.1 | 539 | 155.1 | 6.0 | 2.85 | 307.6 | 170.1 | 113.3 | 154.3 | 193.7 | 28.1 | 69.0 | 33.6 |
| 12 × 1 $F_1$ | 28.3 | 734 | 116.8 | 7.2 | 2.52 | 351.9 | 215.9 | 119.3 | 155.2 | 226.8 | 30.0 | 55.8 | 35.1 |
| Ratio | 1.341 | 1.362 | 0.753 | 1.200 | 0.884 | 1.144 | 1.269 | 1.053 | 1.006 | 1.171 | 1.068 | 0.809 | 1.045 |
| Av. of ratios | 1.461 | 1.448 | 0.661 | 1.208 | 0.814 | 1.155 | 1.380 | 1.077 | 1.101 | 1.137 | 1.043 | 0.923 | 1.045 |

TABLE 39.—*Summary of relative development of $F_1$ hybrids and their pure line parents.*

| Plant characters | Counts and measurements | | | |
|---|---|---|---|---|
| | Actual | | Relative | |
| | Parents | Hybrid | Parents | Hybrid |
| (1) | (2) | (3) | (4) | (5) |
| Days to maturity | 115 | 117 | 100 | 102 |
| Stalk height (feet) | 4.3 | 6.5 | 100 | 151 |
| Ear height (feet) | 1.7 | 3.2 | 100 | 188 |
| Stalk diameter at base (mm.) | 19.8 | 29.3 | 100 | 148 |
| Approximate stalk volume (cu. mm.) | 130,848 | 439,036 | 100 | 335 |
| Leaf area per plant (sq. in.) | 704 | 1,028 | 100 | 146 |
| No. vascular bundles in cross section of stalk | 519 | 743 | 100 | 143 |
| No. bundles in one square cm. of stalk | 177.8 | 111.0 | 100 | 62 |
| No. vascular bundles along 1 diameter of stalk | 5.7 | 6.8 | 100 | 119 |
| No. bundles along 1 cm. of stalk diameter | 2.85 | 2.21 | 100 | 77 |
| Average diameter of 1 bundle of stalk (mm.) | .300 | .347 | 100 | 115 |
| Diameter of 1 pith cell (mm.) | .1126 | .1190 | 100 | 106 |
| Length of 1 pith cell (mm.) | .160 | .182 | 100 | 114 |
| Approximate volume of 1 pith cell (cu. mm.) | .0016037 | .0020230 | 100 | 126 |
| Thickness of leaf (mm.) | .200 | .226 | 100 | 113 |
| Thickness of average epidermal cell of leaf (mm.) | .0307 | .0321 | 100 | 104 |
| Width of average cell of leaf (mm.) | .0337 | .0355 | 100 | 105 |
| No. vascular bundles in 1 cm. of leaf width | 69.6 | 64.7 | 100 | 93 |

Averages for seven $F_1$ hybrids, 4x1, 2x10, 12x2, 4x12, 10x5, 12x5, 10x12, and for their pure line parents. The parents were included in the average as often as they occur in the hybrids.

These data are summarized from Tables 14, 16, and 38.

thickness was 14 per cent greater, (11) the average thickness of the upper and lower epidermal cell was 4 per cent greater, (12) the number of vascular bundles in one centimeter cross section of the leaf was 8 per cent lower, (13) the width of epidermal cells on the upper and lower leaf surface averaged 4 per cent greater. This, in view of a 46 per cent increase in leaf area, suggests a larger increase in cell numbers than in cell size.

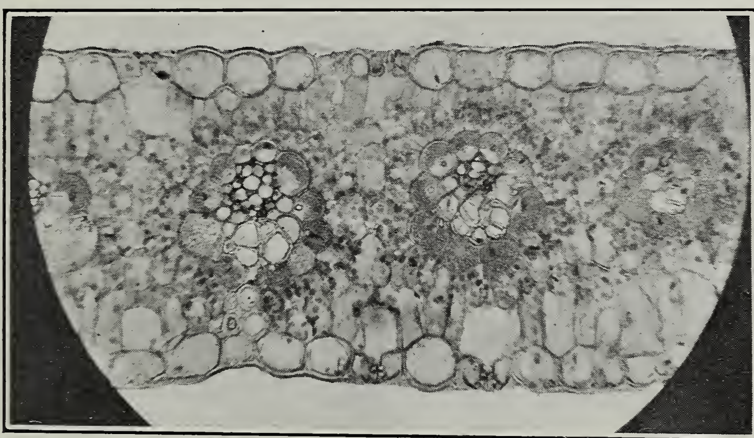


Fig. 23.—Cross section of corn leaf taken midway between midrib and margin. Arrangement of cells and vascular bundles is shown. Some histological leaf measurements for corn hybrids and their inbred parents are given in Tables 38 and 39.

From the above comparisons it may be concluded that crossing of homozygous (pure line) plants is accompanied by a marked increase in both size and number of histological units. The homozygous plants appear to be more sluggish in their physiological activities than are heterozygous (hybrid) plants, since it takes practically the same length of growing period to mature a much smaller number of cells which are also smaller in size.

An interesting point in connection with heterosis, or increase of growth resulting from crossing pure lines, is, how much of this increase is due to increase in cell size and how much to increase in cell numbers.

Most of the cells in a corn plant are so irregular in shape and so irregularly arranged that it is very difficult to determine their relative sizes. Therefore most of the cell measurements were confined to pith cells of the stalk and epidermal cells of the leaves.

If we assume that other cells differ as much in size on an average as the pith cells do, we may make such comparisons as follow.

The approximate volumes of inbred and hybrid stalks, Table 39, were 130,848 cubic mm. and 439,036 cubic mm., giving a ratio of 100:335. The volumes of average inbred and hybrid pith cells for the same strains and hybrids were .0016037 cubic mm. and .0020230 cubic mm., giving a ratio of 100:126. These data suggest that 10.6 per cent of the increased size due to crossing results from an increase in cell size and 89.4 per cent of it from increased numbers. The cell size increased 26 per cent and the cell number 209 per cent. Cell measurements in other tissues suggest that the average cell size of the plant was not increased to a greater percentage than were the pith cells.

## EAR-TO-ROW BREEDING

### TESTS WITH HOGUE'S YELLOW DENT CORN

Ear-to-row breeding of corn consists in the separate comparative yield determination of individual ears of a commercial variety with the object of isolating the more productive strains. An ear-to-row strain is the progeny in direct line of descent from an individual ear of corn. A number of plans for continuing the apparently superior strains after once being determined have been compared at the Nebraska Experiment Station. These plans are as follows:

1. Continuous ear-to-row selection in which progressive improvement is attempted annually by ear-to-row selection within the most productive ear-to-row strains. This work has been continued with three of the most productive "Class I" ear-to-row strains selected in 1903 from among 104 ears tested.

In 1907 two separate selections were made from one of these and continued as separate strains. For this reason, strains 425 and 459 as shown in chart 4 were identical during the first three years. The pedigree record of yields which indicates the choice of plats from which seed selections were made for continuing the strains is given in chart 4. In several instances selections were not made from the highest yielding plat, because quality as well as yield was taken into consideration.

Seed for the comparative yield test reported in Table 40 was prepared each year by mixing the well-developed ears of the highest yielding rows of the four strains.

(2) Continuing the strain by increasing the original ear

CHART 4.—*Tracing the yield pedigree of four Class I ear-to-row strains of Hogue's Yellow Dent corn which have undergone continuous selection during the period of 1903-1916.*

| Strain No. | Yield of grain per acre—bushels | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 |
| | | 74.5 | 99.7 | 74.3 | 97.4 | .... | 25.5 | 54.8 | 37.4 | 43.2 | 13.9 | 51.4 | 82.6 | 30.1 |
| | | 81.6 | 89.8 | 77.1 | 81.6 | .... | 34.5 | 65.0 | 30.3 | 47.0 | 14.1 | 50.6 | 74.8 | 35.3 |
| 403 | 91.5 | 76.5 | 88.5 | 69.0 | 82.8 | .... | 25.6 | 57.5 | 34.9 | 45.7 | 6.9 | 52.4 | 73.5 | 42.6 |
| | | 71.0 | ..... | .... | 93.1 | .... | 26.7 | 56.1 | 32.3 | 45.0 | 15.7 | 49.2 | 71.9 | 26.7 |
| | | 78.7 | ..... | .... | 78.7 | .... | 34.8 | .... | 34.4 | 45.1 | 19.6 | 37.7 | 86.6 | 33.8 |
| | | 81.6 | ..... | .... | 87.7 | .... | 26.6 | .... | 35.5 | 42.8 | 14.0 | 54.8 | 86.6 | 19.9 |
| | Average.... | 77.3 | 92.7 | 73.5 | 86.9 | | 28.9 | 58.3 | 34.1 | 44.8 | 14.0 | 49.3 | 79.3 | 31.4 |
| | | 44.4 | 76.6 | 99.1 | 76.8 | .... | 28.1 | 49.7 | 37.7 | 52.0 | 13.0 | 50.9 | 88.2 | 36.7 |
| | | 61.7 | 118.2 | 87.3 | 84.3 | .... | 33.0 | 52.3 | 35.8 | 56.2 | 17.7 | 53.4 | 94.0 | 24.0 |
| 425 | 95.0 | 69.1 | 99.7 | 78.9 | 78.4 | .... | 23.5 | 47.7 | 38.5 | 47.3 | 13.5 | 50.8 | 96.1 | 33.0 |
| | | 88.4 | ..... | .... | 93.0 | .... | 29.6 | 52.5 | 39.3 | 65.3 | 19.6 | 47.7 | 97.3 | 22.1 |
| | | 37.3 | ..... | .... | 87.1 | .... | 27.3 | 49.2 | 38.9 | 53.6 | 13.1 | 60.8 | 101.6 | 31.2 |
| | | 78.4 | ..... | .... | 88.1 | .... | 27.1 | 48.7 | 31.6 | 57.8 | 15.8 | 55.0 | 78.7 | 23.2 |
| | Average.... | 63.2 | 98.2 | 88.4 | 84.6 | | 28.1 | 50.0 | 37.0 | 55.4 | 15.4 | 53.1 | 92.6 | 28.4 |
| | | 44.4 | 76.6 | 99.1 | 99.3 | .... | 30.6 | 57.9 | 31.6 | 49.5 | 15.1 | 47.5 | 96.6 | 35.7 |
| | | 61.7 | 118.2 | 87.3 | 90.9 | .... | 39.5 | 50.3 | 37.6 | 48.8 | 13.1 | 64.5 | 92.6 | 31.0 |
| 459 | 95.0 | 69.1 | 99.7 | 78.9 | 83.7 | .... | 37.3 | 59.5 | 33.0 | 44.8 | 14.9 | 39.9 | 93.6 | 38.1 |
| | | 88.4 | ..... | .... | 91.5 | .... | 34.2 | 56.9 | 35.4 | 42.0 | 12.0 | 48.0 | 94.7 | 39.0 |
| | | 37.3 | ..... | .... | 83.8 | .... | 33.7 | 54.2 | 33.6 | 50.1 | 13.8 | 44.2 | 96.5 | 42.5 |
| | | 78.4 | ..... | .... | 89.7 | .... | 31.1 | .... | 36.6 | 53.9 | 13.0 | 50.6 | 95.1 | 38.3 |
| | Average.... | 63.2 | 98.2 | 88.4 | 89.8 | | 34.4 | 55.8 | 34.6 | 48.2 | 13.6 | 49.1 | 94.8 | 37.4 |
| | | 73.9 | 80.9 | 84.7 | 90.3 | .... | 29.1 | 45.7 | 34.4 | 59.3 | 19.2 | 51.4 | 70.1 | 28.0 |
| | | 62.0 | 101.1 | 77.7 | 87.7 | .... | 28.7 | 39.4 | 37.2 | 53.0 | 10.9 | 44.0 | 86.0 | 33.4 |
| 4182 | 100.8 | 80.7 | 102.0 | 91.8 | 81.9 | .... | 23.2 | 44.4 | 30.5 | 60.3 | 13.4 | 54.3 | 82.0 | 40.9 |
| | | 60.1 | 97.7 | .... | 91.9 | .... | 15.5 | 49.1 | 27.7 | 54.6 | 10.6 | 49.4 | 79.3 | 35.5 |
| | | 77.8 | 105.0 | .... | 75.8 | .... | 23.7 | 48.8 | 37.6 | 58.7 | 8.1 | 45.4 | 86.3 | 41.0 |
| | | 80.7 | 88.2 | .... | 90.8 | .... | 22.6 | .... | 39.9 | 51.4 | 12.8 | 41.6 | 92.3 | .... |
| | Average.... | 72.5 | 95.8 | 84.7 | 86.4 | | 23.8 | 45.5 | 34.5 | 56.2 | 12.5 | 47.7 | 82.7 | 35.8 |

The average yields for the four families Nos. 403, 425, 459, and 4182 for all years were respectively 55.87, 57.86, 58.96, and 56.65 bushels per acre, while the corresponding yields of the individual ear-to-row plats selected for continuation each year were 60.48, 67.27, 66.16, and 62.44. This is an average difference of 6.7 bushels in favor of the selected plats.

remnant of the high yielding ear in an isolation plat and thereafter always growing it isolated from other corn to avoid "contamination." The remnant of a single high yielding ear (No. 64) of the Class II ear-to-row tests made in 1906 and 1907 furnishes the basis for this study. In 1907, strain No. 64 yielded 81.2 bushels per acre as compared with 64.4 bushels for the original Hogue's Yellow Dent. In 1908 the one-third remnant of the original ear was grown isolated from other corn. The seed stock has been continued since by shelling together a large number of the better developed ears and growing in an isolation plat. Similarly selected seed was used in the comparative yield tests reported in Table 40.

(3) Mixing several productive ear-to-row strains and increasing thereafter in a single isolation plat without further selection except the choice of well-developed seed ears. This seed stock originated in four productive "Class II" ear-to-row strains. In the initial tests in 1906 and 1907 these four ears

FIG. 24.—Harvesting ear-to-row breeding plats. The corn from the various rows is weighed separately and placed in piles at the end of the field for study of ear type and quality. Special samples are saved for making shrinkage and shelling determinations. The flatboat has three compartments on each side, and permits husking six rows at each round by three huskers.

were outstanding in yield, averaging 79.4 bushels per acre in 1907, as compared with 64.4 bushels for the original corn.

A number of well-developed progeny ears grown from each of these four strains were shelled together into one composite sample for planting an isolation increase plat. This composite sample of four strains has ever since been continued in the same manner by merely selecting a large number of well-developed ears to be shelled together in composite. Seed for the comparative yield test reported in Table 40 has been obtained each year in the same manner.

(4) Natural crossing of high yielding ear-to-row strains. Hybridization of ear-to-row strains was commenced in 1909, using as a basis the same four "Class I" strains that have been used in the continuous ear-to-row breeding experiments. The first year, two rows of each strain were planted in the middle of a twelve-row plat of one of the other strains. These two rows were detasseled to supply the hybrid seed. In the following year, and thereafter, the seed stock was continued by intercrossing the four hybrid combinations just as described for the individual strains the first year. The strains had lost their identity after the first few years and future crossing practically amounted to using seed from detasseled rows. The four hybrids have been mixed each year for the yield test reported in Table 40.

### RESULTS FROM THE VARIOUS METHODS OF EAR-TO-ROW BREEDING WITH HOGUE'S YELLOW DENT CORN

The comparative yields from the various methods of ear-to-row breeding with Hogue's Yellow Dent corn are given in Table 40 for the seven-year period 1911-1917. All special selections are compared directly with each other and with the original Hogue's Yellow Dent corn, which has been continued by merely selecting well-developed ears for seed each year.

Continuous ear-to-row selection for a period of eight to fourteen years resulted in an average yield of 0.3 bushels per acre less than the original. Continuing a single strain in an isolation plat for a period of four to ten years resulted in an average yield of 5.9 bushels per acre less than the original. Mixing four high yielding ear-to-row strains and growing for a period of two to eight years in an isolation plat without further special selection resulted in an average yield of 1.4 bushels per acre greater than the original. Crossing ear-to-row strains for a period of two to eight years resulted in a yield of 0.9 bushel per acre more than the original.

TABLE 40—*Effect of ear-to-row breeding on the yield of corn (Hogue's Yellow Dent corn). Seven years, 1911 to 1917.*

| Kind of ear-to-row breeding | Yield per acre | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | Av. |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) | *Bu.* (9) |
| 1. Original Hogue's Yellow Dent | 42.6 | 51.6 | 9.8 | 62.8 | 79.5 | 71.7 | 57.4 | 53.6 |
| 2. Continuous ear-to-row selection since 1903 | 44.0 | 52.9 | 7.7 | 65.3 | 76.8 | 69.8 | 56.6 | 53.3 |
| 3. Increased from single high yielding strain selected in 1906 | 38.2 | 45.6 | 7.3 | 55.0 | 75.3 | 58.9 | 53.6 | 47.7 |
| 4. Increased from composite of four strains selected in 1906 | 42.5 | 54.6 | 12.1 | 63.5 | 80.0 | 74.4 | 57.9 | 55.0 |
| 5. Intercrossing of four strains selected in 1906 | 41.6 | 55.3 | 9.1 | 64.7 | 84.1 | 69.4 | 57.3 | 54.5 |
| Number of replications | 4 | 4 | 5 | 3 | 7 | 4 | 4 | |

| Kind of ear-to-row breeding | Summary of plant characteristics, 4-year average, 1914-1917 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tasseling | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (10) | *Inches* (11) | (12) | (13) | *Per cent* (14) | (15) | (16) | (17) | *Per cent* (18) | *Per cent* (19) |
| 1 | 92 | 48 | 7/29 | 9/22 | 22 | 16 | 96 | 28 | 10.3 | 84.6 |
| 2 | 90 | 47 | 7/29 | 9/22 | 22 | 16 | 97 | 22 | 8.9 | 85.0 |
| 3 | 93 | 47 | 7/29 | 9/22 | 23 | 10 | 94 | 25 | 8.5 | 84.7 |
| 4 | 93 | 46 | 7/28 | 9/22 | 20 | 11 | 101 | 38 | 9.7 | 84.9 |
| 5 | 94 | 47 | 7/28 | 9/22 | 21 | 15 | 95 | 25 | 8.3 | 84.9 |

The entire range of results from the various ear-to-row breeding methods varies from a reduction in yield of 12.5 per cent to an increase of 2.6 per cent over the original corn. Allowing for a small possible experimental error, we may conclude that the slight improvement in yield indicated for eighteen years of ear-to-row breeding offers little promise in a practical way.

FIG. 25.—Two plats in an initial ear-to-row test in 1907. Row No. 64 yielded 81.2 bushels and row No. 65 yielded 58.7 bushels in comparison with 64.4 bushels for the original Hogue's Yellow Dent. The remnant of ear No. 64 was increased and grown thereafter in an isolation plat. During the seven years, 1911-1917, this seed has produced 5.9 bushels less per acre than the ordinary variety from which it was selected, probably due to close breeding. See Table 40 for method No. 3. (From Nebraska Bulletin 112, figure 2.)

We should bear in mind that this work has been done with a well-adapted variety. Had a poorly acclimated variety been used, doubtless marked improvement might have resulted from continuous ear-to-row breeding thru selection of the better adapted strains.

## EAR-TO-ROW BREEDING OF NEBRASKA WHITE PRIZE CORN

An initial ear-to-row test was made in 1911 with Nebraska White Prize corn. Remnants of these two hundred ears were given a duplicate test in 1912. Remaining remnants of the eight best producing ears were planted in ear-to-row plats in 1913 to be used thereafter in a continuous ear-to-row experiment.

Six well-developed ears were selected from each of these plats and planted in individual ear-to-row plats in 1914. Six ears were in turn selected from the most productive one of the six rows representing each strain, for planting in 1915 and successive years.

In a second experiment a small amount of seed from the remnants of each of the above high yielding ears was mixed in 1913 for planting in an isolation plat. This seed stock has been continued each year in an isolation plat, without further selection aside from the choice of a large number of well-developed ears which were shelled in composite.

In a third experiment the eight strains have been intercrossed each year in the manner described on page 105 for Hogue's Yellow Dent.

For the comparative yield test of corn continued by the various methods of ear-to-row breeding reported in Table 41, seed of the eight strains subjected to any one treatment has been mixed, so that the yields are for the eight strains in composite.

As an average for the five years, compared with the original Nebraska White Prize corn, (1) continuous ear-to-row breeding yielded 0.5 bushel less; (2) isolation increase of eight high yielding strains in composite yielded 3.0 bushels less; (3) intercrossing of eight best strains yielded 1.1 bushels more.

The yields in the initial ear-to-row tests during 1911 and 1912 of the eight strains used in the above tests are given in Table 42. As an average for the two years, these eight strains surpassed the original Nebraska White Prize corn by 12.8 bushels. Much of the earlier enthusiasm for ear-to-row breeding was based upon the indication of superiority in the initial tests of the mother ears before the work had progressed sufficiently far to make more extensive practical field progeny tests.

TABLE 41.—*Effect of ear-to-row breeding on the yield of corn (Nebraska White Prize corn). Seven years, 1913-1917 and 1920-1921.*

| Kind of ear-to-row breeding | Yield of grain per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1913 | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | 7-year average 1913–1921 | 5-year average 1915–1921 |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) | *Bushels* (9) | *Bushels* (10) |
| 1. Original Nebraska White Prize | 10.0 | 52.3 | 75.5 | 73.8 | 48.2 | 52.4 | 68.6 | 54.4 | 63.7 |
| 2. Continuous ear-to-row breeding | 10.4 | 50.0 | 72.2 | 73.0 | 46.8 | 55.7 | 68.5 | 53.8 | 63.2 |
| 3. Composite of 8 best strains | 12.3 | 49.0 | 71.6 | 72.5 | 47.7 | 47.0 | 64.6 | 52.1 | 60.7 |
| 4. Intercrossing of strains | ...... | ...... | 73.7 | 74.1 | 47.9 | 59.1 | 69.4 | ......... | 64.8 |
| Number of replications | 3 | 6 | 6 | 4 | 4 | 3 | 3 | | |

| Kind of ear-to-row breeding | Summary of plant characteristics, 5-year average, 1915-1917 and 1920-1921 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tasseling | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (11) | *Inches* (12) | (13) | (14) | *Per cent* (15) | (16) | (17) | (18) | *Per cent* (19) | *Per cent* (20) |
| 1 | 101 | 50 | 8/3 | 9/22 | 28 | 12 | 104 | 18 | 10.0 | 82.9 |
| 2 | 99 | 51 | 8/5 | 9/22 | 26 | 11 | 102 | 13 | 15.1 | 82.8 |
| 3 | 100 | 48 | 8/3 | 9/22 | 29 | 7 | 95 | 16 | 10.7 | 81.0 |
| 4 | 101 | 51 | 8/3 | 9/23 | 28 | 11 | 99 | 16 | 10.8 | 82.2 |

The seed used in these ear-to-row experiments has its origin in the eight highest yielding strains reported in Table 42.

TABLE 42.—*Comparative yields of original corn and eight highest yielding Nebraska White Prize ear-to-row plats out of 200 rows planted during 1911 and 1912.*

| Strain No. | Yield per acre | | |
|---|---|---|---|
| | 1911 | 1912 | Average |
| | *Bushels* | *Bushels* | *Bushels* |
| 3 | 52.0 | 63.0 | 57.5 |
| 217 | 48.8 | 60.2 | 54.5 |
| 69 | 54.0 | 54.0 | 54.0 |
| 179 | 49.0 | 56.0 | 52.5 |
| 22 | 48.0 | 57.0 | 52.5 |
| 5 | 46.0 | 58.0 | 52.0 |
| 171 | 45.8 | 54.5 | 50.1 |
| 14 | 41.0 | 62.0 | 51.5 |
| Average | 48.1 | 58.1 | 53.1 |
| Original | 35.8 | 44.9 | 40.3 |

These strains furnish the basis for the various lines of ear-to-row work reported in Table 41.

## DETASSELING GOOD VERSUS POOR STALKS IN THE SEED PLAT

During the eleven year period 1907-1917, an experiment was conducted to determine whether a profitable increase in production might be had by selecting the seed corn from a seed plat in which the apparently inferior plants had been detasseled to insure against the use of seed which had been fertilized by plants of inferior appearance.

In 1906, two isolation seed plats were planted to Hogue's Yellow Dent corn. In the one plat the poorest one-half of the plants were detasseled and in the other the best one-half of the plants were detasseled. The following year these two lots of seed were continued in separate isolation seed plats by merely shelling together a large number of well-developed ears from each plat. Both plats were again subjected to the same treatment as that of the previous year, and so thruout the entire period of eleven years. Thus there was opportunity for cumulative effect to assert itself.

Each year these two lots of seed were compared with each other and with the original Hogue's Yellow Dent corn in a separate yield test. During the last seven years of the test, a cross between the two lots of seed was also included. The results are given in Table 43.

As an average for eleven years, the seed fertilized by the best one-half of the plants yielded 0.9 bushel more than the seed fertilized by the poorest one-half of the plants. However, both yielded respectively 1.5 bushels and 2.4 bushels less than the original corn. This slight reduction in yield suggests a possible effect of somewhat narrowing down the fertilization in both cases. An increase in yield over the two lots respectively of 3.7 bushels and 2.4 bushels per acre from a cross between the two during the last seven years tends to substantiate this.

TABLE 43.—*Good versus poor stalks detasseled. Hogue's Yellow Dent corn. 1907-1917.*

| Year | No. of replications | Original Hogue's Yellow Dent | Good stalks detasseled | Poor stalks detasseled | $F_1$ cross of good and poor stalks detasseled |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| 1907 | 1 | 63.7 | 66.1 | 70.2 | ........... |
| 1908 | 1 | 34.2 | 34.7 | 33.9 | ........... |
| 1909 | 4 | 38.6 | 37.1 | 32.7 | ........... |
| 1910 | 4 | 55.4 | 51.7 | 53.9 | ........... |
| 1911 | 4 | 42.6 | 39.1 | 37.6 | 42.6 |
| 1912 | 4 | 51.6 | 48.7 | 55.6 | 52.8 |
| 1913 | 5 | 9.8 | 5.9 | 3.8 | 6.2 |
| 1914 | 3 | 57.1 | 55.1 | 54.2 | 59.2 |
| 1915 | 7 | 79.5 | 69.5 | 72.7 | 76.1 |
| 1916 | 4 | 71.7 | 70.5 | 71.1 | 75.9 |
| 1917 | 4 | 57.4 | 57.1 | 60.1 | 59.2 |
| Average 11 years | ........ | 51.1 | 48.7 | 49.6 | ........... |
| Average 7 years | ........ | 52.8 | 49.4 | 50.7 | 53.1 |

It is evident that detasseling the poorest appearing one-half of the plants in a seed plat has not resulted in an increased yield over the original corn produced and selected in the ordinary way. The difficulty of establishing inherent inferiority by mere appearance is probably an obstacle in the way of effective improvement by this method.

## NATURAL COMPETITION AS A FACTOR IN CORN IMPROVEMENT

Competition and survival of the fittest has long been recognized as a principle in the evolution of living organisms. Investigations have been made with two varieties of corn—Hogue's Yellow Dent and Nebraska White Prize—to determine whether this natural principle might be utilized in the improvement of corn. With reference to this principle, corn was planted in three rather large plats at the rates of 1, 3, and 5 plants per hill respectively. Hills were 44 inches apart each way.

In the case of Hogue's Yellow Dent corn, continuous seeding at the three rates has been carried on since 1905, and with the other variety since 1911. Each year from thirty to fifty of the best developed ears produced under the respective planting rates were mixed for continuing the seed the next year. The seed ears were harvested from the standing stalks to be certain that they actually came from plants growing at the specified rates. Typical seed ears of the three groups are shown in figure 26.

In addition to the seed increase plats, other plats have been planted for determining the comparative yields of the various lots. In these yield tests, each of the three lots of Hogue's Yellow Dent have been compared at the three planting rates, viz. 1, 3, and 5 plants per hill. The Nebraska White Prize, on the other hand, has been tested for yield only at the rate of three plants per hill, which is considered normal for this region. The yields per acre are given in Tables 44 and 45.

As an average for the seven years 1911 to 1917, when the Hogue's Yellow Dent was tested at the normal rate of three plants per hill, the seed which had been previously grown at the rate of five plants per hill has yielded 0.6 bushel more while seed previously grown at the rate of one plant per hill has yielded 1.8 bushels less per acre than the seed grown at the customary rate of three plants per hill.

In a similar comparison during eight years with Nebraska White Prize, the seed previously grown at the rate of five plants per hill has yielded 0.2 bushel more while seed from the one rate yielded 0.1 bushel per acre less than the seed grown at the customary rate of three plants per hill.

The results obtained from the Hogue's Yellow Dent "competition" strains when tested at the respective rates of one plant and five plants per hill were rather similar to those obtained

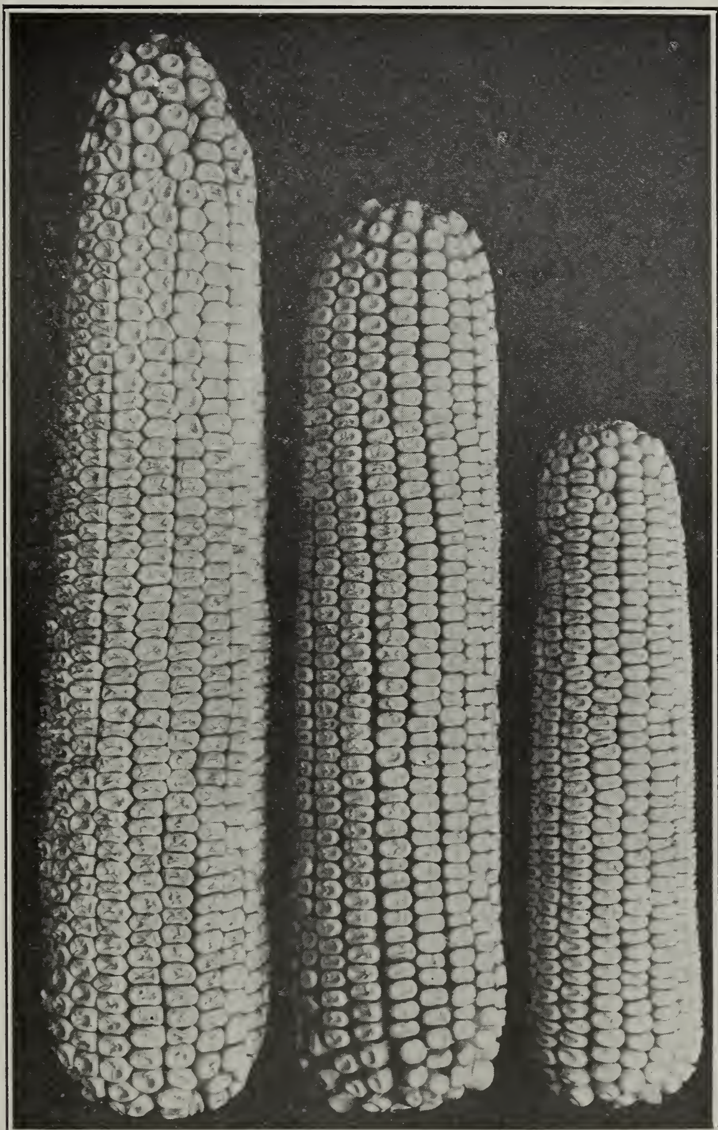


FIG. 26.—Effect of previous rate of planting upon seed value.

Left to right: Representative seed ears selected from Nebraska White Prize corn grown continuously at the respective rates of 1, 3, and 5 plants per hill. When tested during 8 years at a uniform normal rate of planting, the respective average yields were 48.3, 48.4, and 48.5 bushels per acre. (Table 45.)

TABLE 44.—*Effect of previous rate of planting upon the seed value of corn (Hogue's Yellow Dent). Seven years, 1911-1917.*

| Previous rate of planting per hill | Summary of plant characteristics for period | | | | | | | | | Yield of grain per acre | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | Av. |
| (1) | *Inches* (2) | *Inches* (3) | (4) | *Per cent* (5) | (6) | (7) | (8) | *Per cent* (9) | *Per cent* (10) | *Bu.* (11) | *Bu.* (12) | *Bu.* (13) | *Bu.* (14) | *Bu.* (15) | *Bu.* (16) | *Bu.* (17) | *Bu.* (18) |
| YIELD TEST MADE AT RATE OF 1 PLANT PER HILL | | | | | | | | | | | | | | | | | |
| 1 | 88 | 45 | 9/24 | 10 | 36 | 160 | 93 | 9.9 | 82.8 | 33.1 | 45.9 | 8.6 | 42.3 | 56.1 | 33.2 | 30.7 | 35.7 |
| 3 | 88 | 45 | 9/24 | 12 | 39 | 169 | 99 | 10.7 | 84.2 | 33.8 | 52.0 | 9.8 | 44.4 | 52.6 | 33.6 | 27.3 | 36.2 |
| 5 | 89 | 45 | 9/24 | 10 | 42 | 182 | 110 | 10.9 | 82.7 | 36.2 | 49.0 | 12.1 | 42.1 | 64.0 | 34.2 | 27.7 | 37.9 |
| Average | 88 | 45 | 9/24 | 11 | 39 | 170 | 101 | 10.5 | 83.2 | 34.4 | 49.0 | 10.2 | 42.9 | 57.6 | 33.7 | 28.6 | 36.6 |
| Replications | | | | | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| YIELD TEST MADE AT RATE OF 3 PLANTS PER HILL | | | | | | | | | | | | | | | | | |
| 1 | 88 | 44 | 9/23 | 27 | 10 | 80 | 23 | 10.4 | 83.8 | 49.9 | 35.5 | 5.7 | 44.1 | 80.5 | 38.0 | 49.4 | 43.3 |
| 3 | 87 | 44 | 9/23 | 28 | 11 | 89 | 25 | 9.9 | 83.6 | 55.5 | 40.1 | 6.4 | 46.1 | 80.2 | 38.2 | 48.9 | 45.1 |
| 5 | 88 | 44 | 9/23 | 24 | 11 | 89 | 28 | 10.1 | 83.3 | 60.5 | 39.6 | 7.8 | 44.3 | 78.6 | 35.1 | 51.8 | 45.4 |
| Average | 88 | 44 | 9/23 | 26 | 11 | 86 | 25 | 10.1 | 83.6 | 55.3 | 38.4 | 6.6 | 44.8 | 79.8 | 37.1 | 50.0 | 44.6 |
| Replications | | | | | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| YIELD TEST MADE AT RATE OF 5 PLANTS PER HILL | | | | | | | | | | | | | | | | | |
| 1 | 88 | 43 | 9/22 | 33 | 7 | 59 | 10 | 10.1 | 81.5 | 48.3 | 24.0 | 2.3 | 33.7 | 83.6 | 26.7 | 53.7 | 38.9 |
| 3 | 88 | 43 | 9/22 | 38 | 8 | 64 | 9 | 9.1 | 82.4 | 54.8 | 29.4 | 4.8 | 30.3 | 78.7 | 30.4 | 58.8 | 41.0 |
| 5 | 87 | 43 | 9/22 | 33 | 9 | 65 | 10 | 11.7 | 82.4 | 58.0 | 29.2 | 4.4 | 32.1 | 79.4 | 27.9 | 56.3 | 41.0 |
| Average | 88 | 43 | 9/22 | 35 | 8 | 63 | 10 | 10.3 | 82.1 | 53.7 | 27.5 | 3.8 | 32.0 | 80.6 | 28.3 | 56.3 | 40.3 |
| Replications | | | | | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| AVERAGE FOR YIELD TESTS MADE AT THE RATES OF 1, 3, AND 5 PLANTS PER HILL | | | | | | | | | | | | | | | | | |
| 1 | 88 | 44 | 9/23 | 23 | 18 | 100 | 42 | 10.1 | 82.7 | 43.8 | 35.1 | 5.5 | 40.0 | 73.4 | 32.6 | 44.6 | 39.3 |
| 3 | 88 | 44 | 9/23 | 26 | 19 | 107 | 44 | 9.9 | 83.4 | 48.0 | 40.5 | 7.0 | 40.3 | 70.5 | 34.1 | 45.0 | 40.8 |
| 5 | 88 | 44 | 9/23 | 22 | 21 | 112 | 49 | 10.9 | 82.8 | 51.6 | 39.3 | 8.1 | 39.5 | 74.0 | 32.4 | 45.3 | 41.5 |

TABLE 45.—*Effect of previous rate of planting upon the seed value of corn (Nebraska White Prize). Eight years, 1912-1917 and 1920-1921.*

| Previous rate of planting per hill | Yield per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| (1) | *Bushels* (2) | *Bushels* (3) | *Bushels* (4) | *Bushels* (5) | *Bushels* (6) | *Bushels* (7) | *Bushels* (8) | *Bushels* (9) | *Bushels* (10) |
| 1 plant per hill | 54.3 | 8.3 | 52.4 | 69.4 | 34.4 | 49.5 | 52.0 | 66.2 | 48.3 |
| 3 plants per hill | 53.8 | 7.6 | 50.9 | 73.8 | 38.3 | 45.9 | 52.4 | 64.9 | 48.4 |
| 5 plants per hill | 51.8 | 8.4 | 52.1 | 72.7 | 33.7 | 52.0 | 53.1 | 65.1 | 48.6 |
| Number of replications | 8 | 10 | 12 | 12 | 8 | 8 | 6 | 6 | |

| Previous rate of planting per hill | Summary of plant characteristics, 6-year average, 1914-1917 and 1920-1921 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tasseling | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (11) | *Inches* (12) | (13) | (14) | *Per cent* (15) | (16) | (17) | (18) | *Per cent* (19) | *Per cent* (20) |
| 1 | 102 | 49 | 8/1 | 9/22 | 27 | 6 | 85 | 12 | 5.6 | 82.0 |
| 3 | 100 | 48 | 8/1 | 9/22 | 26 | 8 | 89 | 14 | 5.4 | 81.8 |
| 5 | 101 | 50 | 7/31 | 9/22 | 26 | 8 | 89 | 14 | 5.3 | 81.7 |

when tested at the rate of three plants per hill as previously indicated.

In view of the rather fluctuating results from year to year, the results in favor of seed from a specially thick planted seed plat are probably too slight to justify much consideration.

## SELECTION FOR SPECIFIC PLANT AND EAR CHARACTERS

### "HIGH LEAF AREA" AND "LOW LEAF AREA" STRAINS

During the six-year period 1905-1910, two distinct types of Hogue's Yellow Dent corn differing in relative leafiness became fairly well established by continuous ear-to-row selection. The specific character in which a difference was sought for in the two types was the ratio of total leaf area per plant (in square

TABLE 46.—*Plant characteristics of a high leaf area strain and low leaf area strain of Hogue's Yellow Dent corn during 6 years of continuous ear-to-row selection for these respective types. 1905-1910.*

| Year | Stalk height | Ear height | Dry matter | | | Leaf area per plant | Leaf area per gram dry matter |
|---|---|---|---|---|---|---|---|
| | | | Stover | Ear | Total | | |
| (1) | *Inches* (2) | *Inches* (3) | *Grams* (4) | *Grams* (5) | *Grams* (6) | *Sq. in.* (7) | *Sq. in.* (8) |
| HIGH LEAF AREA, FAMILY NO. 5113 | | | | | | | |
| 1905 | ...... | ...... | 375 | 310 | 685 | 1,788 | 2.61 |
| 1906 | 129 | 58 | 216 | 259 | 475 | 1,386 | 2.92 |
| 1907 | 109 | 45 | 205 | 248 | 453 | 1,366 | 3.01 |
| 1908 | 106 | 48 | 255 | 270 | 526 | 1,439 | 2.74 |
| 1909 | 115 | 50 | 261 | 285 | 546 | 1,537 | 2.82 |
| 1910 | 116 | 45 | 232 | 255 | 487 | 1,359 | 2.80 |
| Average | | | | | | 1,479 | 2.81 |
| LOW LEAF AREA, FAMILY NO. 5123 | | | | | | | |
| 1905 | ...... | ...... | 320 | 480 | 800 | 1,069 | 1.34 |
| 1906 | 123 | 58 | 211 | 305 | 516 | 1,111 | 2.15 |
| 1907 | 107 | 44 | 187 | 279 | 466 | 974 | 2.09 |
| 1908 | 104 | 40 | 194 | 221 | 415 | 962 | 2.32 |
| 1909 | 111 | 46 | 225 | 260 | 485 | 1,131 | 2.33 |
| 1910 | 112 | 43 | 213 | 249 | 462 | 1,068 | 2.31 |
| Average | | | | | | 1,052 | 2.09 |

A number of ears of the 1910 progeny of each of these two strains were mixed in 1911 and grown in two isolation plats thereafter, to provide a seed source for the yield tests reported in Table 47.

Table 47.—*Comparative yields of high-leaf and low-leaf area corn. Hogue's Yellow Dent. 1911-1917.*

| Description | Yield per acre (bushels) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | Average |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Original Hogue's Yellow Dent | 52.7 | 47.4 | 7.7 | 57.1 | 79.5 | 71.7 | 57.4 | 53.4 |
| High leaf area selection | 39.6 | 49.4 | 4.6 | 42.0 | 72.8 | 67.5 | 58.9 | 47.8 |
| Low leaf area selection | 46.7 | 48.2 | 8.1 | 53.7 | 75.2 | 72.7 | 53.0 | 51.1 |
| $F_1$ hybrid high × low leaf area | 52.6 | 53.6 | 9.0 | 52.0 | 87.0 | 69.3 | 57.5 | 54.4 |
| Number of replications | 4 | 4 | 5 | 3 | 7 | 4 | 4 | |

| Description | Date tasseling | Date ripe | Stalk height | Ear height | Leaf area | Suckers per 100 plants | Barren stalks per 100 | 2-eared stalks per 100 plants | Lodged stalks per 100 plants | Shrinkage of ear corn | Shelling per cent |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *In.* | *In.* | *Sq. in.* | | | | | *Per cent* | *Per cent* |
| (1) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) |
| Original Hogue's Yellow Dent | 7/28 | 9/22 | 91 | 48 | 1,195 | 28 | 2 | 19 | 22 | 8.8 | 84.6 |
| High leaf area selection | 7/29 | 9/25 | 91 | 49 | 1,340 | 31 | 2 | 16 | 23 | 9.7 | 83.3 |
| Low leaf area selection | 7/25 | 9/20 | 91 | 48 | 1,034 | 32 | 2 | 13 | 21 | 8.1 | 85.8 |
| $F_1$ hybrid high × low leaf area | 7/28 | 9/22 | 90 | 48 | 1,171 | 29 | 3 | 16 | 26 | 8.3 | 85.0 |

inches) to the total dry matter produced (in grams). The basis of selection on the one hand was a high ratio of leaf area to total plant weight, and on the other hand a low ratio of leaf area to total plant weight. The characteristics of the progeny grown each year are shown in Table 46. In 1911 these two types were planted in isolation plats without further selection aside from the use of well-developed ears for seed. These isolation plats have each year provided the seed for the comparative yield test during the six years 1911-1917 which is reported in Table 47.

While neither strain has surpassed the original corn in yield, the low leaf area strain has outyielded the high leaf area strain 3.3 bushels per acre. The low leaf area strain actually yielded 2.3 bushels less than the original while the $F_1$ hybrid between the two strains, which was made each year by natural crossing, yielded 3.2 bushels more than the low leaf and 6.5 bushels more than the high leaf area strains. The data as a whole suggest a possible superiority of the low leaf area over the high leaf area strains, but also suggest a reduction in yield, probably due to narrow fertilization resulting from the restricted type selection.

## SELECTION FOR PLANT CHARACTERS OF NEBRASKA WHITE PRIZE CORN

In 1914 eight lots of ears in composite were selected from a field of Nebraska White Prize corn, representing (1) three degrees of ear height, viz, high, medium, and low; (2) three degrees of erectness of ear on the stalk, viz, erect, medium drooping, and drooping; and (3) two degrees of lodge resistance, viz, standing stalks versus lodged stalks. These various plant types were tested for yield in adjacent plats during the five years 1915-1917 and 1920-1921. Continuous type selection of the most extreme plants for seed was practiced yearly within these same plats. Thus, the pollination was promiscuous between the types, and the selection was confined primarily to the mother parent.

During the five years (Table 48), selection for high, medium, and low ears yielded respectively 51.6, 53.1, and 53.6 bushels per acre. The plants with low ears yielded two bushels per acre more than those having high ears. As an average for the period, the plants resulting from these three lines of ear height selection averaged 54, 47, and 44 inches for ear height, and 102, 98, and 93 inches for stalk height. None of these surpassed the original corn in yield of grain per acre.

Selection for erectness of ears resulted in a somewhat higher per cent of plants having erect ears than where drooping ears were chosen for seed. The drooping ears yielded 2.3 bushels more than the erect, while the medium drooping ear yield was 0.1 bushel less. The original corn surpassed that with drooping ears 0.4 bushel per acre.

Seed selected from standing stalks outyielded seed from lodged stalks by 5.6 bushels per acre, and surpassed the original corn 1.6 bushels per acre.

Since selection from the low ear, drooping ear, and standing stalks yielded most in their respective groups, the data suggest that a very slight increase in yield might be expected from selection for a combination of these characters. This increase might approximate three per cent.

The various lots of seed do not transmit nearly so large a type difference as exists between the selected plants upon which the seed was grown.

## RELATION OF EAR TYPE TO YIELD OF GRAIN

During six years, 1914-1917 and 1920-1921, four distinct ear types have been selected annually from the standard Nebraska White Prize variety and compared for yield. Ten or more ears were mixed for the seed of each type. The selection has not been continuous, and results indicate the immediate effect of selecting ear types in bulk. Under the circumstances, the male parentage is entirely uncontrolled and represents a mixture of types. The progeny ears of the several types, therefore, do not and cannot be expected to differ in the same degree as did the seed ears from which they were grown. However, there is usually a very apparent tendency in the direction of the special selection. The characteristics of both the ears planted and the ears harvested as well as the plant characteristics and yields per acre are given in Table 49.

In the six-year comparison with long, slender, smooth ears, the long, large, rough ears averaged 5.0 bushels less per acre, ripened four days later, and had a 4.7 per cent greater shrinkage of ear corn. Short, slender, smooth ears and short, large, rough ears yielded practically alike, and intermediate between the other two types. The long, slender, smooth type of ear surpassed all the others and yielded 0.8 bushel more than the original corn, which is a natural mixture of rough, smooth, and intermediate types. These data do not indicate what difference would have resulted from prolonged continued selection.

TABLE 48.—*Effect of continued selection for certain plant characters. Nebraska White Prize corn. Five years, 1915-1917 and 1920-1921.*

| | Plant character selected | Yield of grain per acre | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| | (1) | *Bushels* (2) | *Bushels* (3) | *Bushels* (4) | *Bushels* (5) | *Bushels* (6) | *Bushels* (7) |
| | SELECTION FOR EAR HEIGHT | | | | | | |
| 1 | Ears high | 66.2 | 37.8 | 43.0 | 54.3 | 56.8 | 51.6 |
| 2 | Ears medium high | 59.9 | 44.6 | 45.2 | 54.0 | 61.8 | 53.1 |
| 3 | Ears low | 61.7 | 43.7 | 49.1 | 53.7 | 59.6 | 53.6 |
| | SELECTION FOR ERECTNESS OF EAR | | | | | | |
| 4 | Ears erect | 66.1 | 33.7 | 47.0 | 55.5 | 60.9 | 52.6 |
| 5 | Ears medium drooping | 66.0 | 30.0 | 45.0 | 56.5 | 65.1 | 52.5 |
| 6 | Ears drooping | 67.7 | 39.5 | 49.3 | 54.7 | 63.4 | 54.9 |
| | SELECTION FOR LODGE RESISTANCE OF STALKS | | | | | | |
| 7 | Stalks up | 70.4 | 45.9 | 50.0 | 53.6 | 64.5 | 56.9 |
| 8 | Stalks down | 61.5 | 33.9 | 46.8 | 52.1 | 62.3 | 51.3 |
| 9 | Original Nebraska White Prize | 67.3 | 43.0 | 49.4 | 53.8 | 63.0 | 55.3 |
| | Number of replications | 4 | 4 | 4 | 3 | 3 | |

Table 48 Concluded.—*Effect of continued selection for certain plant characters. Nebraska White Prize corn. Five years, 1915-1917 and 1920-1921.*

| Plant character selected for | Summary of plant characteristics for 5-year average | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date ripe | Ears erect | Lodging | Suckers per 100 plants | 2-eared stalks per 100 plants | Ears per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (8) | *Inches* (9) | (10) | *Per cent* (11) | *Per cent* (12) | (13) | (14) | (15) | *Per cent* (16) | *Per cent* (17) |
| SELECTION FOR EAR HEIGHT | | | | | | | | | | |
| 1 Ears high | 102 | 54 | 9/22 | ......... | 27 | 16 | 9 | 87 | 7.3 | 81.8 |
| 2 Ears med. high | 98 | 47 | 9/21 | ......... | 24 | 23 | 7 | 93 | 5.4 | 82.1 |
| 3 Ears low | 93 | 44 | 9/21 | ......... | 23 | 18 | 9 | 90 | 5.8 | 82.4 |
| SELECTION FOR ERECTNESS OF EAR | | | | | | | | | | |
| 4 Ears erect | 100 | 49 | 9/21 | 42 | 23 | 22 | 11 | 90 | 6.2 | 82.4 |
| 5 Ears med. droop. | 100 | 49 | 9/21 | 29 | 25 | 18 | 9 | 87 | 6.7 | 81.9 |
| 6 Ears drooping | 102 | 49 | 9/21 | 21 | 24 | 16 | 9 | 93 | 6.6 | 82.5 |
| SELECTION FOR LODGE RESISTANCE OF STALKS | | | | | | | | | | |
| 7 Stalks up | 101 | 48 | 9/21 | ......... | 22 | 17 | 10 | 96 | 5.3 | 82.9 |
| 8 Stalks down | 102 | 50 | 9/21 | ......... | 29 | 25 | 9 | 87 | 5.9 | 83.1 |
| 9 Orig. Neb. W. Prize | 101 | 51 | 9/21 | ......... | 26 | 17 | 8 | 94 | 6.1 | 82.7 |

TABLE 49.—*Relation of ear type to yield of corn (annual bulk selection of Nebraska White Prize). Six years, 1914-1917 and 1920-1921.*

| Type of ear planted | Yield of grain per acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Av. |
| | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| 1 Long, large, rough | 30.0 | 65.3 | 64.4 | 45.9 | 55.2 | 64.0 | 54.1 |
| 2 Short, large, rough | 44.4 | 68.9 | 65.1 | 49.9 | 51.5 | 63.8 | 57.3 |
| 3 Short, slender, smooth | 45.0 | 72.6 | 60.1 | 49.2 | 50.4 | 65.5 | 57.1 |
| 4 Long, slender, smooth | 48.7 | 66.4 | 65.2 | 54.9 | 56.0 | 63.2 | 59.1 |
| 5 Ordinary Nebraska White Prize | 48.7 | 64.8 | 65.5 | 53.5 | 53.7 | 63.7 | 58.3 |
| Number of replications | 6 | 8 | 14 | 7 | 3 | 3 | |

| Type of ear planted | Summary of plant characteristics, 6-year average | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date tassel-ing | Date ripe | Lodg-ing | Suckers per 100 plants | Ears per 100 plants | Shrink-age of ear corn |
| | *Inches* | *Inches* | | | *Per cent* | | | *Per cent* |
| (1) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| 1 | 100 | 50 | 8/2 | 9/22 | 29 | 11 | 85 | 9.6 |
| 2 | 100 | 50 | 8/1 | 9/21 | 25 | 12 | 91 | 8.8 |
| 3 | 99 | 47 | 7/30 | 9/18 | 28 | 14 | 97 | 4.7 |
| 4 | 101 | 47 | 7/30 | 9/18 | 28 | 11 | 98 | 4.9 |
| 5 | 100 | 47 | 8/1 | 9/21 | 27 | 14 | 95 | 5.4 |

| Type of ear planted | Ear measurements, 6-year average | | | | | |
|---|---|---|---|---|---|---|
| | Ear length | Ear circum-ference | Number of rows per ear | Ear weight | Kernel length | Kernel width |
| | *Inches* | *Inches* | | *Pounds* | *Inch* | *Inch* |
| (1) | (17) | (18) | (19) | (20) | (21) | (22) |
| | MEASUREMENTS OF EARS PLANTED | | | | | |
| 1 | 9.9 | 7.7 | 21.5 | 1.05 | .56 | .32 |
| 2 | 7.4 | 7.4 | 20.0 | 0.80 | .56 | .33 |
| 3 | 7.2 | 5.8 | 15.5 | 0.51 | .45 | .33 |
| 4 | 10.0 | 6.2 | 15.5 | 0.79 | .46 | .33 |
| | MEASUREMENTS OF EARS HARVESTED[1] | | | | | |
| 1 | 7.0 | 6.3 | 19.1 | 0.46 | .51 | .32 |
| 2 | 6.9 | 6.2 | 18.6 | 0.48 | .51 | .32 |
| 3 | 7.5 | 5.8 | 17.1 | 0.47 | .48 | .31 |
| 4 | 7.3 | 5.8 | 17.0 | 0.47 | .46 | .32 |

[1]In 1921, the percentage of rough, medium, and smooth ears was determined for the progeny of each type of ear planted.

The percentages of rough, medium, and smooth ears harvested from the large rough, small rough, small smooth, long smooth, and original unselected corn planted were respectively: 52, 35, and 13; 50, 33, and 17; 13, 39, and 38; 16, 40, and 44; 30, 38, and 32.

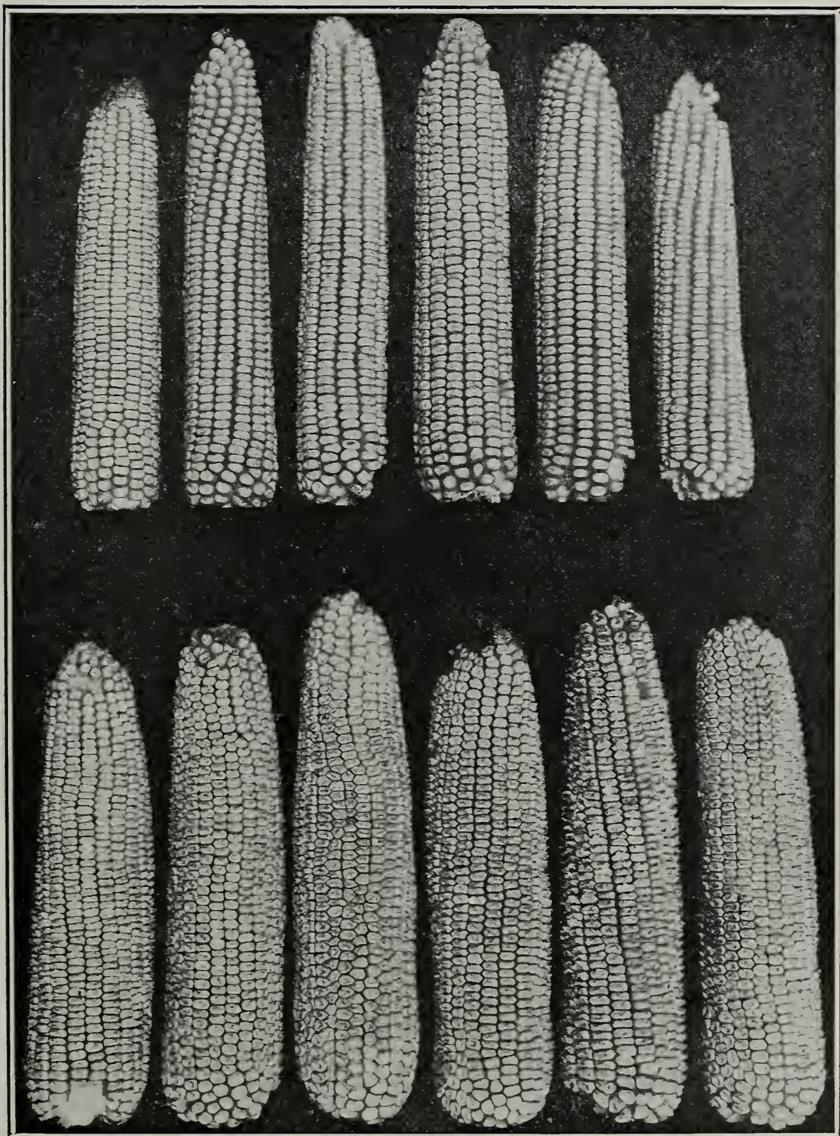


Fig. 27.—Upper row shows long, slender, smooth type of ears and lower row large, rough ears of Nebraska White Prize corn.
Annual bulk selection of the smooth type has surpassed the rough 5.0 bushels per acre during the six years 1914-1917 and 1920-1921.

During the years 1916 and 1917, deep-grained rough ears and shallow-grained smooth ears were selected in bulk and compared for yield with the original Hogue's Yellow Dent corn. As an average for the two years, the grain yields were respectively 64.0, 69.6, and 64.5 bushels per acre for the three lots. The smooth ears surpassed the original corn 5.1 bushels per acre and the rough corn 5.6 bushels, and showed a tendency for greater earliness. The results are given in Table 50.

TABLE 50.—*Relation of ear type to yield of Hogue's Yellow Dent corn. 1916 and 1917.*

| Ear type | Summary of plant characteristics for 2 years | | | | | | Yield per acre | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Date tasseling | Date ripe | Ears per 100 plants | Shrinkage of ear corn | Shelling per cent | 1916 | 1917 | Average |
| (1) | *Inches* (2) | (3) | (4) | (5) | *Per cent* (6) | *Per cent* (7) | *Bu.* (8) | *Bu.* (9) | *Bu.* (10) |
| Deep, rough kernel | 87 | 8/3 | 9/26 | 99 | 8.0 | 85.5 | 72.0 | 56.0 | 64.0 |
| Shallow, smooth kernel.......... | 87 | 8/1 | 9/24 | 112 | 7.4 | 84.8 | 80.1 | 59.2 | 69.6 |
| Original........... | 88 | 8/4 | 9/25 | 101 | 8.5 | 85.0 | 71.7 | 57.4 | 64.5 |
| Number of replications.......... | | | | | | | 4 | 4 | |

Further data from this Station, reported in part by Montgomery in 1909 in Bulletin 112, regarding the relation of ear type and yield are given in Table 51. During the six years 1905-1910, long, smooth ears of Reid's Yellow Dent were con-

TABLE 51.—*Long smooth compared with standard medium rough type of Reid's Yellow Dent. 1905-1910.*[1]

| Ear type | Yield of grain per acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | Av. |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) |
| Long, smooth type....... | 69.7 | 47.2 | 69.9 | 56.8 | 37.9 | 62.6 | 57.3 |
| Standard medium rough type | 59.4 | 51.4 | 64.1 | 51.2 | 35.6 | 58.4 | 53.3 |
| Number of plats grown..... | 1 | 1 | 1 | 1 | 4 | 4 | |

[1]Data for the first four years taken from Nebraska Agricultural Experiment Station Bulletin No. 112, by Montgomery.

trasted for yield with standard medium rough ears of the same variety. The smooth surpassed the rough type 4.0 bushels per acre. This was a test of continuous selection in which seed for the smooth type was repeatedly selected from the smooth type of the preceding year.

In all three of the preceding experiments, covering a total of twelve different years, the long, smooth type of ear surpassed all other types. There are seasonal fluctuations in which the rough equals or surpasses the smoother corn, probably owing largely to climatic conditions favoring the plant type which the rougher ears represent. Since we can not foresee the sort of weather which the season will bring forth, it would seem advantageous to select a somewhat longer, smoother, and shallower grained ear type wherever the corn being grown is a full-season, late-maturing crop. This general conclusion has been reached at least in Ohio, Illinois, and Kansas in addition to Nebraska. Experiments in these four states and in Minnesota and New York have indicated that ear type considerations aside from maturity, soundness, and adaptability are rather neutral in their relation to yield.

The relation of kernel depth to moisture content and freezing injury in a year of late maturity in the fall was shown forcefully in a field of Hogue's Yellow Dent corn at the Experiment Station in 1917. The ears harvested from this field on December 29 were divided into five groups according to their apparent soundness, maturity, and solidity. The moisture content, germination, and kernel length were determined for the grain in each group. Beginning with the most solid and mature group, the germinations, after curing, for the five groups were respectively 93, 59, 14, 5, and 0 per cent. The moisture contents at time of husking, December 29, were respectively 15, 16, 19, 21, and 28 per cent, while the average kernel lengths were 0.49, 0.50, 0.52, 0.54, and 0.57 inches. The deep kernels, representing later maturing plants, contained more water at the time of freezing weather, and for this reason were more subject to freezing injury. Extensive data regarding the correlation between moisture content and susceptibility to freezing injury have been reported in Agricultural Experiment Station Research Bulletin No. 16.

There has been considerable controversy in the past fifteen years regarding the relation of ear type to yield of corn. In lieu of actual experimental evidence, a sudden public interest was gratified for a time in the early nineties by comparing vari-

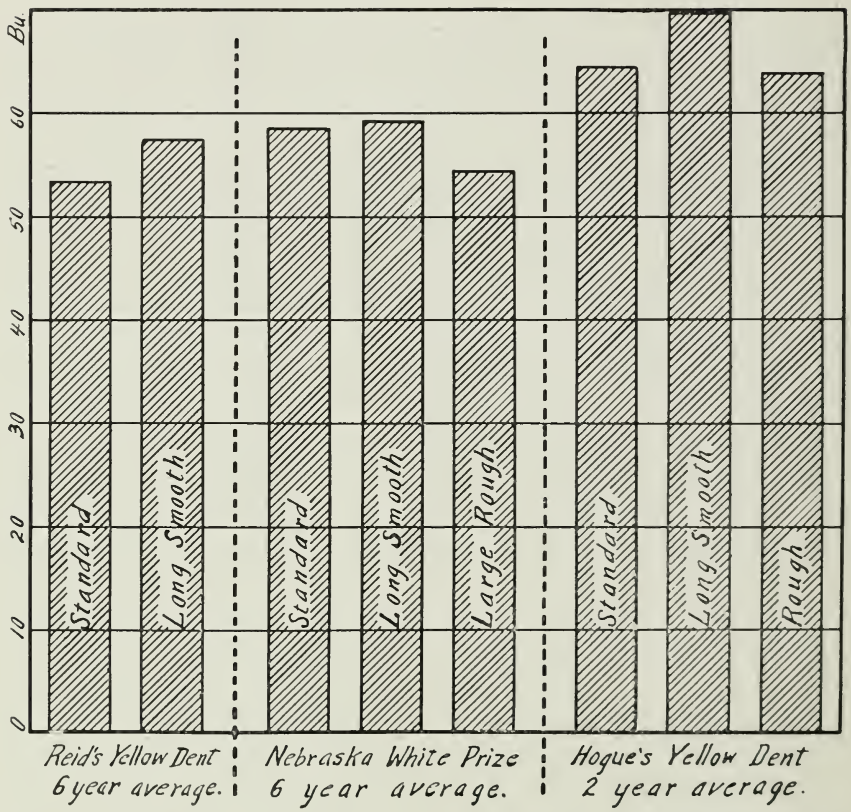



CHART 5.—Relation of ear type to yield. The standard type represents the ordinary unselected seed of the variety tested. Data taken from Tables 49, 50, and 51.

ous ear characteristics with the quantity of grain on an ear. Without further consideration. the amount of grain per ear and shelling per cent came to be regarded as expressive of grain yield per acre. Arbitrary ear standards were improvised and offered as ideals for seed selection. Experimental evidence and farm experience in later years have served to disprove the above correlations for many sections of the country. It is now apparent that ear and kernel type are primarily significant only to the extent that they indicate certain correlated plant characteristics. The reliability of such indication hinges upon previous knowledge of the corn's source and adaptation.

It is possible, indirectly, to exert marked influence upon the general vegetative character of a corn variety thru ear type selection. Within a variety, roughness, large ear circumference, many rows on the ear, deep kernels, and high shelling percentage indicate late maturity, large stalk, and relatively large leaf area. These plant characters are concerned in the balance between plant requirement and environment. Thus, it is not the ear character which is the vital consideration in yield, but rather the plant character which is reflected in the ear.

A sharp distinction must be made between ear type selection as herein spoken of and ear type selection for conformity with arbitrary competitive score card specifications. The ear type selections herein spoken of refer essentially to certain plant type corollaries, without any reference to the ear's possible rating for perfection and symmetry of development according to corn show standards. Extensive data from the Nebraska Experiment Station and other institutions and individuals, bearing evidence of the inconsequential nature of many ear characteristics which have been stressed in competitive exhibitions, have been summarized by the writer and accepted for publication in the January, 1922, issue of the Journal of the American Society of Agronomy.

### COMPARATIVE YIELDS OF SEED FROM DIFFERENT PARTS OF THE EAR

Corn growers have always been interested in the relative yields to be expected from seed produced on different parts of the ear. During six years, comparative tests have been made of seed taken respectively from the butt, tip, and middle sections of the ear. The results given in Table 52 show no material differences in the respective crops in any regard. The respective yields for butts, tips, and middles were 59.3, 60.4, and 60.2 bushels per acre. Altho the kernels at the tip of an ear are relatively small and their early seedling development is slightly backward, they still contain sufficient food material to support the seedling until its own synthetic activities are established. The reserve food material in the average kernel of dent corn appears to be greater than the young seedlings require under ordinary field conditions.

It seems, therefore, that little is to be gained by discarding kernels from the butt and tip ends of the ear aside from a somewhat more uniform dropping by the corn planter and a better germination under certain conditions of freezing injury.

TABLE 52.—*Yield of grain from different portions of the ear. Nebraska White Prize corn. Six years, 1914-1917 and 1920-1921.*

| Portion of ear used for seed | Yield of grain per acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Av. |
| (1) | *Bu.* (2) | *Bu.* (3) | *Bu.* (4) | *Bu.* (5) | *Bu.* (6) | *Bu.* (7) | *Bu.* (8) |
| 1 Butt | 48.8 | 77.0 | 65.0 | 49.6 | 52.3 | 62.8 | 59.3 |
| 2 Tip | 49.6 | 75.3 | 69.3 | 52.7 | 52.8 | 62.8 | 60.4 |
| 3 Middle | 48.0 | 76.8 | 68.8 | 49.4 | 54.8 | 63.7 | 60.2 |
| Number of replications | 3 | 7 | 7 | 7 | 3 | 3 | |

| Seed from | Summary of plant characteristics during period | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date ripe | Lodging | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (9) | *Inches* (10) | (11) | *Per cent* (12) | (13) | (14) | *Per cent* (15) | *Per cent* (16) |
| 1 | 104 | 49 | 9/22 | 29 | 93 | 9 | 7.5 | 82.5 |
| 2 | 103 | 49 | 9/22 | 31 | 95 | 10 | 8.3 | 83.2 |
| 3 | 104 | 49 | 9/22 | 31 | 96 | 10 | 7.2 | 83.3 |

## RELATION OF SEED MATURITY TO YIELD OF GRAIN

In years of late maturity, the question of special field selection of slightly immature seed corn to escape frost injury commonly arises. A two-year test reported in Table 53 indicates that carefully cured corn selected midway between silking and maturity may possess both high germinative and yielding ability. Corn selected at five weekly intervals before ripe yielded in no case more than two per cent less than fully matured seed. Even tho viability and yield may not be impaired by immature selection, thoro field curing of seed should be practiced as far as possible, since difficulty of curing and preservation are thereby greatly reduced. The above test does not include the effect of unfavorable growth conditions in some seasons. It is possible that small, immaturely harvested seeds would be handicapped under unfavorable climatic or seed bed conditions.

TABLE 53.—*Relation of maturity of seed to yield per acre. Hogue's Yellow Dent corn, 1916 and 1917.*

| Date of seed harvest | Condition of grain | Days since fertilization[1] | Weight of 100 kernels | Ratio weight of embryo to weight of kernel[2] | Germination | Yield per acre | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1916 | 1917 | Av'ge |
| | | | *Grams* | | *Per cent* | *Bu.* | *Bu.* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Sept. 1... | Late milk stage... | 25 | 17.5 | .105 | 94 | 73.2 | 53.6 | 63.4 |
| Sept. 8... | Roasting ear...... | 32 | 21.1 | .110 | 96 | 76.9 | 51.1 | 64.0 |
| Sept. 15... | Late roasting ear.. | 39 | 24.8 | .103 | 97 | 73.2 | 52.8 | 63.0 |
| Sept. 22... | Denting.......... | 46 | 28.4 | .106 | 97 | 76.2 | 53.8 | 65.0 |
| Sept. 29... | Glazing.......... | 53 | 31.1 | .112 | 97 | 72.5 | 55.5 | 64.0 |
| Oct. 6... | Mature.......... | 60 | 31.6 | ............ | 98 | 74.3 | 54.7 | 64.5 |
| Number of replications........ | | | | | | 2 | 2 | |

[1]Pollination occurred on July 31 and August 10 in 1916 and 1917, respectively.
[2]Data for 1917 only.

## EFFECT OF TIME OF SELECTION AND PRESERVATION OF SEED CORN UPON YIELD

This test has previously been reported in Nebraska Agricultural Experiment Station Bulletin No. 163. The object was to determine the effect of the time of harvesting seed corn upon its yielding ability provided care is taken in selection to obtain equally high germination. Comparative yield tests were made in 1915, 1916, and 1917 of September, November, and March field selections made from Nebraska White Prize corn grown at the Experiment Station. The seed was carefully preserved in a dry, well-ventilated place upon being harvested. Only those

TABLE 54.—*Relative yields from seed corn selected at various dates during the fall and winter. 1915-1917.*

| Date of seed selection | Duplications each year | Yield per acre | | | |
|---|---|---|---|---|---|
| | | 1915 | 1916 | 1917 | Three-year average |
| | | *Bu.* | *Bu.* | *Bu.* | *Bushels* |
| (1) | (2) | (3) | (4) | (5) | (6) |
| September............ | 4 | 66.6 | 36.1 | 38.3 | 47.0 |
| November............ | 4 | 65.9 | 37.3 | 41.6 | 48.3 |
| March............... | 4 | 64.7 | 42.1 | 42.6 | 49.8 |
| Check............... | 4 | 66.3 | 40.3 | 41.1 | 49.2 |

1. The seed was harvested about the 15th of each month.
2. The check seed was harvested from the same field while husking in November.

seed ears were selected which showed a bright, clear germ and thereby promised good germination. A large number of ears were mixed for each selection.

The results given in Table 54 indicate that corn which has been left standing in the field during the cold of winter may yield quite as well as specially fall selected seed, provided its germinative power has not been impaired.

Prudence, however, suggests provision for the next year's seed supply in the fall before the time of possible frost injury. Such early provision greatly reduces the anxiety and extra labor which accompany the selection from among frost injured ears. Frost injury and moisture content of the grain have been shown in Nebraska Research Bulletin No. 16 to be closely correlated. Therefore the time and manner of seed corn preservation may safely be made to vary in different seasons according to prevailing conditions.

## SELECTION OF SEED EARS FOR FREEDOM FROM ROOT-ROT DISEASES

Root-rot diseases of corn and their control have been so stressed recently by a number of investigators that it seemed desirable to procure some information based on local experiments. In March, 1921, 959 ears of Hogue's Yellow Dent corn and 497 ears of Nebraska White Prize corn were tested for the presence of root-rot diseases by the accredited germinator test described by Holbert and Hoffer in United States Department of Agriculture Farmers' Bulletin No. 1176. Methods for testing and identification described by these authors were duplicated as nearly as possible. Acknowledgment is extended Dr. G. L. Peltier and Professor R. W. Goss, plant pathologists of the Nebraska Experiment Station, for assistance in identifying the disease and reading the germinator tests. The corn used in these tests consisted of seed ears selected in the ordinary manner from Experiment Station fields used for continuing the ordinary "check" seed of these two varieties. Neither variety had ever been subjected to close selection for type or specialized breeding.

### IDENTIFICATION OF ROOT-ROT DISEASES BY THE GERMINATOR TEST

The manner of testing is illustrated in figure 28 and figure 29. The rag doll consists of a sterilized muslin cloth, 12×54 inches, laid upon a sheet of water fibre paper of equal width and six inches greater length. The ten kernels removed spirally from each ear were laid germ down across the cloth in rows two

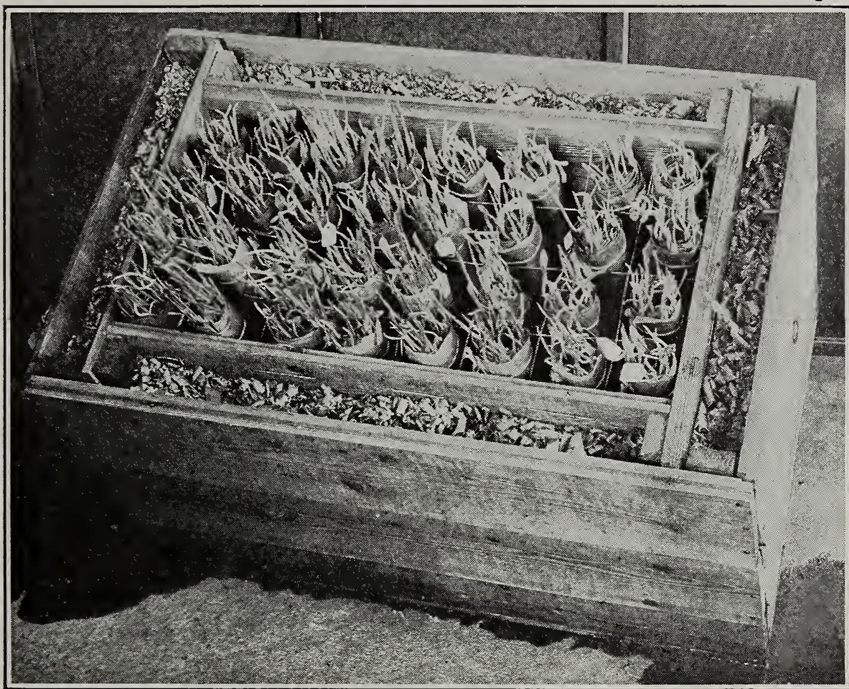


Fig. 28.—Rag doll germinator test for root-rot diseases of individual seed ears employed in these tests. Each doll tests twenty ears, making 640 ears per box. Four such boxes were run in one battery. The inside box is surrounded by three inches of moist sawdust on the sides and below. It has drainage holes at the bottom for draining off free moisture at time of sprinkling the rag dolls. This is a duplicate of the method recommended by Hoffer and Holbert.

inches apart. The kernels all pointed toward one edge of the cloth so that the rolled up rag doll might be placed vertically in the germinator box with the assurance that the root and stem sprouts would point directly down and up respectively. This arrangement facilitated reading the tests and reduced the likelihood of row to row contamination of the sprouting kernels.

The box was kept in a heated room at a temperature ranging from 78° to 85° F. The rag dolls were placed in the box in a thoroly moistened condition and sprinkled daily thereafter. The tests were read at the end of seven days. The sprouted kernels for each ear were classified into four groups, viz, (1) "disease free," which included all sprouted kernels showing no indication of disease or rotting; (2) "diseased but not rotting," which included all sprouted kernels free from rotting but with apparently characteristic mycelium of *Fusaria* spp. present; (3) "diseased and rotting," which included all sprouted kernels that showed rotting and otherwise corresponded to those of group 2; (4) "dead kernels," which failed to germinate.

The results of the germination test are summarized for each variety in Table 55. As an average of the two varieties, 54.6 per cent of the sprouted kernels were disease free, 29.3 per cent were diseased but showed no rotting, 14.5 per cent were both diseased and rotting, 1.45 per cent were dead. Of the 1,456 ears

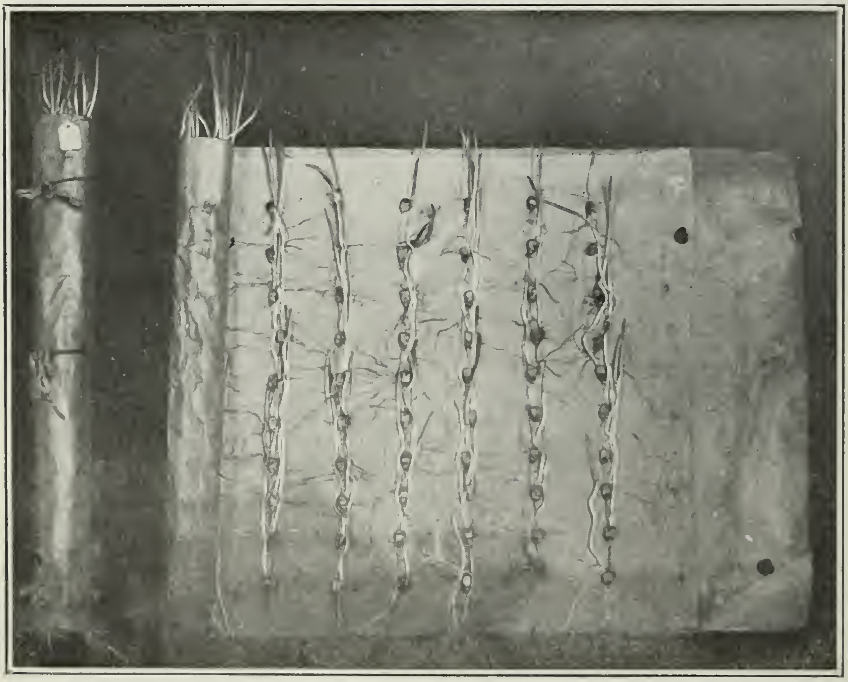


FIG. 29.—A rolled up rag doll at the left, showing its appearance at the end of six days' germination in a temperature of 78 to 85 degrees F. A partially unrolled doll showing the sprouted kernels is given at the right. The doll consists of a sterilized muslin cloth 18x58 inches placed on a sheet of water-finished fiber paper of equal width and six inches greater length. Ten kernels, taken spirally from an ear, are placed in a row. They are placed germ side down and pointing toward that edge of the cloth which is to be placed down in the germinator box.

tested, 11.4 per cent were entirely disease free and 88.6 per cent showed more or less disease present, while 10.3 per cent of all were classified as very badly diseased.

In an identification test of root-rot diseases made by T. F. Manns and J. F. Adams, pathologists of the Delaware Experiment Station, the unselected Nebraska White Prize corn used in these tests was found to be 20 per cent infected with *Cephalosporium sacchari*, 20 per cent infected with *Fusarium moniliforme*, and 20 per cent with *Diplodia zeae*. As an average for seed of the 1920 crop from fourteen different sources in Nebraska, 44 per cent of infection with rot diseases was found.

#### RELATION BETWEEN EAR TYPE AND PRESENCE OF ROOT-ROT DISEASES AS INDICATED BY THE GERMINATOR TEST

Descriptive notes were taken individually of all 1,456 ears tested, regarding the following characters: (1) Ear length, (2) ear diameter, (3) ear weight, (4) roughness, (5) starchiness, (6) luster of germ, (7) moldiness, (8) kernel discoloration, (9) color of shank, and (10) soundness of shank.

Those physical ear and kernel characters of Hogue's Yellow

TABLE 55.—*Results of germinator test to determine amount of root-rot disease present in two standard varieties of dent corn grown at the Nebraska Experiment Station (Hogue's Yellow Dent and Nebraska White Prize). 1921.*

| Classification of ears and kernels | Variety tested | | |
|---|---|---|---|
| | Hogue's Yellow Dent | Nebraska White Prize | Average |
| Number of ears tested | 959 | 497 | ........ |
| Total number of kernels tested | 9,590 | 4,970 | ........ |
| Disease free kernels (per cent) | 57.9 | 51.4 | 54.65 |
| Kernels diseased but not rotted (per cent) | 23.8 | 34.9 | 29.35 |
| Kernels diseased and rotted (per cent) | 16.8 | 12.3 | 14.55 |
| Kernels dead (per cent) | 1.5 | 1.4 | 1.45 |
| Germination (per cent) | 98.5 | 98.6 | 98.55 |
| Ears disease free (per cent) | 14.4 | 8.5 | 11.45 |
| Ears diseased (per cent) | 85.6 | 91.5 | 88.55 |
| Ears badly diseased (per cent)[1] | 10.6 | 10.0 | 10.30 |

[1] "Ears badly diseased" refers in the case of Hogue's Yellow Dent to ears of which five or more of the ten kernels tested showed disease accompanied by rotting. In case of the Nebraska White Prize, a number of ears were included which showed somewhat less rotting, but in such cases not less than eight of the ten kernels indicated disease.

Dent corn which might possibly be related to the susceptibility to or presence of disease are correlated in Table 56 with the disease readings obtained in the germinator test. Since the ear type and disease readings were made entirely independently of each other, and the ears were arranged in order by random selection, we may assume that the likelihood of systematic errors was eliminated.

Classified according to roughness, the rough, medium, and smooth ears had respectively 49, 55, and 63 per cent of their kernels disease free, while 23, 19, and 12 per cent of the kernels respectively were diseased and rotting. Of the rough, medium, and smooth ears, 8, 13, and 19 per cent respectively were disease free, while 14, 8, and 4 per cent respectively had all of their kernels diseased. Some correlation between degree of roughness and disease is apparent.

Classified according to color of shank, ears with yellow, pink, brown, and normal colored shanks had respectively 75, 66, 49, and 61 per cent disease free kernels, while 14, 10, 24, and 15 per cent of the kernels were respectively diseased and rotting.

Of the ears with yellow, pink, brown, and normal colored shanks, 28, 18, 8, and 18 per cent respectively had no diseased kernels, while 0, 3, 9, and 7 per cent respectively had all of their kernels diseased. Brown shank discoloration appears to be somewhat indicative of disease. The pinkish and yellowish shank colorations noted in these tests were not indicative of disease.

Classified according to soundness of shank, ears with sound, split, and shredded shanks had respectively 57, 60, and 60 per cent of their kernels disease free, while 17, 16, and 17 per cent of the kernels respectively were diseased and rotting.

Of the ears with sound, split, and shredded shanks, 14, 17, and 4 per cent respectively had no diseased kernels, while 8, 8, and 2 per cent respectively had all kernels diseased.

A lower per cent of ears with shredded shanks appear to be entirely disease free than in the case of split or sound shanks.

Classified according to lustre of germ, ears having bright, medium, and dull germs had respectively 57, 59, and 49 per cent of their kernels disease free, while 17, 17, and 19 per cent of the kernels respectively were diseased and rotting.

Of the ears with bright, medium, and dull germs, 16, 12, and 12 per cent respectively had no diseased kernels, while 8, 5, and 16 per cent respectively had only diseased kernels.

Classified according to "starchiness," ears with horny,

TABLE 56.—*Relation between ear and kernel characteristics and the presence of root-rot disease as determined by the germinator test. (959 ears of Hogue's Yellow Dent corn, 1920 crop.) 1921.*

| Classification of ears | Number of ears in class | Number of kernels tested in class | Presence of disease: Number of kernels | | | | Per cent of kernels | | | | No. of ears with | | Per cent of ears with | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Disease free | Diseased but not rotting | Diseased and rotting | Dead | Disease free | Diseased but not rotting | Diseased and rotting | Dead | All kernels disease free | All kernels diseased | All kernels disease free | All kernels diseased |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| EARS CLASSIFIED ACCORDING TO ROUGHNESS | | | | | | | | | | | | | | |
| Rough........ | 145 | 1,450 | 719 | 361 | 336 | 34 | 49.6 | 24.9 | 23.2 | 2.3 | 11 | 20 | 7.6 | 13.8 |
| Medium rough. | 422 | 4,220 | 2,341 | 1,038 | 786 | 55 | 55.5 | 24.6 | 18.6 | 1.3 | 54 | 35 | 12.8 | 8.3 |
| Smooth........ | 392 | 3,920 | 2,487 | 890 | 491 | 52 | 63.4 | 22.7 | 12.5 | 1.3 | 73 | 16 | 18.6 | 4.1 |
| EARS CLASSIFIED ACCORDING TO COLOR OF SHANK | | | | | | | | | | | | | | |
| Natural....... | 469 | 4,690 | 2,855 | 1,057 | 720 | 58 | 60.9 | 22.5 | 15.4 | 1.2 | 85 | 35 | 18.1 | 7.5 |
| Brown......... | 377 | 3,770 | 1,849 | 947 | 907 | 67 | 49.0 | 25.1 | 24.1 | 1.8 | 31 | 33 | 8.2 | 8.8 |
| Pinkish........ | 95 | 950 | 623 | 211 | 100 | 16 | 65.6 | 22.2 | 10.5 | 1.7 | 17 | 3 | 17.9 | 3.2 |
| Yellow........ | 18 | 180 | 135 | 17 | 26 | 2 | 75.0 | 9.4 | 14.4 | 1.1 | 5 | 0 | 27.8 | 0.0 |
| EARS CLASSIFIED ACCORDING TO SOUNDNESS OF SHANK | | | | | | | | | | | | | | |
| Sound shank... | 686 | 6,860 | 3,908 | 1,671 | 1,164 | 117 | 57.0 | 24.4 | 17.0 | 1.7 | 97 | 52 | 14.1 | 7.6 |
| Split shank.... | 228 | 2,280 | 1,362 | 535 | 359 | 24 | 59.7 | 23.5 | 15.7 | 1.1 | 39 | 18 | 17.1 | 7.9 |
| Shredded shank. | 45 | 450 | 271 | 100 | 75 | 4 | 60.2 | 22.2 | 16.7 | 0.9 | 2 | 1 | 4.4 | 2.2 |
| EARS CLASSIFIED ACCORDING TO LUSTER OF GERM | | | | | | | | | | | | | | |
| Bright germ.... | 541 | 5,410 | 3,113 | 1,340 | 900 | 57 | 57.5 | 24.7 | 16.6 | 1.1 | 86 | 44 | 15.7 | 8.1 |
| Medium germ.. | 368 | 3,680 | 2,168 | 833 | 611 | 68 | 58.9 | 22.6 | 16.6 | 1.9 | 46 | 19 | 12.5 | 5.2 |
| Dull germ ..... | 50 | 500 | 247 | 133 | 94 | 26 | 49.4 | 26.6 | 18.8 | 5.2 | 6 | 8 | 12.0 | 16.0 |
| EARS CLASSIFIED ACCORDING TO STARCHINESS OF KERNEL | | | | | | | | | | | | | | |
| Starchy kernel.. | 88 | 880 | 456 | 211 | 193 | 20 | 51.8 | 24.0 | 21.9 | 2.3 | 8 | 13 | 9.1 | 14.8 |
| Medium kernel. | 328 | 3,280 | 1,898 | 803 | 524 | 55 | 57.9 | 24.5 | 16.0 | 1.7 | 44 | 23 | 13.4 | 7.0 |
| Horny kernel... | 543 | 5,430 | 3,232 | 1,258 | 871 | 69 | 59.5 | 23.2 | 16.0 | 1.3 | 76 | 25 | 14.0 | 4.6 |
| EARS CLASSIFIED ACCORDING TO DEPTH OF KERNEL | | | | | | | | | | | | | | |
| Deep kernel.... | 320 | 3,200 | 1,686 | 855 | 605 | 54 | 52.7 | 26.7 | 18.9 | 1.7 | 32 | 34 | 10.0 | 10.6 |
| Medium kernel. | 586 | 5,860 | 3,536 | 1,330 | 906 | 88 | 60.3 | 22.7 | 15.5 | 1.5 | 98 | 34 | 16.7 | 5.8 |
| Shallow kernel.. | 53 | 530 | 309 | 118 | 100 | 3 | 58.3 | 22.3 | 18.9 | 0.6 | 8 | 3 | 15.1 | 5.7 |
| EARS CLASSIFIED ACCORDING TO DIAMETER OF EAR | | | | | | | | | | | | | | |
| Large (2.25 in.). | 323 | 3,230 | 1,721 | 804 | 646 | 59 | 53.3 | 24.9 | 20.0 | 1.8 | 40 | 34 | 12.4 | 10.5 |
| Medium (2 in.). | 584 | 5,840 | 3,470 | 1,401 | 895 | 74 | 59.4 | 24.0 | 15.3 | 1.3 | 89 | 36 | 15.2 | 6.2 |
| Small (1.75 in.). | 52 | 520 | 331 | 119 | 62 | 8 | 63.7 | 22.9 | 11.9 | 1.5 | 9 | 1 | 17.3 | 1.9 |

medium starchy, and starchy grain had respectively 59, 58, and 52 per cent disease-free kernels, while 16, 16, and 22 per cent of their kernels respectively were diseased and rotting.

Of the ears with horny, medium, and starchy grain, 14, 13, and 9 per cent respectively had no diseased kernels, while 5, 7, and 15 per cent respectively had all kernels diseased. A slight correlation between starchiness and disease indication is apparent.

Classified according to depth of kernel, ears with shallow, medium, and deep grain had respectively 58, 60, and 53 per cent disease free kernels, while 19, 15, and 19 per cent of their kernels respectively were diseased and rotting.

Of the ears having shallow, medium, and deep grain, 15, 17, and 10 per cent respectively had no diseased kernels, while 6, 6, and 11 per cent respectively had all kernels diseased. Ears with deep kernels appear to be relatively most subject to disease.

Classified according to ear diameter, ears with large, medium, and small diameter had respectively 53, 59, and 64 per cent of their kernels disease free, while 20, 15, and 12 per cent of their kernels respectively were diseased and rotting.

Of the ears with large, medium, and small diameters, 12, 15, and 17 per cent respectively had no diseased grain, while 10, 6, and 2 per cent respectively had all their kernels diseased. Large ear circumference appears to be somewhat correlated with the disease indication of the germinator test.

While there appears to be no reliable correlation between any of the ear characters and the presence of root-rot disease, it seems that the selection of smooth, slender ears having a sound natural colored shank and bright vitreous kernels of only medium depth will materially reduce its presence.

## RELATIVE YIELD PERFORMANCE OF DISEASED AND DISEASE FREE CORN AS DETERMINED BY THE GERMINATOR TEST

In 1921, yield tests were made of the comparative performance in the field of badly diseased and disease free ears of Hogue's Yellow Dent and Nebraska White Prize corn as determined by the preceding germinator tests. Seventy disease free Hogue's Yellow Dent ears were compared with the 59 most diseased ears of the same variety in duplicate ear-to-row plats 44 hills in length. Duplicate 4-row plats were also planted from composite seed of these diseased and disease free ears respectively. Similar tests were made for Nebraska White Prize, comparing 40 disease free ears with the 40 most diseased ears.

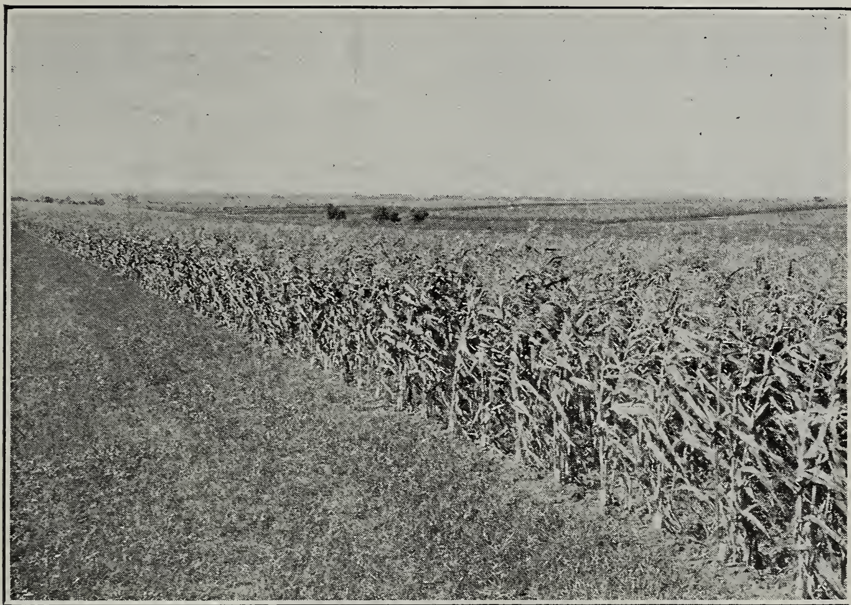


Fig. 30.—The field in which 475 plats were devoted to a study of root-rot diseases in relation to yield in 1921. (See Table 57.)

In these experiments it was thought that failure to produce a plant due to disease should be charged up against the affected seed. The corn was, therefore, planted definitely at the standard rate of three kernels per hill and the yield determined for the entire plat, rather than to plant thick and reduce to a perfect stand. Only ears were used which showed 100 per cent germination in the viability tests. This reduced the complication resulting from lack of vitality due to other causes than disease.

Extensive detailed notes were taken on each field plat regarding stand and growth characteristics which might prove of interest in interpreting results. These are summarized in Tables 57 and 58, to which the reader is referred for comparisons. It is apparent that the disease free, diseased, and original corn were almost identical in (1) the number of plants coming up in the spring, (2) plant survival till harvest, (3) number of weak plants in the spring, (4) date tasseling, (5) date ripe, (6) plant height, (7) suckers per 100 plants, (8) barrenness, (9) per cent lodging, (10) shrinkage of ear corn, (11) shelling percentage, and (12) yield of grain per acre.

TABLE 57.—*Field performance of disease free versus diseased corn as indicated by germinator test. (Two varieties and two methods of comparison.) 1921.*

| | Duplicate ear-to-row plats | | | | | | Duplicate 4-row plats with composite seed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hogue's Yellow Dent | | | Nebraska White Prize | | | Hogue's Yellow Dent | | | Nebraska White Prize | | |
| | Disease free | Diseased | Original | Disease free | Diseased | Original | Disease free | Diseased | Original | Disease free | Diseased | Original |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| No. of plats averaged | 140 | 118 | 30 | 78 | 78 | 19 | 2 | 2 | 2 | 2 | 2 | 2 |
| No. of seeds planted per plat | 132 | 132 | 132 | 132 | 132 | 132 | 528 | 528 | 528 | 528 | 528 | 528 |
| Stand 21 days after planting (per cent) | 87.4 | 85.4 | 87.1 | 86.8 | 86.3 | 86.1 | 83.3 | 88.0 | 83.9 | 85.0 | 84.0 | 83.7 |
| Weak plants 21 days after planting (per cent) | 2.3 | 3.1 | 3.0 | 1.8 | 2.3 | 2.4 | 3.2 | 3.2 | 1.8 | 3.0 | 3.2 | 2.8 |
| No. of plants per plat in fall (actual) | 111.6 | 110.2 | 112.0 | 107.3 | 108.2 | 107.8 | 434.5 | 449.5 | 433.0 | 425.5 | 439.5 | 432.5 |
| Per cent stand in fall | 84.5 | 83.4 | 84.9 | 81.3 | 82.0 | 81.7 | 82.3 | 85.1 | 82.0 | 80.6 | 83.2 | 81.9 |
| Date tasseling | 7/16 | 7/16 | 7/16 | 7/23 | 7/22 | 7/23 | 7/17 | 7/17 | 7/17 | 7/22 | 7/22 | 7/22 |
| Date ripe | 9/1 | 9/1 | 9/1 | 9/4 | 9/4 | 9/4 | 9/2 | 9/2 | 9/2 | 9/5 | 9/5 | 9/5 |
| Height of plants (inches) | 104 | 104 | 104 | 111 | 109 | 110 | 103 | 102 | 102 | 112 | 109 | 111 |
| Suckers per 100 plants | 11.2 | 12.9 | 13.3 | 4.4 | 5.3 | 4.3 | 8.6 | 8.4 | 8.5 | 3.5 | 8.2 | 8.7 |
| Barren plants per 100 | 6.5 | 7.8 | 7.5 | 9.9 | 8.6 | 11.3 | 5.2 | 5.2 | 7.5 | 8.6 | 7.5 | 5.1 |
| Lodged plants per 100 | 85.2 | 82.3 | 83.3 | 84.6 | 84.9 | 84.5 | 84.0 | 83.3 | 84.8 | 82.7 | 82.9 | 81.3 |
| Ears per 100 plants | 96.4 | 95.1 | 95.0 | 91.0 | 91.6 | 91.8 | 92.1 | 94.0 | 91.0 | 91.9 | 86.8 | 91.7 |
| Shelling per cent | 85.0 | 85.1 | 84.9 | 82.1 | 82.4 | 82.0 | ........ | ........ | ........ | ........ | ........ | ........ |
| Shrinkage of ear corn (per cent) | 0.45 | 0.30 | 0.61 | 1.72 | 1.95 | 1.24 | ........ | ........ | ........ | ........ | ........ | ........ |
| Yield per acre (bushels) | 58.22 | 57.53 | 57.44 | 44.20 | 46.54 | 45.14 | 51.39 | 53.45 | 50.18 | 46.87 | 44.79 | 46.23 |

The average yields for both varieties, averaged for both types of plats, were as follows: (1) Disease free, 50.2 bushels; (2) badly diseased, 50.6 bushels; (3) original, 49.7 bushels.

[1]Barrenness and number of ears are for independent counts and therefore do not quite agree.

No lodging was apparent until August 26—four to seven days before the corn was ripe. On this date a very unusual wind of sixty miles per hour occurred, and another of sixty-five miles per hour on September 2. All three lots of corn withstood the windstorms about equally well.

As a grand average for both varieties planted in both ear-to-row and composite tests, (1) the disease free ears yielded 50.2 bushels, (2) the diseased ears yielded 50.6 bushels, and (3) the original untested seed yielded 49.7 bushels per acre.

TABLE 58.—*Summary showing field performance of disease free versus diseased corn as indicated by germinator test. (Average of two varieties and two methods of comparison.) 1921.*

| | Disease free | Dis-eased | Original |
|---|---|---|---|
| Number of plats averaged | 222 | 200 | 51 |
| Number of seeds planted per plat | 330 | 330 | 330 |
| Stand 21 days after planting (per cent) | 85.6 | 85.9 | 85.2 |
| Weak plants 21 days after planting (per cent) | 2.6 | 2.9 | 2.5 |
| Number of plants per plat in fall (actual) | 269.7 | 276.8 | 271.3 |
| Per cent stand in fall | 82.2 | 83.4 | 82.6 |
| Date tasseling | 7/19 | 7/19 | 7/19 |
| Date ripe | 9/3 | 9/3 | 9/3 |
| Height of plants (inches) | 107 | 106 | 107 |
| Suckers per 100 plants | 6.9 | 8.7 | 8.7 |
| Barren plants per 100 | 7.5 | 7.3 | 7.8 |
| Lodged plants per 100 | 84.1 | 83.3 | 83.5 |
| Ears per 100 plants | 92.8 | 91.9 | 92.4 |
| Shelling per cent | 83.5 | 83.7 | 83.4 |
| Shrinkage of ear corn (per cent) | 1.1 | 1.1 | 0.9 |
| Yield per acre (bushels) | 50.2 | 50.6 | 49.7 |

These data are summarized from Table 57.

In Table 59 the yields for the two varieties are so assembled as to compare the ten highest yielding ears selected for freedom from disease with the ten highest yielding ears selected as being badly diseased by means of the germinator test. The same comparisons are also made for the ten lowest yielding ears of each group. It was thought that this manner of comparing extremes for the diseased and disease free selections should emphasize any detrimental effect of the disease. The averages for both varieties indicate that the best ten ears selected for freedom from disease yielded 1.8 bushel below the diseased, while the ten lowest yielding ears selected for freedom from disease yielded 0.3 bushel more than the diseased.

The results seem to indicate that selection for freedom from root-rot disease by the germinator test does not increase grain production under the conditions of the experiment. While these disease investigations cover only one year, yet temperature and moisture conditions thruout the corn growing season were unusually favorable for the development of this disease.

Our data suggest that agitation over the root-rot diseases of dent corn in this State would not be warranted in the present state of knowledge regarding their significance and control.

TABLE 59.—*Yields of ten highest and ten lowest yielding ears of both diseased and disease free Hogue's Yellow Dent and Nebraska White Prize corn.*

| TEN HIGHEST YIELDING EARS | Yield per acre |
|---|---|
| | *Bushels* |
| Hogue's Yellow Dent selected for freedom from disease | 66.8 |
| Nebraska White Prize selected for freedom from disease | 50.2 |
| Average for both varieties | 58.5 |
| Hogue's Yellow Dent selected as badly diseased | 65.2 |
| Nebraska White Prize selected as badly diseased | 55.4 |
| Average for both varieties | 60.3 |
| TEN LOWEST YIELDING EARS | |
| Hogue's Yellow Dent selected for freedom from disease | 48.2 |
| Nebraska White Prize selected for freedom from disease | 38.9 |
| Average for both varieties | 43.5 |
| Hogue's Yellow Dent selected as being badly diseased | 47.7 |
| Nebraska White Prize selected as being badly diseased | 38.8 |
| Average for both varieties | 43.2 |

## SOIL AND AIR TEMPERATURES IN THE FIELD IN WHICH YIELD TESTS WERE MADE (1921)

Since the development of the rot fungi most prevalent is enhanced by warm temperature during the time of germination and early growth, continuous temperature records were taken in the cornfield thruout the growing season. These were taken by means of a combination air and soil thermograph. The air temperature was taken within a regulation instrument shelter, at a height of one foot above the ground. The soil temperature record is for a depth of three inches, which corresponds with the depth at which the seed was planted. The instruments were fully surrounded by a normal stand of corn in a representative portion of the field.

The data in Table 60 indicate that the soil temperatures approximated closely the prescribed temperatures for disease tests made in the germinator and were favorable for disease development. Together with the very favorable soil moisture which prevailed, this provided soil conditions conducive to the development of the rot diseases.

TABLE 60.—*Soil and air temperatures in the cornfield in which the root-rot disease studies reported in Table 57 were made. 1921.*

| Week ending | Mean hourly temperatures | | | | | |
|---|---|---|---|---|---|---|
| | Air temperature one foot above ground | | | Soil temperature three inches below surface | | |
| | [1]Night | [1]Day | Maximum | Night | Day | Maximum |
| | *Deg. F.* | *Deg. F.* | *Deg. F.* | *Deg. F.* | *Deg. F.* | *Deg. F.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| May 29 | 75.2 | 84.8 | 94.4 | 73.7 | 76.3 | 83.6 |
| June 5 | 69.1 | 71.4 | 80.1 | 71.6 | 73.4 | 78.9 |
| June 12 | 71.0 | 79.1 | 85.1 | 74.4 | 78.1 | 85.3 |
| June 19 | 78.8 | 87.7 | 94.1 | 83.6 | 86.3 | 93.9 |
| June 26 | 74.7 | 81.3 | 91.9 | 83.3 | 82.6 | 91.7 |
| July 3 | 80.5 | 84.8 | 97.3 | 83.2 | 82.7 | 89.7 |
| July 10 | 74.0 | 80.3 | 88.7 | 77.3 | 78.3 | 81.7 |
| July 17 | 74.4 | 79.9 | 85.4 | 82.6 | 83.0 | 86.7 |
| July 24 | 70.3 | 76.7 | 81.1 | 77.6 | 77.8 | 80.9 |
| July 31 | 72.7 | 79.2 | 85.9 | 79.9 | 80.1 | 84.1 |
| August 7 | 64.1 | 70.2 | 76.3 | 74.6 | 74.3 | 77.9 |
| August 14 | 72.6 | 83.0 | 89.3 | 74.9 | 75.3 | 78.9 |
| August 21 | 70.7 | 77.3 | 82.3 | 74.0 | 74.1 | 78.9 |
| August 28 | 75.6 | 80.0 | 90.0 | 77.8 | 77.5 | 82.1 |
| September 4 | 81.9 | 83.1 | 96.0 | 78.8 | 77.2 | 81.6 |
| Average for season | 73.7 | 79.9 | 87.9 | 77.8 | 78.5 | 83.7 |

[1]Night period was from 8 P. M. to 8 A. M. Day period was from 8 A. M. to 8 P. M.

## EAR TYPE SELECTION VERSUS SELECTION FOR FREEDOM FROM ROOT-ROT DISEASES

In the preceding yield tests, 70 disease free ears and 59 badly diseased ears of Hogue's Yellow Dent corn were compared for yield in duplicate ear-to-row plats with a check plat of the original unselected corn planted after every tenth plat. The presence or absence of disease had been established previously by the recognized germinator test, and the above ears were selected as extremes from among 959 ears tested. Their selection for the yield test was based entirely upon the disease indication without reference to ear type, which had been theretofore independently determined and recorded. The ears were planted in the order of germinator testing without regard to ear type, thus distributing the various types by chance among the test


CHART 6.—Ear type versus root-rot disease selection. Two hundred seven ear-to-row plats are compared in duplicate for grain yield per acre with unselected bulk seed of the original variety. The ear-to-row seed ears are classified first according to presence or absence of root-rot disease by means of the germinator test, and are then grouped according to ear type irrespective of disease. Data taken from Table 61.

plats. Four hundred and ninety-seven ears of Nebraska White Prize corn were subjected to the same manner of testing and treatment. From among these, 39 disease free ears and 39 badly diseased ears were tested in ear-to-row plats.

The relation between type of ear planted and yield per acre in these diseased and disease free classes is shown in Table 61 and charts 6 and 7. For both varieties no advantage was found in selection for freedom from disease by the germinator test.

On the other hand, the smooth ears definitely surpassed the rough ears for both varieties, and in all cases except the disease free Nebraska White Prize they distinctly surpassed the original corn from which they were selected.

In case of the disease free Hogue's Yellow Dent, the smooth

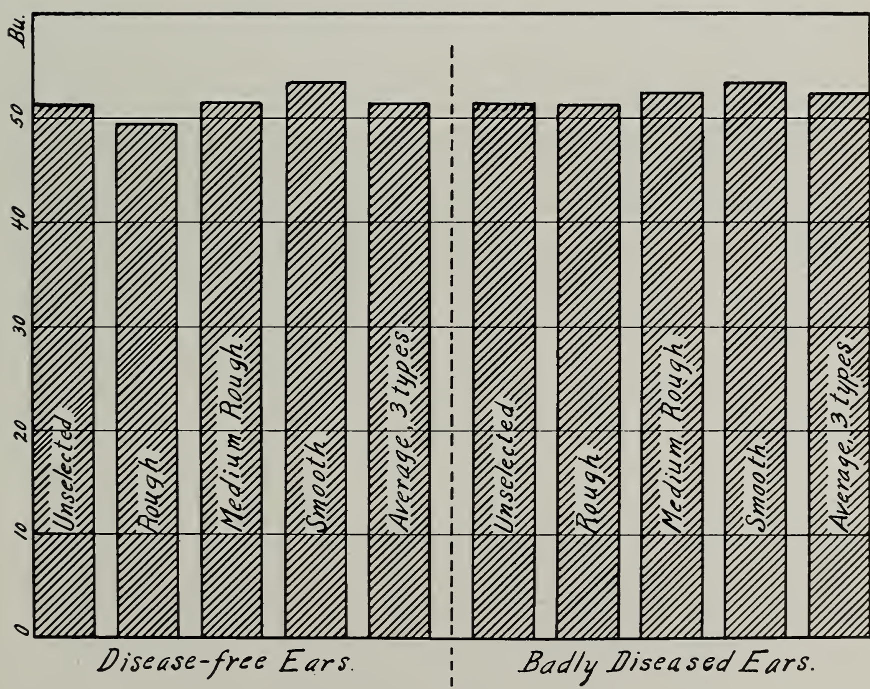



CHART 7.—Ear type versus root-rot disease selection. At the left and right are shown the grain yields of ordinary unselected seed corn in comparison with ear-to-row plats which had been classified respectively by the germinator test into disease free and badly diseased groups. The ear-to-row plat yields are grouped according to the type of seed ear planted. Data taken from Table 61.

TABLE 61.—*Rough versus smooth ears of corn selected either for presence or for absence of root-rot disease. 1921.*

| Classification of seed | Type of ear planted | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. of plats averaged[1] | | | | Grain, yield per acre | | | |
| | Rough | Medium | Smooth | Total | Rough | Medium | Smooth | All plats |
| (1) | (2) | (3) | (4) | (5) | *Bushels* (6) | *Bushels* (7) | *Bushels* (8) | *Bushels* (9) |
| Hogue's Yellow Dent— | | | | | | | | |
| Disease free | 44 | 66 | 30 | 140 | 55.25 | 58.51 | 61.71 | 58.22 |
| Diseased | 68 | 36 | 14 | 118 | 56.19 | 59.59 | 58.83 | 57.53 |
| Average of both | ... | ... | ... | ... | 55.72 | 59.05 | 60.27 | 57.87 |
| Nebraska White Prize— | | | | | | | | |
| Disease free | 24 | 38 | 16 | 78 | 43.58 | 44.61 | 45.26 | 44.20 |
| Diseased | 38 | 22 | 18 | 78 | 46.45 | 45.30 | 48.01 | 46.54 |
| Average of both | ... | ... | ... | ... | 45.01 | 44.95 | 46.63 | 45.37 |
| Average of both varieties— | | | | | | | | |
| Disease free | 68 | 104 | 46 | 218 | 49.41 | 51.56 | 53.48 | 51.21 |
| Diseased | 104 | 58 | 32 | 194 | 51.32 | 52.44 | 53.42 | 52.03 |
| Average of both | ... | ... | ... | ... | 50.36 | 52.00 | 53.45 | 51.62 |
| Original Hogue's Yellow Dent | ... | ... | ... | 28 | ... | ... | ... | 57.44 |
| Original Nebraska White Prize | ... | ... | ... | 19 | ... | ... | ... | 45.14 |
| Average of both | ... | ... | ... | ... | ... | ... | ... | 51.29 |

[1]The number of ear-to-row strains represented for each type was one-half the number of plats indicated, the tests being made in duplicate.

ears yielded 6.46 bushels or 11 per cent more than the rough, and 4.27 bushels or 7 per cent more than the original. Of the diseased Hogue's Yellow Dent, the smooth ears yielded 2.6 bushels or 5 per cent more than the rough, and 1.39 bushels or 2 per cent more than the original.

The Nebraska White Prize disease free smooth ears surpassed the rough 1.68 bushels or 4 per cent, and yielded 0.12 bushel more than the original. In case of the diseased Nebraska White Prize, the smooth yielded 1.56 bushels or 3 per cent more than the rough, and 2.87 bushels or 6 per cent more than the original Nebraska White Prize.

These data confirm other results favoring the smoother type of ear with a somewhat shallow flinty kernel.

#### RELATION BETWEEN THE EAR TYPE OF THE SEED PLANTED AND OF THE CROP HARVESTED

The progeny ears produced in the ear-to-row plats of the preceding root-rot disease investigation have been classified in Table 62 to show the proportion of rough, medium, and smooth ears produced from seed ears which had been determined as being either badly diseased or disease free by means of the germi-

TABLE 62.—*Character of progeny ears harvested from the ear-to-row plats of Table 61, grouped according to the disease condition of seed ears. 1921.*

| Classification of ears planted | Progeny ears showing mould or decay | Progeny ears classified according to type | | |
|---|---|---|---|---|
| | | Rough | Medium | Smooth |
| | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Hogue's Yellow Dent— | | | | |
| Disease free | 0.00 | 15.8 | 65.1 | 19.1 |
| Diseased | 0.10 | 23.3 | 63.0 | 13.7 |
| Original unselected | 0.13 | 17.4 | 63.7 | 18.9 |
| Nebraska White Prize— | | | | |
| Disease free | 0.10 | 19.4 | 67.4 | 13.2 |
| Diseased | 0.00 | 22.0 | 65.1 | 12.9 |
| Original unselected | 0.00 | 19.2 | 68.4 | 12.4 |
| Average for both varieties— | | | | |
| Disease free | 0.05 | 17.6 | 66.2 | 16.1 |
| Diseased | 0.05 | 22.6 | 64.0 | 13.3 |
| Original unselected | 0.06 | 18.3 | 66.0 | 15.6 |

TABLE 63.—*Immediate effect of the type of seed ear upon the ear type of the progeny of both diseased and disease free corn. 1921.*

| Type of ear planted | Number of strains averaged | Progeny ears classified according to type | | |
|---|---|---|---|---|
| | | Rough | Medium | Smooth |
| | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| HOGUE'S YELLOW DENT | | | | |
| Rough— | | | | |
| Disease free | 22 | 21.1 | 64.4 | 14.5 |
| Diseased | 34 | 27.5 | 62.9 | 9.6 |
| Average | .......... | 24.3 | 63.7 | 12.0 |
| Medium— | | | | |
| Disease free | 33 | 15.6 | 67.8 | 16.6 |
| Diseased | 18 | 20.4 | 63.6 | 16.0 |
| Average | .......... | 18.0 | 65.7 | 16.3 |
| Smooth— | | | | |
| Disease free | 15 | 8.3 | 59.4 | 32.3 |
| Diseased | 7 | 6.9 | 70.4 | 22.7 |
| Average | .......... | 7.6 | 64.9 | 27.5 |
| NEBRASKA WHITE PRIZE | | | | |
| Rough— | | | | |
| Disease free | 12 | 22.7 | 72.0 | 5.3 |
| Diseased | 19 | 21.9 | 69.9 | 8.2 |
| Average | .......... | 22.3 | 71.0 | 6.7 |
| Medium— | | | | |
| Disease free | 19 | 13.9 | 73.7 | 12.4 |
| Diseased | 10 | 16.8 | 70.8 | 12.4 |
| Average | .......... | 15.3 | 72.3 | 12.4 |
| Smooth— | | | | |
| Disease free | 7 | 6.9 | 75.4 | 17.7 |
| Diseased | 8 | 13.0 | 74.9 | 12.1 |
| Average | .......... | 9.9 | 75.2 | 14.9 |
| AVERAGE OF BOTH VARIETIES | | | | |
| Rough— | | | | |
| Disease free | .......... | 21.9 | 63.2 | 9.9 |
| Diseased | .......... | 24.7 | 66.4 | 8.9 |
| Average | .......... | 23.3 | 64.8 | 9.4 |
| Medium— | | | | |
| Disease free | .......... | 14.7 | 70.8 | 14.5 |
| Diseased | .......... | 18.6 | 67.2 | 14.2 |
| Average | .......... | 16.6 | 69.0 | 14.4 |
| Smooth— | | | | |
| Disease free | .......... | 7.6 | 67.4 | 25.0 |
| Diseased | .......... | 9.9 | 72.7 | 17.4 |
| Average | .......... | 8.7 | 70.1 | 21.2 |

nator test. As an average for both varieties, the disease free, diseased, and unselected corn produced respectively 17.6, 22.6, and 18.3 per cent rough ears; 16.1, 13.3, and 15.6 per cent smooth ears; and 66.2, 64.0, and 66.0 per cent of medium rough ears.

These data indicate that a slightly smoother type of corn is represented in those seed ears which had been determined to be free from root-rot disease by the germinator test. Perhaps a more important consideration brought out in Table 62 is the equal and almost insignificant amount of disease or decay present in the progeny ears of both diseased and disease free corn. Only one ear in every two thousand was noticeably affected in either case by mould or decay of any kind.

The progeny ears are further classified in Table 63 according to ear type, and show both the extent to which ear type selection tends to transmit itself in a single generation and also the relation of the ear type of the progeny to the disease condition of the seed ear.

Averaging both varieties, the rough, medium, and smooth seed ears planted produced respectively 23.3, 16.6, and 8.7 per cent rough ears in the progeny. On the other hand, the rough, medium, and smooth seed ears averaged 9.4, 14.4, and 21.2 per cent smooth ears in the progeny.

## RELATION OF STAND TO YIELD OF CORN

In connection with another experiment, both Hogue's Yellow Dent and Nebraska White Prize corn have been grown for a period of years at the rates of 1, 3, and 5 plants per hill. The results are given in Tables 64 and 65. As an average for seven years, Hogue's Yellow Dent yielded 36.6, 44.6, and 40.3 bushels per acre respectively for 1, 3, and 5 plants per hill. As an average for eight years the Nebraska White Prize yielded 37.1, 52.9, and 49.4 bushels per acre.

The yield of the thin stand is augmented by an increased number of ear-bearing suckers, more 2-eared stalks, larger ears, and fewer barren plants. The reverse correlations hold for the heavy planting rate.

Hogue's Yellow Dent is a much more freely suckering variety than is Nebraska White Prize, which enables it to yield relatively better at a very thin rate of planting.

Comparative results for a four-year period with the planting rates of 1, 2, 3, 4, and 5 plants per hill are given in Table 66. The grain yields for these rates were respectively 40.7, 49.4, 52.9,

TABLE 64.—*Relative growth and yield of corn grown at thin, medium, and thick rates of planting. Hogue's Yellow Dent. 1911-1917.*

| Plants per hill | Plants per acre | Yield of grain per acre | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | Average |
| (1) | (2) | *Bushels* (3) | *Bushels* (4) | *Bushels* (5) | *Bushels* (6) | *Bushels* (7) | *Bushels* (8) | *Bushels* (9) | *Bushels* (10) |
| 1 | 3,556 | 34.4 | 49.0 | 10.2 | 42.9 | 57.6 | 33.7 | 28.6 | 36.6 |
| 3 | 10,668 | 55.3 | 38.4 | 6.6 | 44.8 | 79.8 | 37.1 | 50.0 | 44.6 |
| 5 | 17,780 | 53.7 | 27.5 | 3.8 | 32.0 | 80.6 | 28.3 | 56.3 | 40.3 |

| Plants per hill | Summary of plant characteristics for period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (11) | *Inches* (12) | (13) | *Per cent* (14) | (15) | (16) | (17) | *Per cent* (18) | *Per cent* (19) |
| 1 | 88 | 45 | 9/24 | 11 | 39 | 170 | 101 | 10.5 | 83.2 |
| 3 | 88 | 44 | 9/23 | 26 | 11 | 86 | 25 | 10.1 | 83.6 |
| 5 | 88 | 43 | 9/22 | 35 | 8 | 63 | 10 | 10.3 | 82.1 |

TABLE 65.—*Relative growth and yield of corn grown at thin, medium, and thick rates of planting. Nebraska White Prize corn. 1912-1917 and 1920-1921.*

| Plants per hill | Plants per acre | Yield of grain per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1920 | 1921 | Average |
| (1) | (2) | *Bushels* (3) | *Bushels* (4) | *Bushels* (5) | *Bushels* (6) | *Bushels* (7) | *Bushels* (8) | *Bushels* (9) | *Bushels* (10) | *Bushels* (11) |
| 1 | 3,556 | 54.3 | 14.3 | 40.0 | 42.6 | 32.9 | 29.0 | 35.5 | 48.1 | 37.1 |
| 3 | 10,668 | 53.8 | 11.7 | 51.5 | 86.0 | 54.2 | 51.0 | 53.6 | 61.3 | 52.9 |
| 5 | 17,780 | 51.8 | 6.7 | 36.1 | 97.2 | 42.1 | 50.4 | 51.5 | 59.4 | 49.4 |

| Plants per hill | Summary of plant characteristics for 1915-1917 and 1920-1921 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stalk height | Ear height | Date ripe | Lodging | 2-eared stalks per 100 plants | Ears per 100 plants | Suckers per 100 plants | Shrinkage of ear corn | Shelling per cent |
| (1) | *Inches* (12) | *Inches* (13) | (14) | *Per cent* (15) | (16) | (17) | (18) | *Per cent* (19) | *Per cent* (20) |
| 1 | 103 | 53 | 9/20 | 8 | 28 | 148 | 59 | 7.7 | 80.8 |
| 3 | 101 | 49 | 9/20 | 28 | 18 | 104 | 16 | 7.7 | 81.4 |
| 5 | 100 | 49 | 9/19 | 37 | 4 | 78 | 4 | 7.9 | 81.2 |

50.7, and 49.3 bushels per acre. It is very evident that there may be a considerable variation in stand, fluctuating about three per hill, without a material effect upon yield. A stand ranging from about 2.5 to 3.0 plants per hill appears to be optimum for local varieties under Experiment Station conditions. This rate should be gradually reduced from the eastern toward the western part of the State.

In these rates of planting tests, the corn had been planted thick and thinned so as to insure the actual stand of plants indicated.

TABLE 66.—*Comparative yields of Hogue's Yellow Dent corn planted at the rates of 1, 2, 3, 4, and 5 plants per hill. 1914-1917.*

| Plants per hill | Plants per acre | Yield of grain per acre | | | | |
|---|---|---|---|---|---|---|
| | | 1914 | 1915 | 1916 | 1917 | Average |
| | | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Bushels* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1 | 3,556 | 42.9 | 57.6 | 33.7 | 28.6 | 40.7 |
| 2 | 7,112 | 48.2 | 69.7 | 35.2 | 44.5 | 49.4 |
| 3 | 10,668 | 44.8 | 79.8 | 37.1 | 50.0 | 52.9 |
| 4 | 14,224 | 36.1 | 80.3 | 33.1 | 53.4 | 50.7 |
| 5 | 17,780 | 32.0 | 80.6 | 28.3 | 56.3 | 49.3 |

## RELATION OF UNIFORMITY OF STAND TO YIELD OF CORN

During the five years 1915-1917 and 1920-1921, an investigation was made to determine the effect of varied distribution of plants upon the yield of grain per acre. While the number of plants per acre was the same in all cases, the number of plants in adjacent hills differed. The methods of distribution compared were as follows: (1) All hills with uniformly three plants, (2) alternating hills with two and four plants, (3) alternating hills with one, three, and five plants, and (4) alternating hills with one, two, three, four, and five plants.

The results given in Table 67 indicate that the three irregular distributions averaged 58 bushels per acre as compared with 59 bushels for the uniformly three plants per hill rate. Alternating hills with two and four plants yielded fully as well as did uniformly three plants per hill. Alternating hills of one, two, three, four, and five plants per hill yielded 0.4 bushel less, and

TABLE 67.—*Effect of an uneven stand upon the yield of corn. Five-year average, 1915-1917 and 1920-1921.*

| Distribution of plants in successive hills | Plants per acre | Yield of grain per acre | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1915 | 1916 | 1917 | 1920 | 1921 | Av. |
| | | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Uniformly 3 plants | 10,668 | 93.4 | 55.2 | 26.7 | 52.3 | 66.7 | 59.0 |
| Alternating 2 and 4 plants | 10,668 | 89.8 | 58.4 | 28.1 | 51.9 | 68.0 | 59.2 |
| Alternating 1, 3, 5 plants | 10,668 | 88.0 | 52.4 | 26.3 | 48.9 | 64.3 | 56.0 |
| Alternating 1, 2, 3, 4, 5 plants | 10,668 | 95.1 | 54.4 | 30.6 | 50.2 | 62.9 | 58.6 |

Hogue's Yellow Dent was grown in this test during the first three years and Nebraska White Prize thereafter.

the alternating hills of one, three, and five plants yielded 3.0 bushels less.

These data suggest that corn plants, of the larger varieties at least, draw upon the soil fertility and moisture for such a distance that considerable irregularity in stand may exist without markedly affecting the yield.

[5M]