UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 255

CORN ROOT, STALK, AND EAR ROT DISEASES, AND THEIR CONTROL THRU SEED SELECTION AND BREEDING

IN COOPERATION WITH OFFICE OF CEREAL INVESTIGATIONS
BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

By James R. Holbert, W. L. Burlison,
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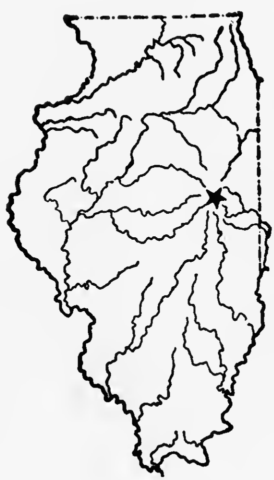
and George H. Dungan



URBANA, ILLINOIS, AUGUST, 1924

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CORN ROOT, STALK, AND EAR ROT DISEASES, AND THEIR CONTROL THRU SEED SELECTION AND BREEDING

By James R. Holbert, W. L. Burlison, Benjamin Koehler, C. M. Woodworth, and George H. Dungan[1]

INTRODUCTION

The relation that stalk, ear, and kernel characters of corn bear to yield has been given much attention by plant breeders and agronomists. Recently the relation which the physical characters of the mother plant and seed ear may bear to disease resistance in the progeny has appeared as one of the most important problems of the corn breeder.

The actual losses caused by corn diseases in the corn belt states cannot be accurately estimated. If it were possible to determine the losses caused by poor stands resulting from the planting of infected seed and also the losses due to the stunting of the growth of the many remaining plants, with the consequent reduction in size of ears, it is believed that the total would be fully 10 percent and perhaps more. Losses varying from 5 to 50 percent have been observed by the authors.

The breeding and multiplication of productive strains and varieties of corn highly resistant to disease and to injury from unfavorable soil and weather conditions is recognized as a problem demanding the attention and active cooperation of experiment station workers, corn breeders, and corn growers. Several years of experimental work bearing on various angles of the subject are reported in the present bulletin. A glance at the table of contents will show the scope of the work. The summary on pages 470 and 471 states briefly the outstanding facts of the study.

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The authors wish to express their appreciation to Dr. Carlton R. Ball, Dr. H. B. Humphrey, Dr. A. G. Johnson, and Mr. Eugene Funk for encouragement and assistance thruout the investigations reported in this bulletin.

PART I

REVIEW OF LITERATURE ON EAR CHARACTERS OF CORN AS RELATED TO YIELD

The results of investigations on ear characters of corn in relation to yield are conflicting, as will be noted from the following review of the literature on this subject.

Montgomery[72] seems to favor the long smooth type of seed ear. He found that extra large ears gave no better yields than ears of medium size. Hartley[36] found no positive relationship between ear characters and yield. Ewing[26] studied many stalk characters in relation to yield, but observed that "in most cases the coefficient of correlation is so small that it is probably not worth while to try to classify it or even to conclude that there is a correlation." Love[63] feels that one of the very important questions arising in the improvement of corn is the extent to which visible seed ear characters are correlated with yield. From his study to determine whether there are certain characters indicative of high yield which should be kept in mind when seed is being selected, he states:

"There is evidently some effect of size of ear, both in respect to length and weight, on the yield of the offspring. On the other hand, such characters as number of rows, average weight of kernel, and ratio of tip to butt do not have any very marked effect on yield."

Funk[27] has long maintained that ears with medium smooth indentation, or medium smooth ears, will outyield rough starchy ones.

Sconce[88] began systematic corn breeding in 1905 in an attempt to determine some of the principles of corn improvement. His first study was the relation which the number of rows of kernels and the shape of the kernels bear to yield. He found that ears with twenty rows stood slightly higher in yield than ears with a larger or a smaller number. He further states that—

"a kernel of medium depth with a large amount of horny material will on the average give the highest yield, and that the yield of an ear of corn having a long, rough, narrow kernel containing a large amount of starch will not compare at all favorably with that of an ear having a kernel of medium length and a well rounded tip."

McCall and Wheeler[66] found no correlation between "length, weight, circumference, and density" of the ear of corn and yield. Williams and Welton,[115] who have reported very completely on the relation of ear characters to yield, find no significant relation between these two factors. Cunningham[14] studied very carefully certain physical characters, such as length of ear, circumference of ear, filling of tips, rounding of butts, indentation of kernels, and percentage of grain to cob in relation to yield. His comments are as follows:

"The data available indicate that certain ear characters have been given more consideration than their worth as related to yield warrants, while other characters have been emphasized that may actually tend to decrease yield. . . . It is a well known fact that under Kansas conditions comparatively smooth types of corn produce better under adverse conditions than the roughly indented types."

In a later publication he[15] stated:

"Every corn grower knows that the smooth type is much to be preferred at husking time. This type is not so subject to damage from molds and other fungi following injury to the ears from the corn ear worm."

Love and Wentz[65] found that—

"The characters of length, ratio of tip circumference to butt circumference, average circumference of cob, weight, average weight of kernels, number of rows of kernels, and average length and width of kernels on the seed ears do not show correlation significant enough to be of value in judging seed corn." There seems to be a negative correlation between percentage of grain in the seed ear and yield. Circumference of the seed ear has some significance.

Hughes,[51] reporting on preliminary trials with prize-winning samples of corn, states that the highest-scoring samples gave the highest yields by about five bushels per acre.

The data of Hutcheson and Wolf[52] show certain relations between ear characters and yield. They state that there is some significance in the relation of length, circumference, uniformity of type, and shape of ears to yield. Emphasis is placed on the fact that "high-yielding strains of corn are high-scoring strains."

Biggar[5] studied the relation between yield and certain ear characters, such as weight and length of ears, number of rows, and shelling percentage. He concludes that:

"There seems to be no special relation between number of rows and yield or between shelling percentage and yield. The characters of length and weight of ears show positive correlation with yield, but they are not consistently large. The character of length seems to be somewhat significant, at least for some of the varieties. The results on the whole would indicate that there is no well marked basis for using ear characters to indicate yield possibilities."

Pearl and Surface[76] found no significant relation in "size or conformation" of seed ears of sweet corn and yield.

Olson, Bull, and Hays[74] have given careful consideration to the question of ear characters as a basis on which to select seed corn ears. Their data—

"offer no encouragement for selection emphasizing length in the hope of obtaining important increases in yield." In the matter of the relation of weight to yield it is suggested that any conscious selection for weight of ears should consist simply of elimination of extremes. "In fact one is probably safe in picking at random so far as weight is concerned.'' The relation of shelling percentage to yield ''indicates no advantage in selecting seed ears of extremely high-shelling percentage, but a slight advantage in eliminating those of very low-shelling percentage.''

These same investigators state that the relation shown between ear circumference and yield was apparently inverse. The differences in yield between the ears of different circumferences were so small as to be practically negligible. In the tests on the relation of character of butts to yield, they found that possibly a slight negative correlation existed. A slight negative correlation was also found in a general way between character of tips and yield. In the matter of kernel uniformity these same investigators felt that possibly some negative relation to yield exists.

Manns and Adams[68] have found that ''Ears having smooth, properly dented kernels, somewhat flinty, make better seed and are freer from disease than the rough ears, which are usually very starchy.'' Valleau[109] found that ''selection for the extremes of smooth ears and rough ears . . . resulted in increases of 39.4 and 13.9 percent in yield for the smooth type over the rough.'' Kiesselbach[58] concludes that ''it will be found that the sound seed occurs in rather slender, solid, hard, smooth, flinty ears with kernels of only medium depth.''

PART II

CAUSES AND SYMPTOMS OF CORN ROT DISEASES

The corn root, stalk, and ear rot diseases are a group of diseases seriously affecting the corn crop. For brevity, these diseases are sometimes called "corn rot diseases," and frequently simply "corn root rot." However, at the outset it must be realized that "corn root rot" is not one disease, but several diseases, some of which do not result in any rotting of either roots or stalks. In general, most of these diseases cause a reduction in field stand, a reduction in health and vigor of surviving plants, and a reduction in both yield and quality of grain. They may cause a chlorosis, or yellowing of the leaves, delayed silking and pollination, firing and a general blighting of the plants, lodging, barrenness, and nubbin production in various forms.

Not all the rot diseases of corn can be traced to the same type of causative agent. In general, the corn rot diseases herein described and discussed are due to a combination of causes brought about thru the interrelation of parasitic organisms with unfavorable environment and inferior genetic constitution of the host. Other disorders of the corn plant which are somewhat similar in above-ground symptoms are primarily the result of a lack of proper nutrient elements in the soil, the physiological balance thus being deranged. Some strains of corn, on account of their genetic constitution, have a very narrow range of adaptability and are able to yield satisfactorily only under the most favorable environment, a condition that frequently does not obtain in actual field practice. However, there is considerable interaction of causative agencies, and any grouping of these agencies must necessarily be more or less general. This close interaction may be illustrated by reference to some of the known facts concerning the relation of one of the parasites of corn to the development of seedling blight.

Gibberella saubinetii (Mont) Sacc., the wheat scab organism, may cause seedling blight of corn and a reduction in early vigor and general health of the corn plant.[46, 18, 19] Dickson,[18, 19] of the Wisconsin Agricultural Experiment Station and the United States Department of Agriculture, has shown that corn seedlings become susceptible to the wheat scab parasite only when grown under certain environmental conditions. He found that they were susceptible when grown in a moist, cool soil, below 20° C., or 68° F., or when grown in a fairly dry soil at a much wider range of temperature. He states:[18]

"The results, therefore, indicate that in this case, at least, disease resistance and predisposition to disease may be largely dependent upon environmental conditions under which the plant is developing."

Eckerson and Dickson[23] have explained the variation in seedlings in their susceptibility to seedling blight as probably due to marked differences in the chemical composition of corn seedlings grown under different soil temperature and moisture conditions. They state:

"Corn seedlings grown at high soil temperatures are high in available carbohydrates and low in available nitrogen. The cell walls, even in early seedling stage, are cellulose, soon impregnated with suberin. Corn seedlings grown at low soil temperatures have little or no available carbohydrates and are high in available nitrogen. The cell walls are composed of pectic materials, cellulose being absent until after photosynthesis begins. . . . The parasite penetrates the walls of pectic materials apparently with little resistance, whereas it penetrates the cellulose walls slowly. . . . These differences apparently explain the variation in their susceptibility to seedling blight produced by *Gibberella saubinetii.*"

Later Dickson, Eckerson, and Link[20] made the following additional statement:

"Because of an abundance of sugar and fat available in the corn embryos at high temperatures, a carbohydrate reserve exists for building thicker, more resistant cell walls."

Data presented later in this bulletin and also data by Koehler, Dickson, and Holbert[60] show that one selection of yellow dent corn may be very susceptible to this parasite while another selection of the same strain grown under the same environmental conditions may be highly resistant. In such cases the genetic constitution of the corn apparently was more important than environmental factors in influencing resistance and susceptibility to this parasite.

The findings of Dickson[19] and of Eckerson and Dickson[23] conflict in no way with the data on the varying susceptibility of corn to seedling blight reported in this bulletin. Environmental factors, including soil factors, are important in influencing predisposition to disease, but the genetic constitution of the corn is equally important. *An adequate understanding of the causes of the corn root, stalk, and ear rot diseases, and variations in susceptibility of different strains of corn to these diseases can be obtained only by a consideration of all the influencing factors.*

Altho bacterial wilt (Stewart's disease) and corn smut and rust are not grouped with the corn root, stalk, and ear rot diseases, and have not been studied specifically by the authors of this bulletin, certain observations have been made regarding the occurrence of these diseases in plots and fields affected with the corn root, stalk, and ear rot diseases. *Selection and breeding for disease resistance and productiveness require a consideration of all possible influencing factors,* and to that end a brief discussion of these diseases also is included in the present bulletin.

PARASITIC FACTORS

SCUTELLUM ROT

The germination test for corn may be used to determine not only viability, but also seedling vigor and seed infection with some of the organisms that produce disease. Under conditions that exist during the germination test, the kernels are subjected to the attack of certain molds, among which *Rhizopus* spp.[40, 1] is the most common. The degree to which kernels from different ears are able to resist the

FIG. 1.—NEARLY DISEASE-FREE SEEDLINGS

Note the sturdy plumules, bright kernels, and large number of strong, vigorous roots. (See Plate I.)

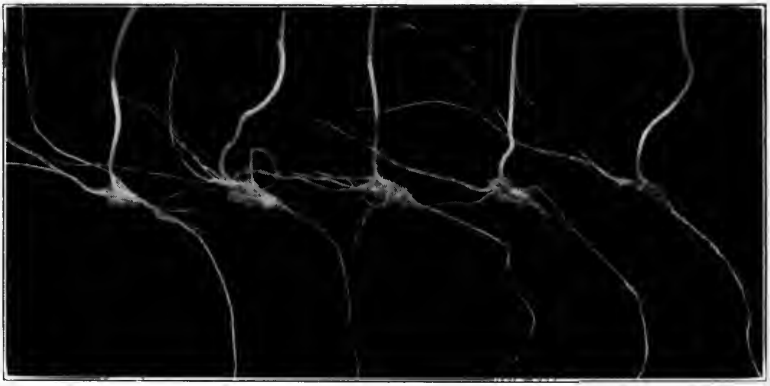


FIG. 2.—SCUTELLUM-ROTTED SEEDLINGS

Note the poor root development and the spindly plumules as compared with those in Fig. 1. Occasionally scutellum-rotted seedlings will have a healthy appearance and can be detected only by cutting the kernels. (See Plate I.) Under most conditions, corn grown from scutellum-rotted seed has produced less both in total yield and in yield of sound grain than corn grown from good seed.

growth of these molds in the germination test has proved to be a more or less accurate index to the field performance of corn grown from their respective ears. Corn grown from ears which on the germinator were badly affected with scutellum rot (see description in legends of colored Plate I and Figs. 1 and 2), a condition usually indicated by invasions with *Rhizopus* spp. on the germinator, has been more susceptible to attacks of soil fungi and to injury from inoculations with certain corn parasites than has corn grown from ears approximately the same in viability and vigor, but neither affected with scutellum rot nor infected with parasitic organisms. Under most conditions, corn grown from scutellum-rotted seed has produced less both in total yield and in yield of sound grain than corn grown from good seed.

FIG. 3.—CORN FROM GOOD SEED

This corn yielded at the rate of 74.7 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 4.)

The fundamental cause of the difference in resistance and susceptibility to *Rhizopus* spp. on the germinator is not known, nor is the disease-susceptibility of corn grown from scutellum-rotted seed fully understood. However, this does not alter the economic value of this feature of the germination test in eliminating ears that are likely to produce corn susceptible to disease.

The most outstanding difference between corn grown from seed affected on the germinator with scutellum rot and that grown from good seed is the reduction in early vigor of the plants in the field (Figs. 3, 4, and 5). Early vigor and yield of grain are closely correlated.[48] Plants that are weak or only moderately strong in their early growth are very likely to be late in forming ears and delayed

FIG. 4.—CORN FROM SCUTELLUM-ROTTED SEED

This corn yielded at the rate of 57.7 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 3.)

FIG. 5.—CORN FROM SCUTELLUM-ROTTED SEED (LEFT) AND FROM GOOD SEED OF THE SAME STRAIN (RIGHT)

An experiment conducted in 1921 on the farm of Mr. Claude Thorpe, De Witt county, the U. S. Department of Agriculture and the Illinois Agricultural Experiment Station cooperating. The outstanding difference between corn grown from seed affected on the germinator with scutellum rot and that grown from good seed is the reduction in early vigor of the plants in the field.

in maturity. If they are decidedly weak in their early growth, they probably will be barren or produce nubbins only. Thus corn from scutellum-rotted seed usually is inferior to corn from good seed in

FIG. 6.—CORN FROM GOOD SEED

Corn grown on a U. S. Department of Agriculture experimental plot on the farm of Mr. Claire Golden, Rock Island county. (Compare with Fig. 7.)

both total yield and quality of grain. Occasionally the contrast at harvest between corn grown from good seed and that grown from scutellum-rotted seed is very marked (Figs. 6 and 7).

FIG. 7.—CORN FROM SCUTELLUM-ROTTED SEED

The seed from which this corn was grown showed a high percentage of scutellum rot on the germinator. (Compare with Fig. 6.) Occasionally the contrast at harvest time between corn grown from good seed and that grown from scutellum-rotted seed is very marked.

PLATE I

A, B Vigorous disease-free seedlings.

Note the clean, healthy appearance of both exterior and interior, as well as the large number of strong roots. *The germination test is a valuable means of selecting seed with superior vigor.*

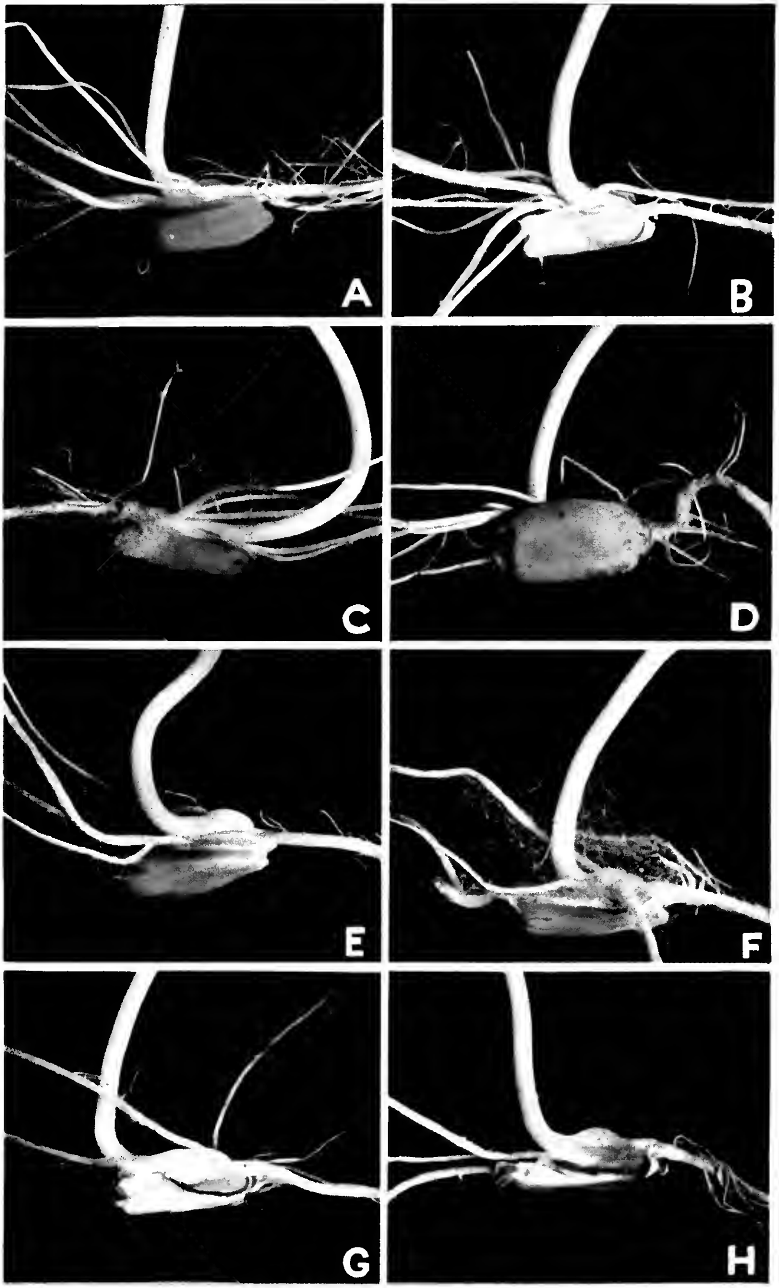
C, D Fusarium-infected seedlings.

The pink-colored fungus growth on the exterior of the kernels is very characteristic of Fusarium-infected seedlings.

E, G Scutellum-rotted seedlings with no conspicious mycelial growth on the exterior of the kernels.

F, H Scutellum-rotted seedlings with Rhizopus growing on the exterior of the kernels.

Note the rotted region (GH) between the endosperm and the embryo portion of the kernel.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DIPLODIA ROOT ROT, EAR ROT, AND SEEDLING BLIGHT

Diplodia zeae (Schw.) Lev. has been recognized for several years as an important parasite of corn. In 1909 Burrill and Barrett[10] found that a large proportion of the loss from ear rots was caused by this organism. Other workers[37, 10, 94, 25, 96, 90, 11] also have called attention to this parasite from time to time. Melhus and Durrell[71] reported a widespread Diplodia infection of seed in eastern and central

FIG. 8.—DIPLODIA-INFECTED SEEDLINGS

Diplodia-infected seed can best be detected by the use of the germination test. (See Plate II.)

FIG. 9.—CORN FROM DIPLODIA-INFECTED SEED (LEFT) AND FROM GOOD SEED OF THE SAME STRAIN (RIGHT), UNIVERSITY SOUTH FARM, URBANA

Seed apparently good but infected with this organism results in a reduced field stand under most conditions.

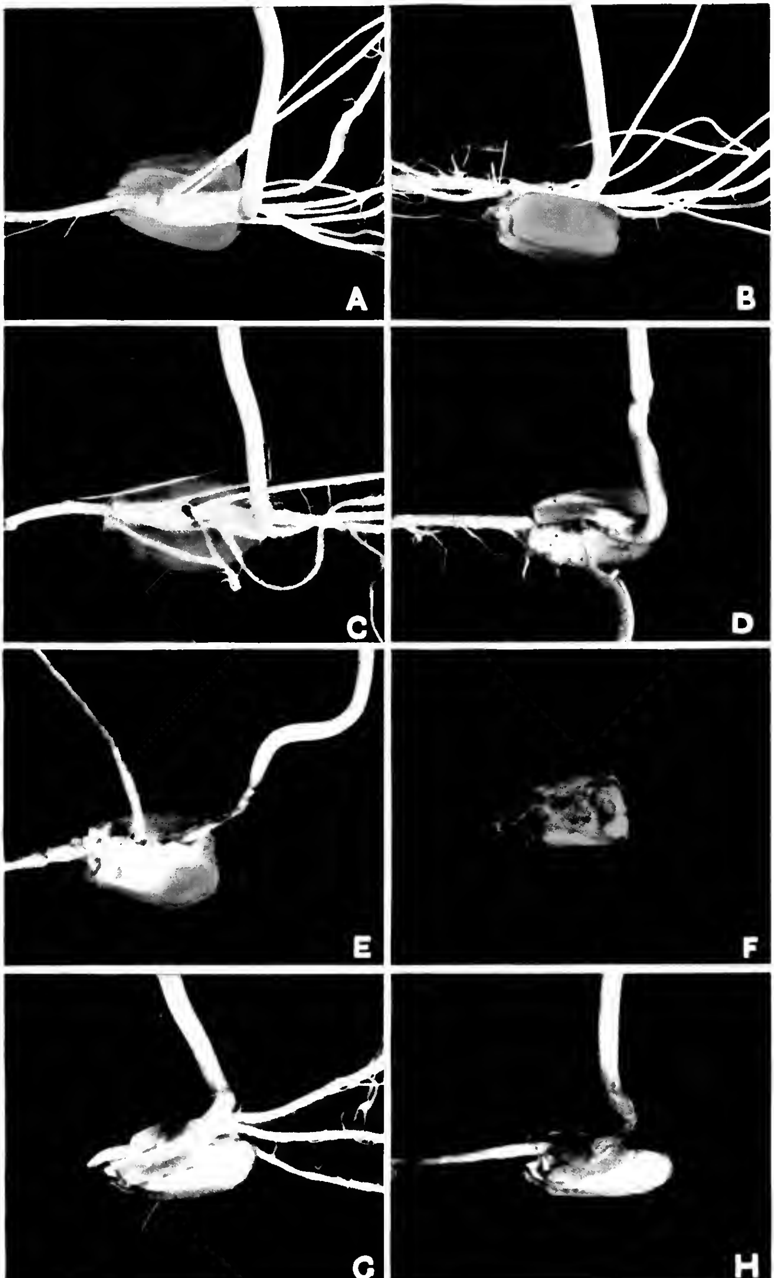
PLATE II

A, B Vigorous, disease-free seedlings.

C-H Diplodia-infected seedlings and kernel (F).

The germination test is a valuable aid in detecting Diplodia-infected seed.

Diplodia zeae develops abundantly on infected kernels in a germination test and causes decay of the shoots in the region near the kernel. In advanced stages the fungus itself appears as a dense, white mold covering part of the kernel.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Iowa as a result of excessive rainfall accompanied by hot weather in the fall of 1921.

Diplodia zeae develops abundantly on infected kernels in a germination test and causes a decay of the shoots in the region near the kernel (Fig. 8 and Plate II). In advanced stages, the fungus itself appears as a dense, white mold covering part of the kernel. The mycelial growth is seldom conspicuous on rotted roots and shoots except near decayed areas.

The planting of seed which is apparently good but infected with this organism results in a reduced field stand under most conditions (Fig. 9). Surviving plants usually make a very irregular growth, depending on the severity of infection, the resistance of the individual plant attacked, and environmental factors (Figs. 10 to 14). Many weak plants (Fig. 15) infected with this parasite wilt and die during the season as a result of the rotting of the roots near the crown. Other infected plants may neither be blighted nor die, the principal above-ground symptoms in such cases being a marked reduction in vigor and in the height of plants (Table 1 and Fig. 16). The mesocotyls of young corn plants grown from Diplodia-infected seed usually appear dry and brown in contrast to the white, healthy appearance of mesocotyls of plants of the same age grown from good seed (Plate III). There is little evidence that this fungus advances up the stalk from the rotted roots and rotted crown.

TABLE 1.—REDUCTION IN HEIGHT OF CORN PLANTS GROWN FROM DIPLODIA-INFECTED SEED

Ontario Parish, near Oneida, 1923

Soil treatment	Age	Number of plants measured in each plot	Mean plant height			Reduction
			Nearly disease-free seed	Diplodia-infected seed	Reduction	Probable error
	days		*inches*	*inches*	*inches*	
None......	17	25	9.3 ± 0.20	7.8 ± 0.23	1.5 ± 0.30	5.0
	17	25	9.3 ± 0.22	7.7 ± 0.15	1.6 ± 0.27	5.9
	17	25	9.1 ± 0.30	7.5 ± 0.22	1.6 ± 0.37	4.3
	32	25	16.0 ± 0.52	15.0 ± 0.86	1.0 ± 1.00	1.0
	32	25	15.5 ± 0.47	13.2 ± 0.60	2.3 ± 0.76	3.0
	42	25	17.6 ± 0.65	15.5 ± 0.47	2.1 ± 0.80	2.6
	42	25	20.9 ± 0.87	17.6 ± 0.68	3.3 ± 1.10	3.3
Lime.......	17	25	10.5 ± 0.16	7.7 ± 0.25	2.8 ± 0.30	9.3
	32	25	19.4 ± 0.47	12.3 ± 0.78	7.1 ± 0.91	7.8
	42	25	21.5 ± 0.55	17.6 ± 0.80	3.9 ± 0.97	4.0
Phosphate .	17	25	11.3 ± 0.26	8.2 ± 0.23	3.1 ± 0.35	8.9
	32	25	23.6 ± 0.43	14.7 ± 0.69	8.9 ± 0.81	11.0
	42	25	24.2 ± 0.42	18.4 ± 0.80	5.8 ± 0.90	6.4
Lime and phosphate	17	25	11.7 ± 0.26	9.0 ± 0.20	2.7 ± 0.33	8.2
	32	25	26.2 ± 0.69	17.7 ± 0.72	8.5 ± 1.00	8.5
	42	25	27.9 ± 0.45	20.3 ± 0.79	7.6 ± 0.91	8.4

Koehler, Dungan, and Holbert[61] have found in experimental work that frequently more leaning and down stalks occur in corn grown from seed infected with Diplodia than in corn grown from good seed. However, in these same Diplodia-infected plots there was no significant increase in the number of broken stalks. Data presented in Table 2 and Chart 1 show that corn grown from Diplodia-infected seed may have less resistance to a vertical pull than corn grown from good seed.

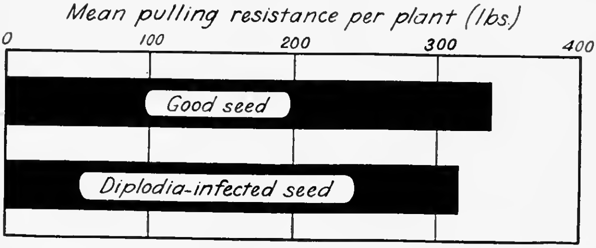

CHART 1.—EFFECT OF DIPLODIA INFECTION ON PLANT ANCHORAGE

Corn from good seed is better anchored, and is less likely to lodge than corn from Diplodia-infected seed (Table 2).

In addition to being carried over the winter as dormant mycelium in the seed, *Diplodia zeae* overwinters in diseased corn roots and stalks and diseased shanks and husks, and also in rotted ears left in the field. The following statements made by Burrill and Barrett[10] in 1909 are still pertinent:

"The first indication of the Diplodia fungus on the dead stalks is the appearance of very small dark colored specks under the rind. In outdoor conditions these may appear during late fall and winter, but usually develop during the spring and summer. [Fig. 17 of this bulletin]. . . . During the summer the necks of the pycnidia begin to break thru the rind of the stalks and in favorable weather conditions send out large numbers of spores. Pieces of diseased stalks one or two years old have been found in July, August, and September almost covered with black tendrils of spores capable of quick germination. . . . Pieces of stalks almost three years old have been found bearing pycnidia and some few of the spores found in them were capable of germination. These were pretty badly decayed, however, and the fungus was not in a very active condition."

Spores of this parasite are picked up by air currents during the summer and fall and may be carried considerable distances. These

TABLE 2.—PULLING RESISTANCE OF CORN GROWN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Planted June 14, 1923, on infested brown silt loam soil, near Bloomington, and pulled October 25-26

Condition of seed	Number of plots	Mean pulling resistance per plant	Difference	Odds
		lbs.	*lbs.*	
Good	13	337	....	......
Diplodia-infected	13	313	24	100:1

spores lodge in cavities between the stalk and sheath, on and around the shank, and on the tip of the ear. Under proper temperature and moisture conditions, these spores germinate and frequently infect the corn plant thru leaf sheaths, nodes, or ear shanks. Durrell[22] states:

"On the leaf sheaths the fungus produces reddish or purplish spots of varying size and shape, appearing after flowering of the corn plant. These lesions may extend down into the node of the stalk or up the leaf, killing or discoloring the midrib."

FIG. 10.—REDUCTION IN VIGOR OF CORN FROM DIPLODIA-INFECTED SEED

Above, a hill of corn grown from nearly disease-free seed. Below, two hills of corn grown from Diplodia-infected seed. These were all planted on the same day, two kernels close together in a hill, under uniform soil conditions.

Ears may be infected either thru the shank or thru the tip of the ear (Figs. 18 and 19). When the infection occurs soon after the ears form, the infected ears are reduced to a char-like mass by the time uninfected ears are well dented. Frequently, early infection of the young ear shoots results in barrenness.

FIG. 11.—CORN FROM GOOD SEED

This corn yielded at the rate of 71.0 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 12.)

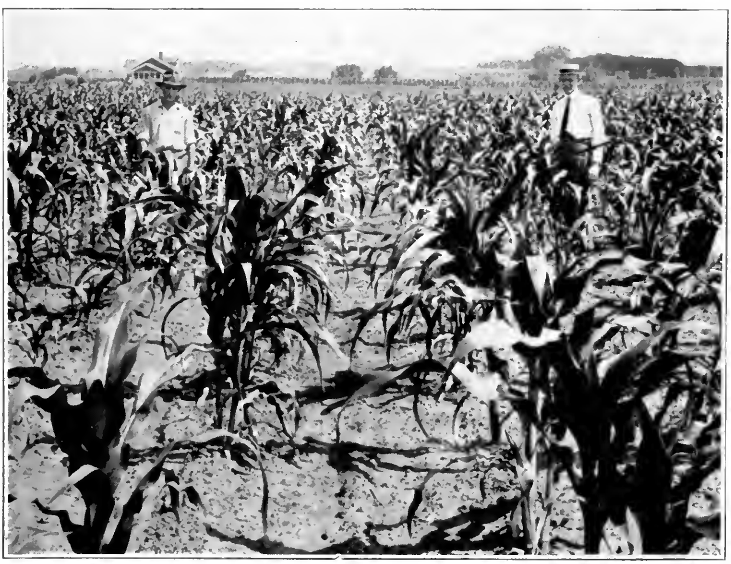

FIG. 12.—CORN FROM DIPLODIA-INFECTED SEED

This corn yielded at the rate of 38.1 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington.

FIG. 13.—INCREASED VIGOR OF DIPLODIA-INFECTED PLANTS IN SOIL RECEIVING LIMESTONE AND PHOSPHATE

Note the irregular growth of the Diplodia-infected plants (left) on the plots receiving no soil treatment (above) as compared with those on the plots receiving limestone and phosphate (below). Experimental plots at Ontario Parish, near Oneida, conducted cooperatively by the U. S. Department of Agriculture, the Illinois Agricultural Experiment Station, and the Men's Club of Ontario, a rural church organization.

PLATE III

A-E Diplodia-infected corn plants.

Note the rotted condition of the mesocotyls and the fewer roots on E as compared with G.

F-G Healthy corn plants.

Note the healthy condition of the mesocotyls and the large number of roots.

The mesocotyls of young corn plants grown from diplodia-infected seed usually appear dry and brown in contrast to the white, healthy appearance of mesocotyls of plants of the same age grown from good seed.

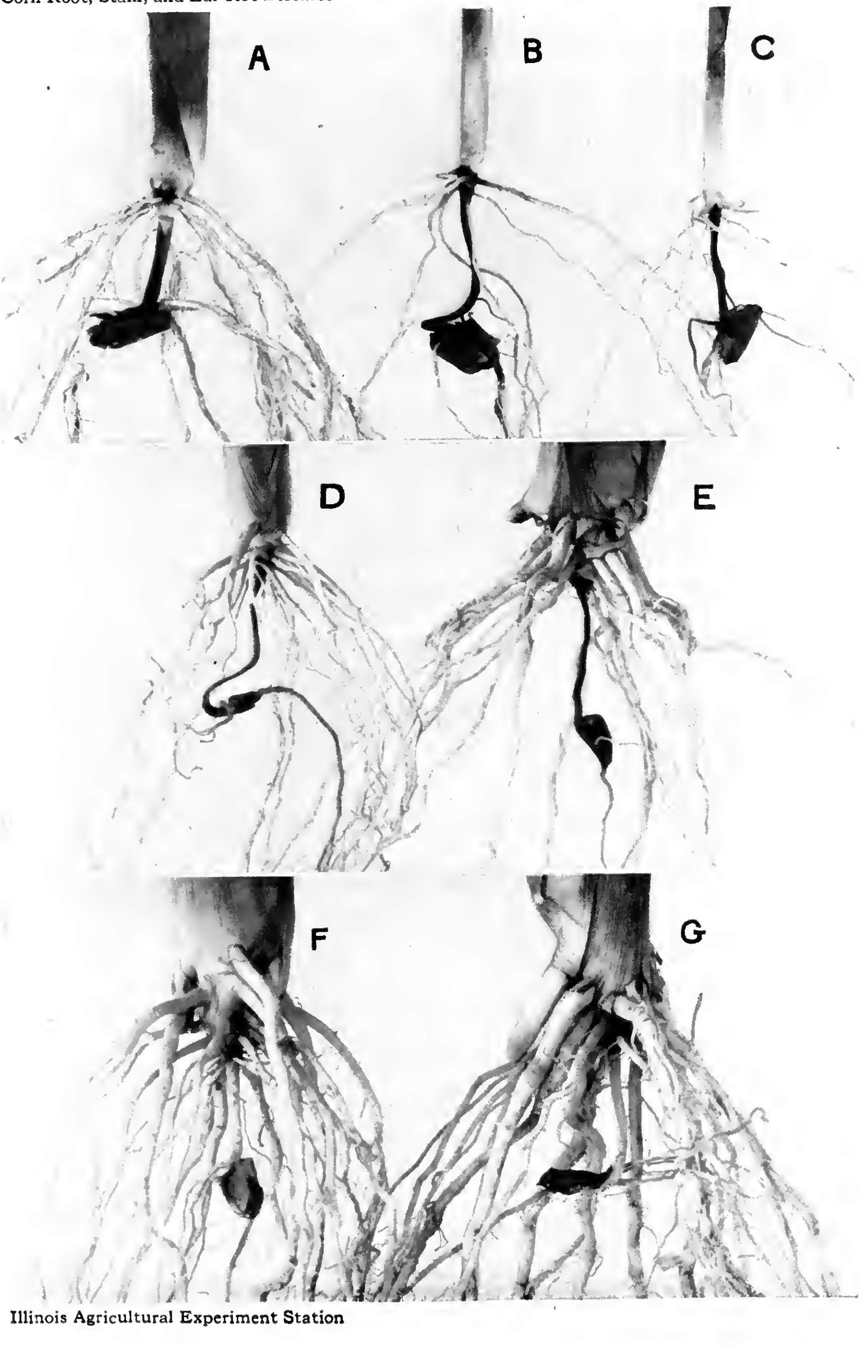
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Fig. 14.—Increased Vigor of Diplodia-Infected Plants on Clean Soil

Note that on the infested soil (above) the growth of the Diplodia-infected plants (left) is very irregular as compared with the plants from nearly disease-free seed (right), while on the clean soil (below) the growth on the two plots is apparently the same. Experimental plots on farms of Charles Gordon and C. A. Atwood near Peoria.

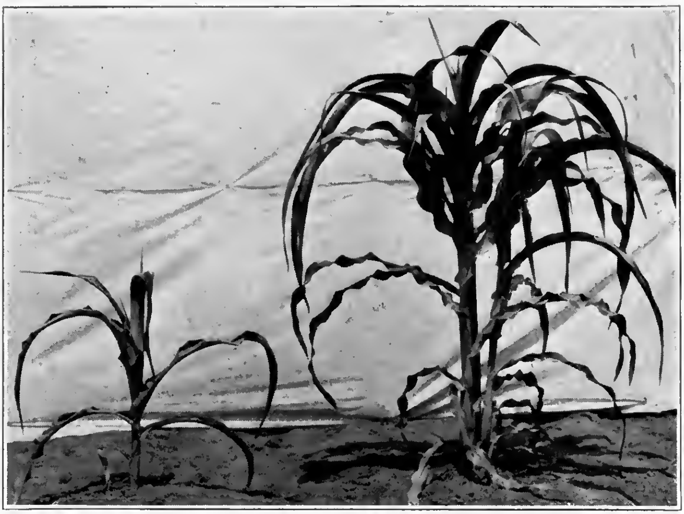


FIG. 15.—CORN FROM DIPLODIA-INFECTED SEED (LEFT) AND FROM GOOD SEED (RIGHT)

These were planted at the same time, three kernels to each hill and photographed July 12, 1921, forty-seven days after planting. Note that only one plant in the hill planted with Diplodia-infected seed has survived and it is wilting. This plant finally grew to nearly normal height but was barren. Many weak plants infected with this parasite wilt and die during the season as a result of the rotting of the roots near the crown.

FIG. 16.—REDUCTION IN HEIGHT OF PLANTS FROM DIPLODIA-INFECTED SEED

Corn grown from Diplodia-infected and from nearly disease-free seed at Bloomington, 1922. The field stand in these plots is unusually good for corn grown from Diplodia-infected seed. The soil had been in virgin prairie sod previous to 1921, when it was planted to corn. The corn from the disease-free seed yielded 93.7 bushels of sound corn, while the corn from the Diplodia-infected seed yielded 72.1 bushels.

FIG. 17.—A DIPLODIA-INFECTED CORN STALK

An old corn stalk from the previous year's crop, showing pycnidia of *Diplodia zeae* discharging spores soon after a warm rain in August.

FIG. 18.—DIPLODIA-INFECTION AT THE BASE OF THE EAR

FIG. 19.—DIPLODIA-INFECTION AT THE TIP OF THE EAR

Every year there is an appreciable amount of the corn crop damaged by ear rots for which Diplodia is chiefly responsible.

In describing the infection of the ear by this fungus, Burrill and Barrett[10] say:

"The slender threads penetrate the young tissues of the grains, cob, and husks, progressing from cell to cell and extracting from their content whatever is of value for food. After the ear has become entirely involved or the growth of the parasite somewhat checked by the maturing of the corn, the fungus begins to form its reproductive stage. This consists of small black bodies which develop in the husks, cobs, and more rarely in the grains, and which contain large numbers of purplish brown, rather slender, two-

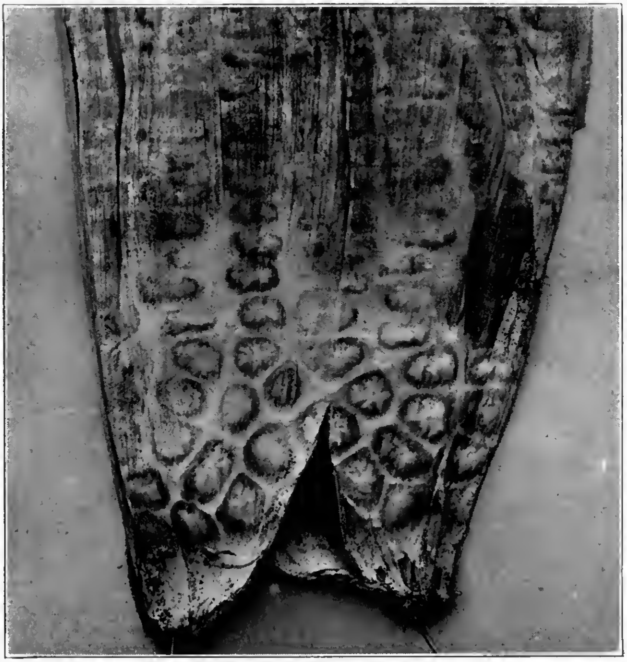


FIG. 20.—INNER HUSK FROM DIPLODIA-INFECTED EAR

In the fruiting stage of the Diplodia fungus the pycnidia outline the position of the kernels against the husks.

celled spores, 25 by 5.2 μ in size. If the outer husks of an ear in a well advanced stage of the disease are pulled down, the spore cases, or pycnidia [Fig. 20 of this bulletin], will be seen as minute black specks slightly elevated above the surface. . . . Diseased ears left in the field under natural conditions eventually develop numerous pycnidia in the grains, giving them a black appearance."

Many apparently good ears have been found infected with this organism (Fig. 21). Such infection can best be detected by the germination test. The appearance of Diplodia-infected seedlings on the germinator is illustrated and described in Fig. 8 and in Plate II.

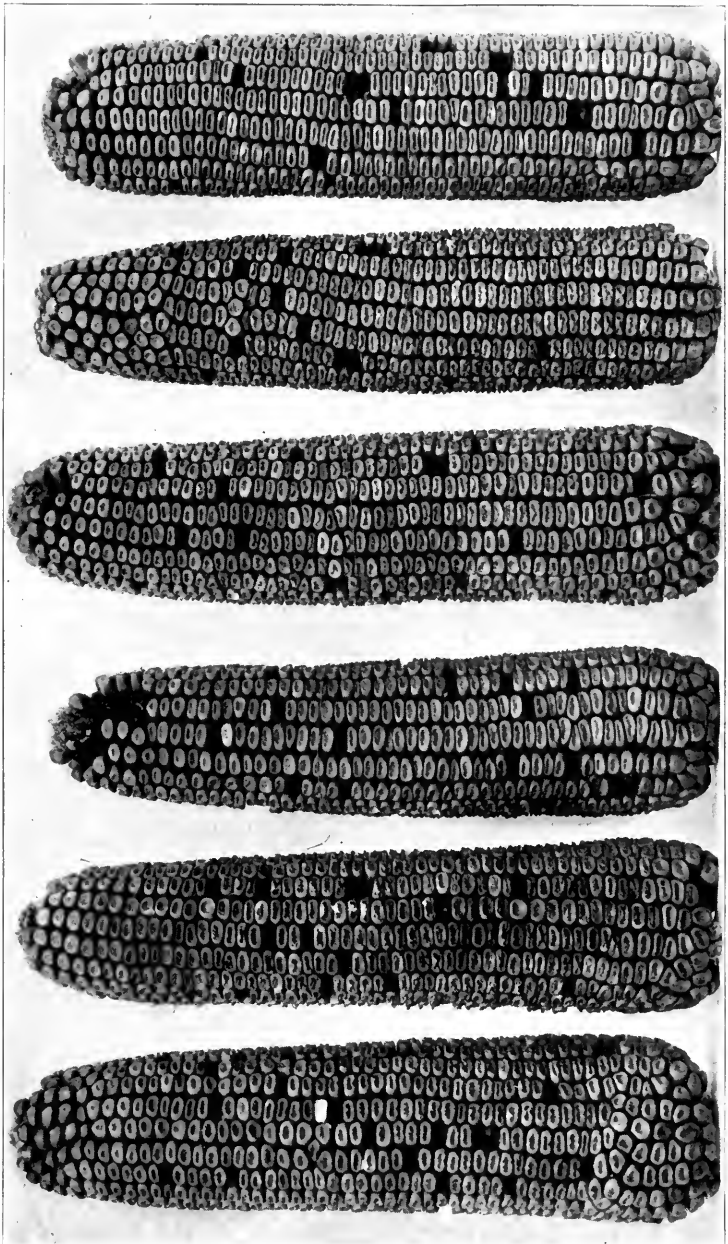


FIG. 21.—DIPLODIA-INFECTED EARS

Typical ears from the Diplodia-infected seed composite used for the 1921 experiments. There was no external evidence of Diplodia mold on any of this seed, yet laboratory tests showed 64 percent of the kernels to be infected. When infection has progressed to the point where external mycelium can be seen, the kernels are dead. Many apparently good ears have been found infected with this organism when tested on the germinator. (See Plate II.)

FUSARIUM ROOT ROT AND EAR ROT

Probably the most common fungus appearing in the germination test of seed corn is *Fusarium moniliforme* Sheldon. In regard to this fungus, Sherbakoff,[92] of the Tennessee Agricultural Experiment Station, makes the following statements:

"Among the Fusaria answering Sheldon's description of *Fusarium moniliforme* are several that differ from each other in more than one important character and are thus apparently different organisms. For this reason and because none of the previously established sections of the genus Fusarium fits the characters of these corn fungi, a new section, Moniliform, is proposed."

FIG. 22.—FUSARIUM-INFECTED SEEDLINGS

These seedlings were apparently fairly vigorous, but the pink fungus was clearly evident on each kernel at this stage. (See Plate I.) The data in Table 39 show that seed with heavy Fusarium infection, as shown in a properly conducted germination test, is inferior for seed purposes.

Miss Grace O. Wineland,[116] of the United States Department of Agriculture and the Wisconsin Agricultural Experiment Station, has found the ascigerous stage of certain strains of *Fusarium moniliforme* isolated from corn, all coming within the limits of the section Moniliform established by Sherbakoff.

Corn seedlings infected on the germinator with this organism are illustrated in Fig. 22 and Plate I, Figs. C and D. The fungus was found in 1904 on rotting corn on several farms in Nebraska and was described by Sheldon as a new species.[91] Burrill and Barrett[10] found *Fusarium* spp. causing ear rots in Illinois, but did not consider them as important a cause of ear rots as *Diplodia zeae*. Pammel, King, and Seal[75] described a root and stalk rot of corn and sorghum which they believed to be caused by *Fusarium* spp. Hoffer and Holbert[40] called attention to the fact that *Fusarium* spp. are among the harmful organisms associated with the corn root, stalk, and ear rot diseases. Valleau,[108] of the Kentucky Agricultural Experiment Station, found

FIG. 23.—CORN FROM NEARLY DISEASE-FREE SEED

This yielded at the rate of 66.3 bushels per acre. U. S. Department of Agriculture experimental plots on the farm of Mr. E. D. Funk, Bloomington. (Compare with Fig. 24.)

FIG. 24.—CORN FROM FUSARIUM-INFECTED SEED

This yielded at the rate of 60.9 bushels per acre. U. S. Department of Agriculture plots on the farm of Mr. E. D. Funk, Bloomington.

this fungus prevalent on a large number of samples of corn from Kentucky and other states.

Manns and Adams,[68, 69] of the Delaware Agricultural Experiment Station, in studying the distribution and prevalence of parasitic fungi, found that this fungus, as well as *Diplodia zeae, Gibberella saubinetii,* and an organism which has since been determined as *Cephalosporium acremonium* Corda, was present in a large number of samples of seed corn from widely different sources. Sherbakoff[92] found *Fusarium moniliforme* to be the common Fusarium of corn. Melchers and Johnston,[70] of the Kansas Agricultural Experiment Station, in discussing the presence of certain fungi on the germinator, report: "*Fusarium moniliforme* is by far the most common and occurs to a greater or less extent on over 95 percent of all the ears so far tested." Others[7, 8, 59, 98, 30] have reported studies with *Fusarium* spp. on corn. It is evident that this fungus is widely distributed and that it has attracted the attention of a number of workers.

As yet field inoculation studies have failed to yield definite data concerning the pathogenicity of *Fusarium moniliforme* as a root rot parasite of corn. Several strains of this fungus exist, however, and undoubtedly they differ greatly in their ability to parasitize the corn plant. Various strains of corn differ widely in their susceptibility to this fungus as an ear rot producing organism. Some strains have been very susceptible, frequently from 15 to 25 percent of the grain being damaged by Fusarium ear rot alone. Other strains growing in adjacent plots have been practically immune from Fusarium ear rots.

It must not be inferred that seed infection with *Fusarium moniliforme* is of little significance. While corn from seed infected primarily with this organism usually suffers but a slightly reduced stand and only a slight reduction in vigor (Figs. 23 and 24), the yield of *sound* corn is greatly lowered (Table 39). Often the differences in yield between corn grown from such infected seed and from good seed are apparent only after the crop has been harvested and the ears separated into sound and marketable grades on a uniform moisture basis. On soils lacking lime and phosphorus, however, the reduction in total yield frequently has been pronounced. Obviously, the roots, stalks, and ears of some strains of corn are very susceptible to rot by this fungus. Seed infection with this organism also apparently indicates that the resulting plants may be susceptible to injury from unfavorable environmental conditions.

Ears conspicuously rotted with Fusarium may be recognized by the characteristic pinkish color of the kernels (Plate I, Figs. C and D, and Plate V). Frequently a number of individual kernels on an ear are badly rotted by *Fusarium* spp., while other kernels on the same ear are unaffected. Also, apparently good seed ears may be heavily infected with this organism (Fig. 25).

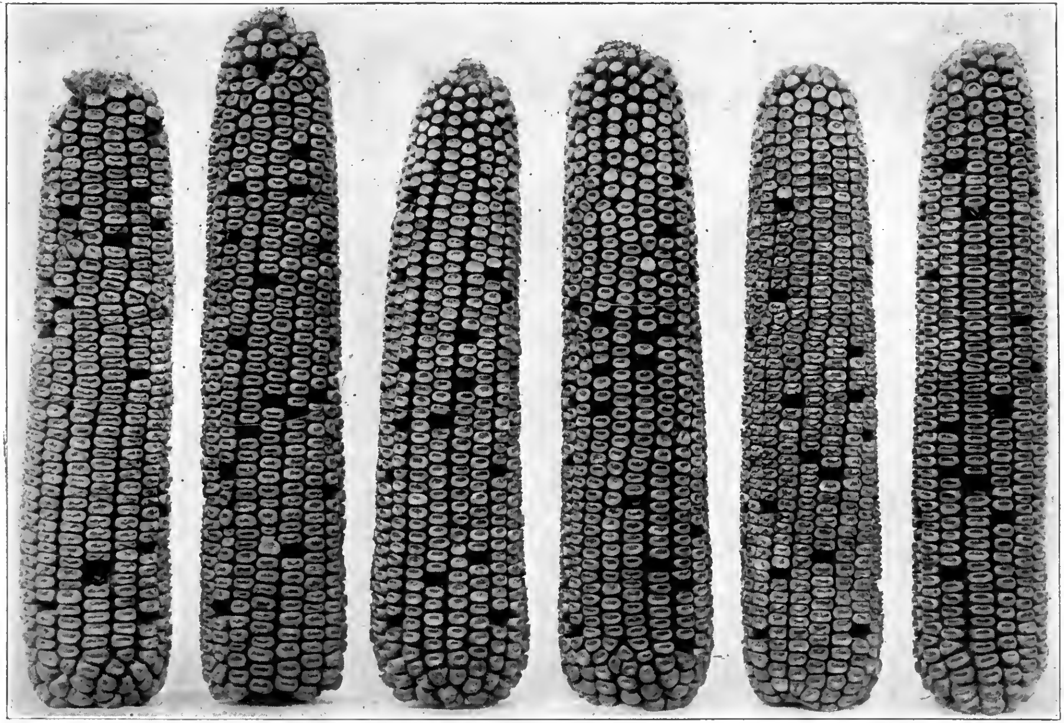


FIG. 25.—FUSARIUM-INFECTED EARS

Typical ears from the Fusarium-infected seed composite used for the 1921 experiments. Only good appearing seed ears were used, all ears showing the presence of mold on kernels or cob being discarded, yet laboratory tests showed that 57 percent of the kernels were infected with *Fusarium moniliforme*. Often differences in yield between corn grown from such infected seed and from good seed are apparent only after the crop has been harvested and the product separated into sound and unmarketable grades on a uniform moisture basis.

BLACK-BUNDLE DISEASE

The black-bundle disease of corn, caused by the fungus *Cephalosporium acremonium* Cord., is being investigated by Dr. Charles S. Reddy, of the United States Department of Agriculture, and James R. Holbert. They[81] make the following statements concerning this important disease and the causal organism:

"Usually symptoms of the black-bundle disease do not become evident during the first half of the growing season. During ear development various symptoms may develop, such as abnormal leaf and stalk colors, barren stalks, nubbin ears, or prolific stalks. Such stalks usually show blackened fibro-vascular bundles.

"In every field of dent, flint, and sweet corn under observation by the writers, it has been noted that many plants have become red or purple on reaching the dough stage. The red coloration appears first at or near the mid-vein of the topmost leaf and progresses downward on the plant, affecting several leaves before progress on the stalk commences. In extreme cases the stalk and all the leaves become reddish purple, but all gradations between the initial appearance of the red color and this extreme condition may be the final color symptoms. Plants having any gradation of this reddening or purpling are designated in this paper as purple-leaf plants.

"This type of reddening does not conform to any of those described by Emerson,[24] who says 'It is of interest to recall in this connection that plant colors of maize—brown no less than the red-purple series—develop first in the older parts where growth first ceases, such as the lower sheaths and the upper parts of the internodes of the culm.' However, a type of reddening, indistinguishable from the one encountered in commercial fields, sometimes occurs in selfed lines of dent corn. Inoculation of open-fertilized dent corn with a particular organism (*Cephalosporium acremonium*) increases the number of purple or red plants.

"This disease is characterized also at this stage of development of the corn plant by high percentages of barren stalks and stalks producing nubbin ears only [Fig. 26 of this bulletin]. Often imperfectly developed ears are observed at a number of nodes on a stalk and more frequently multiple-ear production occurs at one node, showing futile attempts at prolificacy. These manifestations—and large succulent stalks should be included—are the readily apparent symptoms associated with the black-bundle disease of corn and can be noted in any commercial field. When plants having any of these symptoms are cut open, blackened vascular bundles nearly always can be found in the nodes and internodes near the base and sometimes thruout the stalk. Occasionally the fundamental tissue outside the blackened vascular tissues becomes browned or blackened, but usually in only one internode of a stalk. . . .

"Altho purpling, prolific stalks, barren stalks, nubbin ears, and suckering are closely associated with this disease, the blackened fibrovascular bundles are considered the most distinguishing characteristic, hence, the name Black-Bundle Disease of Corn.

"However, the number of plants having these symptoms (excluding the black-bundle symptom) represents only a small part of the total number of plants affected by the disease. Plants, including the ears, may appear outwardly healthy yet be infected from the crown to the tassel and every kernel of fine looking ears may bear the organism internally. In these cases the presence of the black vascular bundles within the stalks is the most distinguishing symptom. The ears may be diagnosed by plating the kernels or by germination in conjunction with microscopic examination.

FIG. 26. — CORN AFFECTED WITH BLACK-BUNDLE DISEASE

Barren stalks and stalks with multiple ears are extreme types of injury from Cephalosporium infection. The black-bundle disease is responsible for much loss to the corn crop. The plant on the left is apparently healthy.

"Infected ears carry the organism (*Cephalosporium acremonium*) internally in the seed. It develops with the germinating kernel and causes a systemic infection of the plant thru the vascular system. By this means, it invades the ears and eventually the kernels. In this manner it is carried over to the following season. Occasionally an ear can be found which is externally overrun. In observations extending over a period of three years, only one such ear has been found. Probably an especially damp harvest season or poor storage conditions are necessary for this development. It seems possible that with such development, the infection might spread from ear to ear. . . . The question of soil infection has not been determined definitely as yet.

"Seed infection can be determined macroscopically on limestone-sawdust germinators, . . . but the symptoms are easily overlooked so that up to the present only a fair degree of accuracy has been attained by this method.

"Infected germinating kernels have blanched, white tips, sometimes with noticeable mycelial growth. Often, however, the mycelial growth cannot be seen until examined microscopically. When the symptoms on the germinator are overlooked, the ears often are chosen for seed because germination and the vigor of the infected seedlings are seldom impaired at this time. . . .

"*Cephalosporium acremonium* has been isolated from black-bundles in first leaves, from bundles in stalks, from the shanks, from the cobs, and from the kernels. . . .

"To reduce losses from this disease, it is well to avoid selection of seed ears from stalks having any of this group of symptoms. Probably the best measure of control will come with the development of resistant strains of corn within the varieties."

MISCELLANEOUS EAR ROTS AND MOLDS

When corn is injured by ear worms (*Chloridea obsoleta*) before it is well dented, considerable damage may follow from ear rots caused by fungi other than *Diplodia* and *Fusarium* spp. These include *Aspergillus* spp., *Penicillum* spp., and other molds. Of these, the black and yellow molds, caused by *Aspergillus niger* and *Aspergillus flavus* Link, respectively, are common. Taubenhaus,[102] of the Texas Agricultural Experiment Station, reports that these two molds are very common in that state and cause much damage to the corn crop. He further states:

"There are cases of late infection where the ears were but slightly injured by the black mold, infection being confined to the place of injury from the ear worm and resulting in an ear more or less normally developed and apparently containing well nourished and fully developed grains, altho their surface may be covered with spores of *Aspergillus niger*."

Taubenhaus found that seed corn from such ears was inferior for seed purposes and recommended that only healthy kernels of absolutely healthy ears should be used for seed. Altho these two molds probably do not cause any serious damage to the corn crop in Illinois, nevertheless they do occur in some seasons. The authors have examined certain lots of seed ears which bore evidence of considerable damage apparently from this source.

Both the black and the yellow molds frequently occur in the testing of corn on the germinator. Owing to the fact that the organism causing the black mold produces an abundance of black spores on the germinator, it often is mistaken by inexperienced persons for smut, which is an entirely different fungus and one which does not appear on the germinator. Ordinarily, however, in a properly conducted germinator test of well selected and properly stored seed neither the black nor the yellow mold appears.

Where early selected seed is not properly cured and properly stored, a large number of facultative parasites may grow over the butts of the cobs (Plate IV) and spread over the surfaces of the ears. In many cases, these fungi may actually penetrate the kernels and seriously affect their seed value. Under moist weather conditions, corn left in the field after heavy killing frosts also may become infected, not only with *Diplodia zeae* and *Fusarium moniliforme*, but with a large number of fungi which under ordinary conditions are saprophytes. *The seed value of corn subjected to such unfavorable field or storage conditions is very questionable.*

BACTERIAL WILT

(Stewart's Disease)

Bacterial wilt, caused by *Aplanobacter stewarti* (E. F. S.) McCul., is the source of much damage to sweet corn[97, 95, 80] and also occurs to some extent in dent corn. In sweet corn the symptoms are rather distinctive and easily recognized (Fig. 27). The organism causing this disease usually confines its activities to the fibrovascular bundles, in which it multiplies and eventually causes a clogging, thus stopping the transpiration stream. By cutting the stalks of diseased plants obliquely, the yellow affected bundles are seen readily. After the cut surface has been exposed for a few minutes, yellow bacterial ooze exudes in small beads at the cut end of the bundles. If these sticky beads are touched with the finger or a knife blade, they may be drawn out in threads. In older plants the infected bundles sometimes present a dark appearance. Leaves of affected sweet corn plants may or may not turn yellow before wilting, according to the extent of infection and to environmental factors. In some cases plants with well developed ears may wilt and die within a few days. The disease is seed borne and apparently does not live over winter in the soil.

On dent corn the symptoms (Fig. 28) are not so pronounced, and the yellow substance in the infected bundles is not so viscous. However, Reddy has shown that the causal organism from either dent, sweet, or flint corn is equally parasitic on the other two species of corn.

Altho this disease is of great economic importance in sweet corn production, there is no evidence to date that it causes any material loss in dent corn.

A bacterial disease of corn in Illinois was described by Burrill[9] in 1889, but only a few scattered reports of its occurrence in this state

FIG. 27.—BACTERIAL WILT (STEWART'S DISEASE) OF SWEET CORN

The hill at the left shows severe infection. Bacterial wilt is the source of much damage to sweet corn, and also occurs to some extent in dent corn.

have been made during the past several years. It seems probable that this disease, in part at least, is the root and stalk rot of corn described more accurately by Rosen[84] of the Arkansas Agricultural Experiment Station, and the causal organism named *Pseudomonas dissolvens*.[85]

Hoffer and Holbert[40] include *Pseudomonas* spp. among the organisms associated with disease in corn. Reddy has isolated bacteria from diseased corn plants, and Reddy and Holbert[81] make the following statement:

"Occasionally bacteria are found associated with *Cephalosporium acremonium* in the infected bundles, especially in the lower internodes. In fact, it was suspected that bacteria might play an important part in causing certain of these disease manifestations. Even yet, the exact status is not fully clear in this respect, but is being investigated further."

GIBBERELLA ROOT ROT, EAR ROT, AND SEEDLING BLIGHT OF CORN

In 1919 and 1920 Dickson, Johann, and Wineland[17] found that *Gibberella saubinetii* (Mont.) Sacc. was the cause of practically all the wheat scab thruout the corn belt and of 94 to 98 percent of all the wheat scab in the United States. This organism also causes scab of other cereals. Selby and Manns,[89] Pammel, King, and Seal,[75] and other workers have observed *Gibberella saubinetii* on corn stalks. In 1918 Hoffer, Johnson, and Atanasoff[41] reported a greater abundance of wheat scab where wheat followed corn that had been infected with the root and stalk rots. They produced scab by inoculating wheat with Gibberella spores from old diseased corn stalks, and also produced root rot and seedling blight of corn under laboratory conditions by inoculating with a culture of this organism from scabbed wheat.

FIG. 28.—BACTERIAL WILT OF DENT CORN
Left, an apparently healthy dent corn plant; right, a plant growing in an adjacent hill badly affected with bacterial wilt.

Since that time other workers[45, 2] have reported observations and presented data which show that the host range of this organism includes both wheat and corn. A rather complete report on this situation is presented by Koehler, Dickson, and Holbert.[60] They found that:

"The yield of corn susceptible to root rot was considerably reduced where corn followed badly scabbed wheat in the rotation. *Gibberella saubinetii* was the principal organism isolated from scabbed wheat heads. The

FIG. 29.—A DISEASE-SUSCEPTIBLE STRAIN (LEFT) AND A HIGHLY RESISTANT STRAIN (RIGHT)

Inbred strains of dent corn growing in contiguous rows, the row on the left in each illustration having been inoculated at planting time with *G. saubinetii*. Note that in the disease-susceptible strain both the stand and the vigor were greatly reduced following inoculation, while the resistant strain apparently suffered no ill effect.

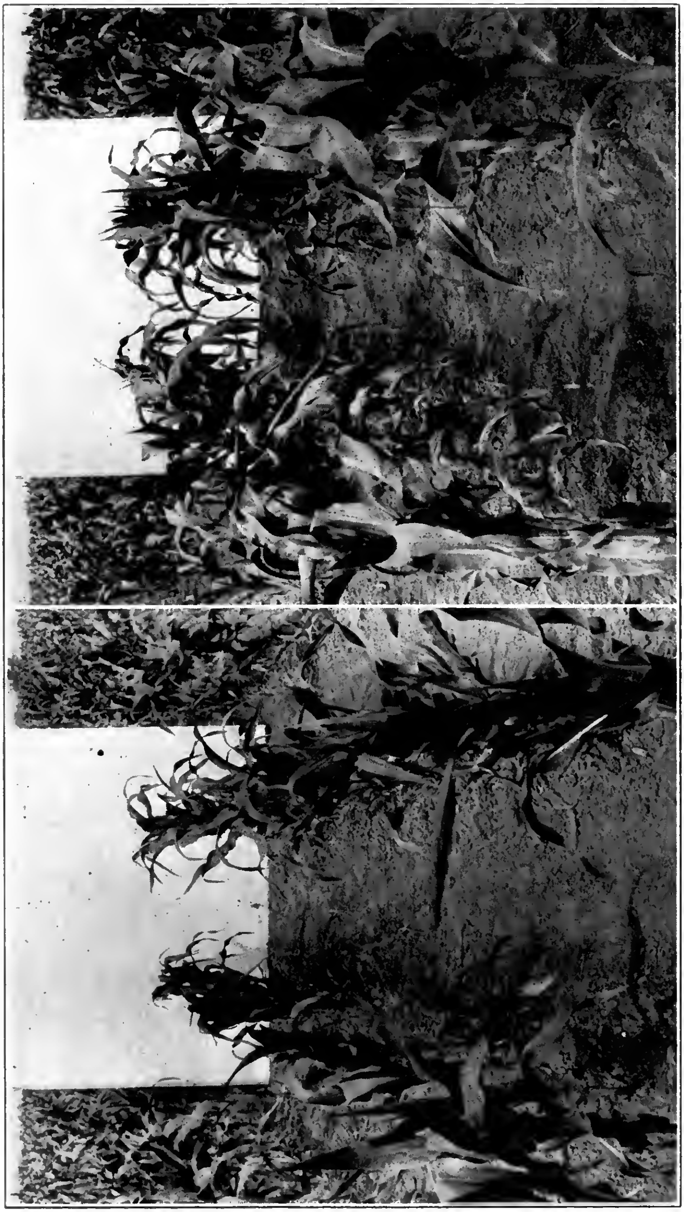


FIG. 30.—A DISEASE-SUSCEPTIBLE STRAIN (LEFT) AND A HIGHLY RESISTANT STRAIN (RIGHT)

Strong-rooted inbred strains of dent corn growing in contiguous rows, the row on the left in each illustration having been inoculated at planting time with *G. saubinetii*. The stand of the disease-susceptible strain was slightly reduced by inoculation, while neither the vigor nor the stand of the resistant strain was affected.

TABLE 3.—INFLUENCE ON FIELD STAND AND PLANT YIELD OF INOCULATION AT PLANTING TIME WITH *Gibberella saubinetii*

Strong-rooted and weak-rooted strains of inbred yellow dent corn planted May 22, 1923, on brown silt loam, near Bloomington

Character of strain	Number of strains in experiment	Final field stand				Mean plant yield			
		Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds
		perct.	*perct.*	*perct.*		*lbs.*	*lbs.*	*lbs.*	
Strong-rooted....	18	90.2	88.5	1.7	7:1	0.644	0.592	0.052	115:1
Weak-rooted....	18	90.0	75.2	14.8	1427:1	0.381	0.364	0.017	10:1

TABLE 4.—INFLUENCE OF EARLY AND LATE PLANTING ON FIELD STAND, PERCENTAGE OF VIGOROUS PLANTS, AND YIELD FOLLOWING INOCULATION WITH *Gibberella saubinetii*

Disease-susceptible yellow dent corn planted on virgin prairie sod near Bloomington, 1921

Date of planting	Field stand				Percentage strong plants				Total acre yield				Acre yield of sound corn			
	Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds
	perct.	*perct.*	*perct.*		*perct.*	*perct.*	*perct.*		*bu.*	*bu.*	*bu.*		*bu.*	*bu.*	*bu.*	
May 11.	92.0	78.5	13.5	> 9999:1	78.8	57.8	21.0	> 9999:1	82.5	69.5	13.0	> 9999:1	56.8	46.6	10.2	> 9999:1
May 28.	92.1	88.6	3.5	34:1	71.8	68.2	3.6	13:1	84.7	82.5	2.2	3:1	53.5	49.2	4.3	18:1

Data based on average of 16 plots for each planting.

same organism was found very abundantly on old corn stalks. The above organism when used as inoculum on disease-susceptible corn caused a considerable decrease in stand, general vigor, and yield.''

They also found that highly resistant corn did not suffer much reduction in yield when grown after scabbed wheat or when inoculated with a pure culture of the organism.

The spores of *G. saubinetii* on infected wheat heads and old infected corn stalks are carried by air currents, and perhaps are disseminated by a number of other agencies. Many of these wind-blown spores lodge on corn plants, where they find a favorable medium for

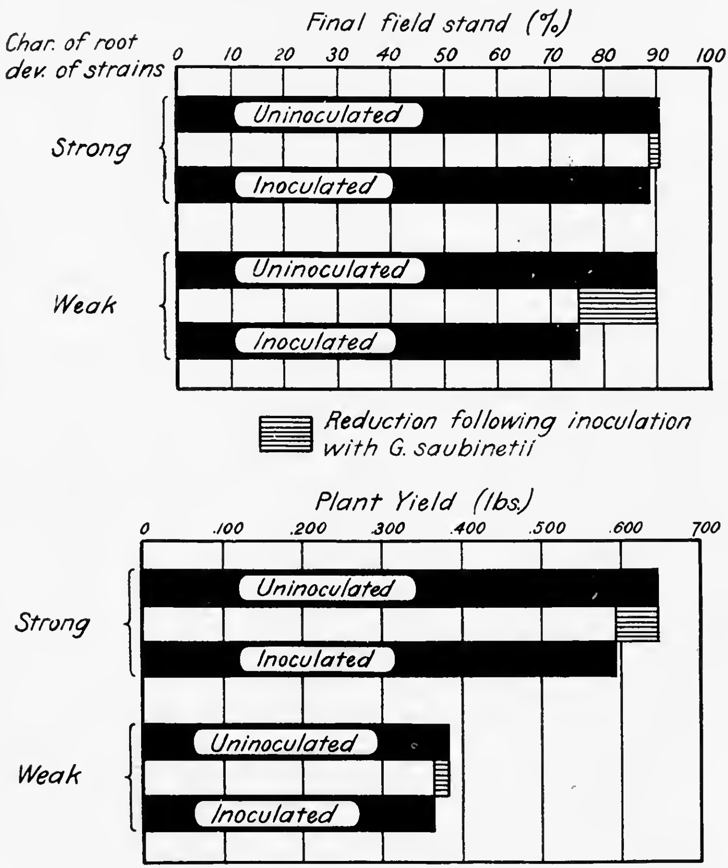


CHART 2.—EFFECT ON STRONG- AND WEAK-ROOTED INBRED STRAINS OF INOCULATION WITH *Gibberella saubinetii*

Field stands of the weak-rooted strains were greatly reduced following inoculation with *G. saubinetii,* but the yield of surviving plants was not reduced as much in proportion as the plant yield of the strong-rooted strains, the field stands of which were reduced only slightly by the inoculation (Table 3).

growth in the moist pollen and dust collected on the ligules at the bases of the leaves, between the sheaths and stalks, and in the cavities surrounding the shanks. Late in the fall and in the following summer perithecia may develop in abundance near the nodes of infected corn stalks. Under certain conditions *G. saubinetii* may do damage as an ear rot producing organism.

Manns and Adams[69] report a rather heavy infection of this organism in seed corn from certain states. In Illinois such infection has not been general. However, various lots of seed have been examined which contained from 10 to 15 percent or ears infected with *G. saubinetii.* The use of seed infected with this organism has resulted in greatly reduced stands and reduced vigor, especially in early plantings. It seems evident that in Illinois *G. saubinetii* does considerable damage to corn in the rôle of a parasitic soil organism causing root rot and seedling blight. There is no evidence that this fungus produces a systemic infection of the plant, but under certain environmental conditions already mentioned, it may do considerable damage to the corn crop by attacking underground parts of the plant. Infected plants frequently are blighted and in severe cases die (Fig. 29). The extent of injury caused by this soil parasite, however, cannot be measured alone by loss in stand due to seedling blight. Certain strains of corn which may produce little evidence of seedling blight following inoculations with pure cultures of this organism, may show marked reductions in vegetative growth during the early summer, which are reflected in notably reduced yields of grain (Fig. 30). Data showing such reduction in field stand and in yield of grain by *G. saubinetii* are presented in Table 3 and Chart 2.

CORN SMUT

The boil smut, or common smut, of corn caused by *Ustilago zeae* (Beckm.) Ung. is a familiar disease (Figs. 31 and 32). At times it has been known to produce heavy losses in Illinois, especially in fields planted with corn very susceptible to smut. During these investigations the authors have observed many instances where plots grown from seed infected with disease-producing organisms were damaged decidedly more by smut than adjacent plots grown from good seed of the same variety. Very frequently strains of corn susceptible to root, stalk, and ear rot diseases have proved very susceptible to injury from smut. Altho smut can be distinguished readily from corn rot diseases and altho it is caused by a widely different organism, it is possible that plants weakened by one of these diseases may become predisposed, under certain conditions, to injury from the other disease.

Jones,[55] of the Connecticut Agricultural Experiment Station, in 1918 called attention to the fact that segregates from inbred strains of corn varied widely in resistance and susceptibility to smut. In connection with their corn-breeding work, the authors of this bulletin have observed numerous instances in which certain inbred strains were almost completely ruined by smut, while other strains in adjacent rows were affected only slightly. More recently, work by Dr. W. H. Tisdale with strains of corn supplied by Mr. C. H. Kyle, of the United States Department of Agriculture, has established, beyond doubt, the fact of inherited resistance and susceptibility to this disease. *Open-pollinated strains of corn which have been selected by the authors over a period of years from plants not affected with smut, have been injured but slightly by this disease.* Thus the recommendation to avoid ears from smutted plants in the selection of seed corn is well founded, and furnishes an effective means for the control of this disease.

Common corn smut attacks only above-ground parts of the corn plant. The organism overwinters in soil, manure, and compost. It spreads by means of small spores (sporidia), which are carried by air currents. These spores lodge on the corn plant and usually infect thru stomata and wounds. Mechanical injuries to the plant, therefore, make possible a severe attack of smut, especially on susceptible strains of corn.

FIG. 31.—CORN SMUT

Altho smut can be distinguished readily from the corn rot diseases and altho it is caused by a widely different organism, it is possible that plants weakened by one of these diseases may become predisposed, under certain conditions, to injury from the other disease.

FIG. 32.—CORN SMUT

An effective means to control this disease is to avoid the use of seed from smutted plants.

Head smut of corn,[79] caused by *Sphacelotheca reiliana* (Kühn) Clinton, occurs only in the semi-arid Middle West and to a certain extent on the Pacific coast.[16] According to Dr. W. H. Tisdale, it is not a serious problem in any locality in the United States.

MISCELLANEOUS SOIL-BORNE DISEASES

In addition to the disease-producing organisms already mentioned that may be soil-borne, there are certain other organisms in the soil which may parasitize the corn plant under certain environmental conditions. Stover,[99] working at the University of Wisconsin in 1921, reports the following:

"A species of Helminthosporium isolated from living corn plants was found to cause a marked seedling blight of corn, . . . mesocotyl, cotyledonary node, and seminal roots were rotted. The diseased region was dark brown to deep black and usually shrunken."

This same investigator found that the disease was more severe with soil temperatures between 16° and 24° C. He also says:

"A relatively high moisture content of the soil is favorable for the development of the disease."

CORN RUST AND OTHER DISEASES

Traces of corn rust caused by *Puccinia sorghi* Schw. can be found in almost every cornfield, but only a few fields have been observed where this disease has resulted in any appreciable damage to the crop. Different strains, as well as individual plants, vary widely in resistance and susceptibility to rust, as noted by Weber,[113] and by Mains, Trost, and Smith,[67] and as observed by the authors. Certain inbred strains have been grown which were very susceptible, both leaves and sheaths becoming covered with rust pustules, while other inbred strains of the same variety in adjacent plots were practically free from rust. By avoiding seed ears from rusted plants, it seems unlikely that this disease will ever become economically important under conditions existing in Illinois.

Brown spot of corn, caused by *Physoderma zeae-maydis* Shaw, causes considerable damage in dent corn in the South Atlantic and Gulf states. It was observed in Illinois by Burrill in 1911. Since then occasional plants affected with this disease have been found almost every year, but no instance of severe damage has been reported in Illinois except on sweet corn. A complete discussion of this disease is given by Tisdale.[105]

Durrell,[21] of the Iowa Agricultural Experiment Station, has described a purple-leaf sheath disease of corn caused by the growth of facultative parasites on pollen accumulated between the leaf sheaths and the stalks. Other leaf-sheath rottings not described by this investigator appear before any pollen has been shed. These troubles may cause slight injuries under certain conditions.

Mosaic disease of corn[6] has been reported in the United States but losses in the corn crop due to this disease probably are very slight. At the present time this disease is confined mostly to the regions producing sugar cane.

Downy mildew of maize, caused by *Sclerospora* spp., results in serious losses in the Orient. Up to the present time it has not been known to occur in the United States. An investigation of this disease in the Philippines has been reported by Weston.[114]

ENVIRONMENTAL FACTORS

The importance of environmental factors in determining growth and development of plant life was recognized by the earliest agricultural workers. The relation of environing factors to the development of plant disease also has been observed in a general way by farmers and plant culturists for many years. More recently certain of these soil and climatic factors have been the subject of much investigation in connection with the occurrence of diseases in field crops. The relation of environment to the development of the corn rot diseases under discussion in this bulletin is a very complex problem, even a partially complete understanding of which will require years of careful study. However, certain data have accumulated during the progress of the investigations which throw considerable light on these complicated relationships.

Altho it is possible, under properly controlled greenhouse conditions, to determine the influence of soil moisture, soil aeration, and certain other factors on the development of the corn rot diseases, yet it must be recognized that such environing factors seldom, if ever, act independently under actual field conditions. A change in one factor usually is accompanied by changes in other factors, as well as by changes in the biological and chemical conditions of the soil, some of which may profoundly affect the normal metabolism of the corn plant and its resistance and susceptibility to the corn rot diseases. But in spite of the complexity of the situation, much progress already has been made in obtaining a clearer understanding of the relation of certain environing factors to the development of such diseases as cabbage yellows,[56, 29] flax wilt,[104] root rot of tobacco,[53] Rhizoctonia of potatoes,[82] potato scab,[57] seedling blight of wheat,[19] and other diseases.

SOIL TEMPERATURE AND TIME OF PLANTING

The effects of soil and air temperature on the corn plant itself are very marked and have been studied by a number of investigators.[87, 33, 4, 111, 35] When the temperature is too low following planting, the leaves turn yellow and the plants grow very slowly. On the other hand, a very high temperature with an abundance of moisture following planting produces a tall, spindly growth. Dickson[19] and others have shown that the ratio of tops to roots of corn is influenced by soil temperatures during this stage. A rather cool temperature favors root development, while a high temperature favors shoot development. The sturdy growth of the young plant essential for the best results is obtained only within a comparatively limited range of temperature, which usually obtains in this latitude during the second or third week in May. Each stage of development in the corn plant is best produced within certain ranges of temperature, a departure from which disturbs the normal activities of the plant and may favor the attack of certain disease-producing organisms if the particular strain of corn is disease-susceptible.

Dickson,[18] as stated above, found that the temperature of the soil was "the most important single factor determining the extent of seedling blight" caused by *Gibberella saubinetii.* Both field plantings and controlled greenhouse experiments by Dickson showed that Gibberella blighting of corn developed most abundantly in soil temperatures under 66° F.

Field data are presented in Table 4 and Chart 3 showing the effect on yield of early and late planting following inoculation with *Gibberella saubinetii.* These experiments were located on soil that was almost ideal from the standpoint of drainage, balanced fertility, and

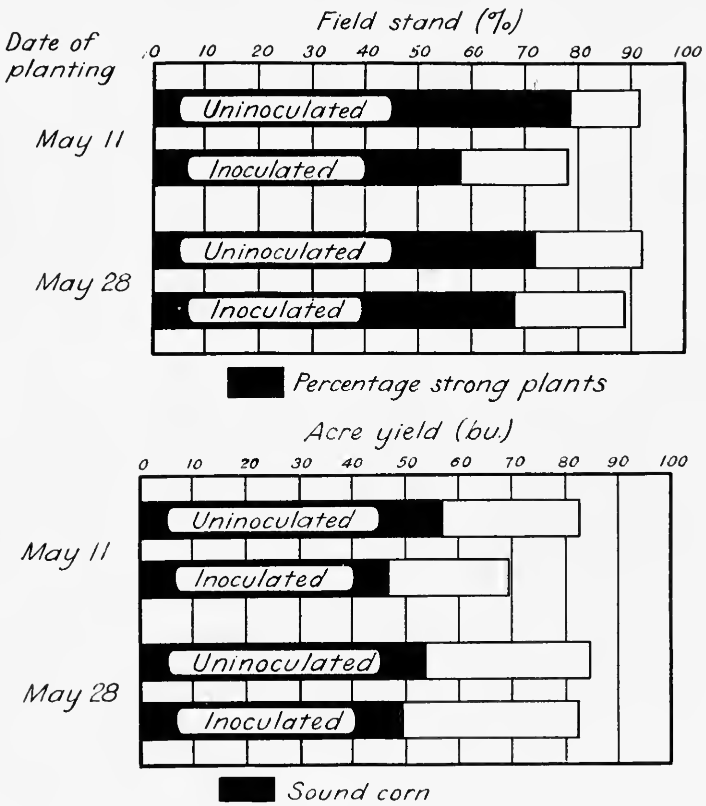


CHART 3.—INFLUENCE OF EARLY AND LATE PLANTING ON INJURY FOLLOWING INOCULATION WITH *Gibberella saubinetii* (Table 4)

There were marked reductions in percentage field stand, percentage of strong plants, and acre yield following inoculation with *G. saubinetii* in the early planting, but only slight reductions in the late planting.

physical condition. In the planting made on May 11, when the mean soil temperature was approximately 58° F., the stand was greatly reduced by the inoculation, whereas in the late planting made on May 28, when the mean soil temperature was above 68° F., it was reduced only slightly. Again, in the early planting the percentage of vigorous plants was reduced from 78.8 percent in the uninoculated plots to 57.8 percent in the inoculated. Both total yield and yield of sound corn also were affected by the inoculation, the reduction of 13.0 bushels per acre in total yield and 10.2 bushels in sound corn being very significant in terms of the odds involved. In the late planting there was little reduction in vigor and no significant reduction in either total yield or yield of sound corn. These data, as well as those presented by Dickson, indicate that soil temperature is a very important

TABLE 5.—INFLUENCE OF DATE OF PLANTING ON YIELD FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED

Grown on brown silt loam of high fertility, University South Farm, Urbana, 1920-1922

Year	Date of planting	Character of seed	Acre yield		Reduction in sound corn following use of susceptible seed	
			Total	Sound		
			bu.	*bu.*	*bu.*	*perct.*
1920	May 19	Good	79.7	70.4		
		Susceptible	73.4	58.9	11.5	16.3
	May 26	Good	79.3	66.9		
		Susceptible	65.8	48.3	18.6	27.8
	June 2	Good	77.8	56.8		
		Susceptible	61.9	39.7	17.1	30.1
1921	May 2	Good	100.7	89.6		
		Susceptible	90.9	73.4	16.2	18.1
	May 10	Good	99.8	85.2		
		Susceptible	86.3	69.4	15.8	18.5
	May 20	Good	90.5	79.1		
		Susceptible	77.0	57.4	21.7	27.4
	May 31	Good	89.9	76.6		
		Susceptible	79.0	55.9	20.7	27.0
1922	May 4	Good	59.2	45.0		
		Susceptible	57.5	43.9	1.1	2.4
	May 13	Good	58.3	44.8		
		Susceptible	54.6	42.1	2.7	6.0
	May 22	Good	56.1	46.6		
		Susceptible	44.7	33.4	13.2	28.3
	May 31	Good	53.0	45.5		
		Susceptible	41.0	33.2	12.3	27.0

factor in determining the extent of damage caused by *G. saubinetii* when seed of strains susceptible to this organism is used.

Altho soil temperature is only one of many factors involved in different dates of planting, yet it is a very important one. On that account data on the influence of date of planting on the development of the scutellum rot and Diplodia diseases are presented in the discussion of this factor. Data relating to the scutellum rot disease are given in Table 5 and Chart 4; the appearance of the corn grown from such seed is illustrated in Fig. 33. In each of the three years reported the time-of-planting factor proved to be very influential in determining the comparative yields of corn grown from scutellum-rotted seed. Corn grown from good seed was affected much less by late planting than corn from scutellum-rotted seed. These data indicate that corn grown from scutellum-rotted seed is affected adversely by conditions usually accompanying late planting (Fig. 34). One of the most important of these environing factors is high soil temperature.

Certain data on the relation of time of planting to the behavior of corn grown from good seed and from Diplodia-infected seed are given in Table 6 and Chart 5. The planting made on May 7 was one

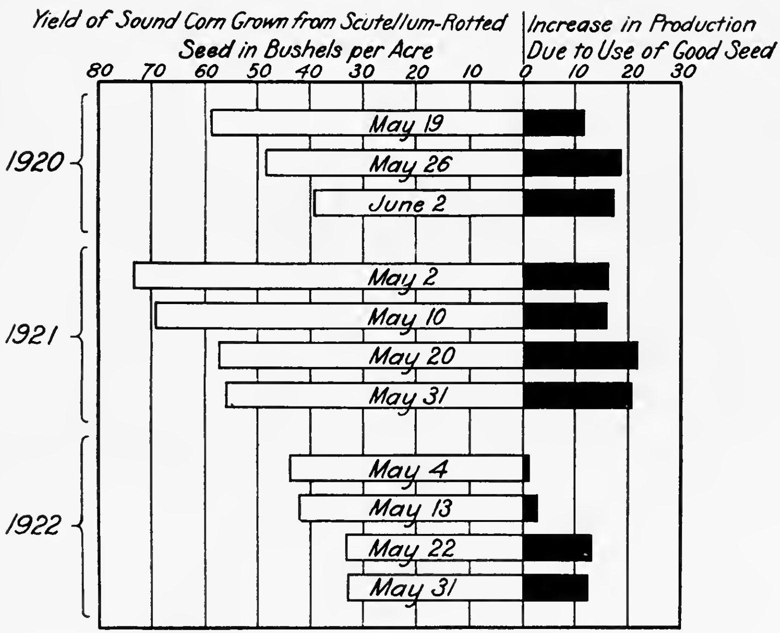


CHART 4.—YIELD FROM SCUTELLUM-ROTTED SEED AS AFFECTED BY DATE OF PLANTING

Reductions in yield of corn from scutellum-rotted seed as compared with corn grown from good seed usually are greater in the later plantings than in the earlier plantings (Table 5).

TABLE 6.—INFLUENCE OF DATE OF PLANTING ON YIELD FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam of medium high fertility, near Bloomington, 1921

Date of planting	Character of seed	Number of replications	Mean acre yield	Reduction following use of infected seed	
			bu.	*bu.*	*perct.*
May 7 ...	Good seed..........	5	66.0 ± 1.3		
	Diplodia-infected...	5	40.5 ± 1.2	25.5 ± 1.8	38.6
May 14 ...	Good seed..........	5	66.3 ± 1.2		
	Diplodia-infected...	5	52.9 ± 3.0	13.4 ± 3.2	20.2
May 21 ...	Good seed..........	5	68.0 ± 0.7		
	Diplodia-infected...	5	53.7 ± 1.7	14.3 ± 1.8	21.0
May 30 ...	Good seed..........	5	71.0 ± 2.5		
	Diplodia-infected...	5	38.1 ± 0.8	32.9 ± 2.6	46.3

of the first in the locality in which the experiment was conducted. The soil was still comparatively cold and rather moist. As the season advanced the soil became warmer rather gradually. At the time of the last, or fourth, planting and for several days thereafter, the soil

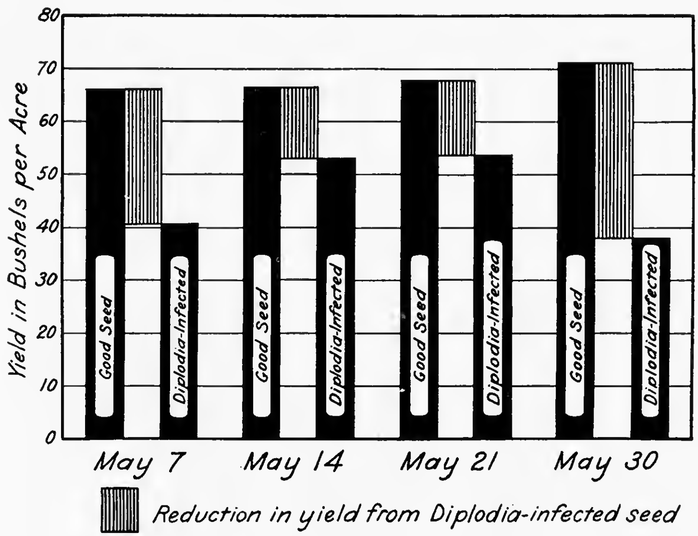
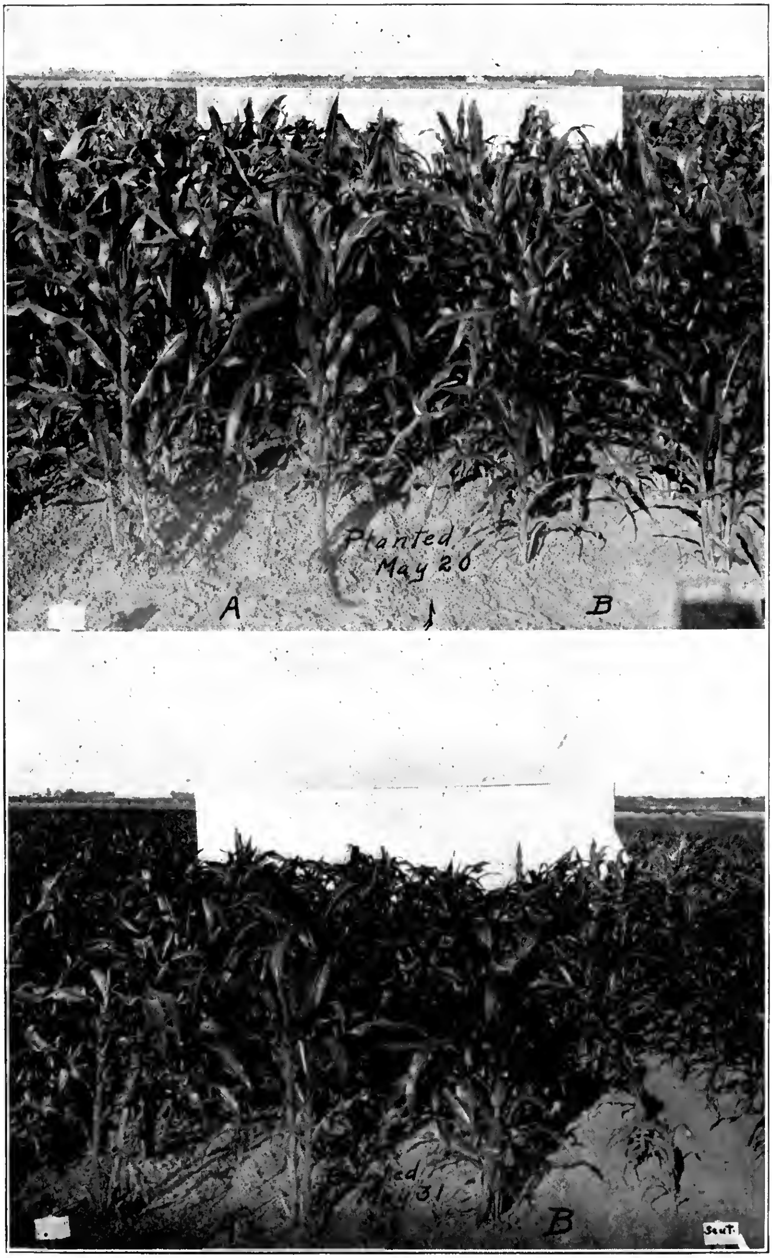


CHART 5.—YIELD FROM DIPLODIA-INFECTED SEED AS AFFECTED BY DATE OF PLANTING

Reductions in yield of corn from Diplodia-infected seed, as compared with corn from good seed, are usually greatest in the early planting and gradually decrease in subsequent plantings. The exception to this general statement occurs when a planting is accompanied by high moisture, in which event the yields may be reduced even more than in the earliest planting (Table 6).

FIG. 33.—REDUCTION IN HEIGHT OF LATE PLANTINGS OF SCUTELLUM-INFECTED CORN (See also following page)



(Fig. 33 cont.) Plots planted at various dates with good seed (A) and with scutellum-rotted seed (B). Note marked reduction in height of corn from scutellum-rotted seed in the last two plantings. University South Farm, Urbana.

temperature was comparatively high. A few days prior to the planting on May 30 there were heavy rains.

The data show that time of planting with its accompanying complex of soil factors has a very pronounced influence on the develop-

FIG. 34.—EFFECT OF LATE PLANTING ON INJURY FROM SCUTELLUM ROT

U. S. Department of Agriculture experimental plots near Bloomington. Corn grown from scutellum-rotted seed is affected much more adversely by conditions usually accompanying late planting than is corn from good seed.

ment of disease in corn grown from Diplodia-infected seed. Of the four plantings at seven-day intervals of corn grown from Diplodia-infected seed, those made on the two intermediate dates gave higher yields than those made on either the early or the late date. The difference in acre yield between the first and second plantings was 12.4 bushels and between the third and fourth plantings, 15.6. The decided reduction probably was due to the combination of high soil temperature and high soil moisture. The yield of corn grown from good seed was only slightly affected by the same changes in environment.

The data presented in Tables 7, 12, and 13, also show that *corn grown from Diplodia-infected seed is affected very adversely by early planting in rather cold soil* (Figs. 35 and 36). The data in Table 7 are presented graphically in Chart 6.

Additional data on the influence of date of planting on the final field stand of corn grown from good seed and from certain lots of diseased seed are given in Table 8. Soil moisture and soil temperature records for the early part of the season are shown in Tables 9 and 10 and in Charts 7 and 8. With the exception of the readings on May 26, there was little variation in soil moisture. Soil temperatures during the first three weeks in May were rather unfavorable for corn germination. Climatic conditions during this period also were considered unusually adverse for corn germination. The mean soil temperatures for fourteen days following each planting are given in Table 11 and Chart 9.

In spite of the unfavorable conditions all plantings of the corn from good seed produced a satisfactory field stand, there being a range of only 5.7 percent between the lowest and highest, which were 88.7 and 94.4 percent, respectively.

The behavior of corn grown from scutellum-rotted and from Diplodia-infected seed is especially interesting in view of the unusually adverse conditions prevailing during the month of May. In the fields planted to scutellum-rotted seed, the increases in stand from 49.8 percent in the first planting to 73.6 percent in the second planting, and to 85.1 percent in the third planting (Table 8) are significant. The drop in field stand to 71.6 percent in the last planting is consistent with the decided reduction in yield from scutellum-rotted seed in the late planting reported in Table 5. In the plots planted to Diplodia-infected seed, there was a gradual increase in percentages of field stands of corn grown from the successive plantings, beginning with 23.6 percent in the first planting and ending with 66.5 percent in the last.

Corn from Fusarium-infected seed was consistently lower in field stand than corn from good seed, but at no time was there a marked difference between the stands of the various plantings. The field stand

TABLE 7.—INFLUENCE OF DATE OF PLANTING ON YIELD FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam of high fertility, near Bloomington, 1923

Date of planting	Character of seed	Number of replications	Mean acre yield of sound corn	Reduction following use of infested seed	
			bu.	*bu.*	*perct.*
May 7...	Good..............	4	79.4 ± 1.8		
	Diplodia-infected...	4	42.3 ± 1.0	37.1 ± 2.1	46.7
May 24...	Good..............	7	83.8 ± 1.1		
	Diplodia-infected...	7	57.3 ± 3.4	26.5 ± 3.6	31.6
May 31...	Good..............	6	85.4 ± 1.0		
	Diplodia-infected...	6	68.2 ± 2.2	17.2 ± 2.4	20.1

of corn grown from Cephalosporium-infected seed was decidedly better in the third planting than in any one of the other plantings.

Acre yields of corn grown from good seed, scutellum-rotted seed, and Diplodia-infected seed planted on four different dates on the North-Central rotation are given in Table 12 and Chart 10. The early

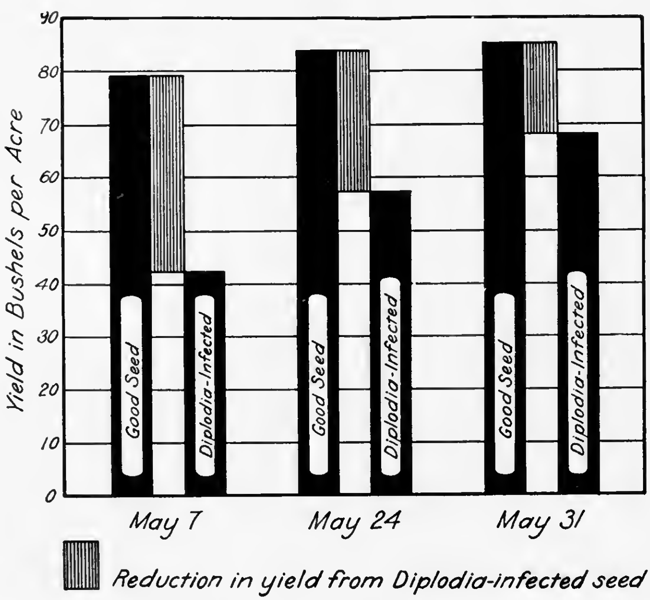


CHART 6.—YIELD FROM DIPLODIA-INFECTED SEED AS AFFECTED BY DATE OF PLANTING (Table 7)

Reduction in yield from Diplodia-infected seed was greatest in the early planting and least in the late planting.

FIG. 35.—DIPLODIA INJURY AS AFFECTED BY TIME OF PLANTING, EXPERIMENTAL PLOTS, BLOOMINGTON

Seed of strong vitality and free from infection can be planted much earlier than Diplodia-infected seed or seed affected with scutellum rot.

TABLE 8.—INFLUENCE OF DATE OF PLANTING ON FIELD STAND FROM GOOD SEED AND FROM CERTAIN LOTS OF DISEASED SEED

Yellow dent corn grown on the University South Farm, Urbana, 1923

Date of planting	Character of seed	North-Central rotation (corn, corn, spring grain, clover)				South-Central rotation (corn, corn, corn, soybeans)				Grand total number of plants	Grand average percentage field stand
		1st year corn after clover		2d year corn after clover		1st year corn after soybeans		3d year corn after soybeans			
		Number of plants	Perct. stand	Number of plants	Perct. stand	Number of plants	Perct. stand	Number of plants	Perct. stand		
May 2	Good	2551	88.6	2476	86.0	2580	89.5	2618	90.8	10225	88.7
	Scutellum-rotted	363	37.8	523	54.5	474	49.3	552	57.4	1912	49.8
	Diplodia-infected	214	22.3	201	20.9	237	24.7	254	26.5	906	23.6
	Fusarium-infected	805	84.0	766	79.8	803	83.6	842	87.7	3216	83.8
	Cephalosporium-infected	552	86.2	546	85.3	550	85.9	559	87.4	2207	86.2
May 14	Good	2702	93.8	2452	85.2	2649	92.0	2661	92.4	10464	90.9
	Scutellum-rotted	713	74.3	697	72.6	792	82.5	622	64.8	2824	73.6
	Diplodia-infected	350	36.5	387	40.3	422	44.0	348	36.2	1507	39.3
	Fusarium-infected	832	86.7	682	71.0	866	90.2	828	86.3	3208	83.6
	Cephalosporium-infected	580	90.6	456	71.2	580	90.6	560	87.5	2176	85.0
May 21	Good	2799	97.1	2549	88.5	2777	96.2	2763	95.8	10888	94.4
	Scutellum-rotted	858	89.4	795	82.8	827	86.2	785	81.8	3265	85.1
	Diplodia-infected	579	60.3	432	45.0	552	57.6	435	45.3	1998	52.1
	Fusarium-infected	891	92.8	804	83.8	911	95.0	753	78.5	3359	87.5
	Cephalosporium-infected	628	98.1	612	95.6	633	98.9	610	95.3	2483	97.0
May 31	Good	2631	91.3	2482	86.2	2495	86.7	2617	90.8	10225	88.8
	Scutellum-rotted	742	77.3	627	65.4	669	69.7	711	74.1	2749	71.6
	Diplodia-infected	678	70.7	635	66.2	554	57.8	683	71.2	2550	66.5
	Fusarium-infected	837	87.3	819	85.3	774	80.7	871	90.7	3301	86.0
	Cephalosporium-infected	614	96.0	575	88.9	524	81.6	566	88.4	2279	88.7

TABLE 9.—SOIL TEMPERATURES FROM MAY 4 TO JUNE 14, 1923, UNIVERSITY SOUTH FARM, URBANA (TABLE 8)

Date	Soil temperatures: 7:00 a. m. Depth 2 in.	Soil temperatures: 7:00 a. m. Depth 4 in.	Soil temperatures: 5:20 p. m. Depth 2 in.	Soil temperatures: 5:20 p. m. Depth 4 in.	Mean daily soil temperature[1] Depth 2 in.	Mean daily soil temperature[1] Depth 4 in.
	°F.	°F.	°F.	°F.	°F.	°F.
May 4	51.0	53.5	65.0	63.0	58.0	58.3
5	51.0	53.5	68.0	64.0	59.5	58.8
6	50.5	53.0	71.5	66.0	61.0	59.5
7	53.0	54.5	65.5	65.0	59.3	59.8
8	51.5	54.0	46.5	50.0	49.0	52.0
9	39.0	43.0	56.5	53.0	47.8	48.0
10	42.5	44.0	61.0	56.5	51.8	50.3
11	60.0	58.0	52.0	54.0	56.0	56.0
12	52.0	54.0	56.0	55.0	54.0	54.5
13	45.5	46.0	64.0	61.0	54.8	53.5
14	49.0	49.0	56.0	56.0	52.5	52.5
15	59.0	57.0	61.0	59.0	60.0	58.0
16	50.0	51.0	56.0	56.0	53.0	53.5
17	50.5	50.0	62.0	60.0	56.3	55.0
18	53.5	53.0	63.5	61.0	58.5	57.0
19	59.0	57.0	69.0	67.0	64.0	62.0
20	61.0	61.0	62.0	62.0	61.5	61.5
21	51.0	53.0	67.0	65.0	59.0	59.0
22	52.5	53.5	61.5	61.0	57.0	57.3
23	51.0	51.5	67.0	65.0	59.0	58.3
24	53.5	54.5	70.0	68.5	61.8	61.5
25	56.0	57.0	72.0	70.0	64.0	63.5
26	63.0	63.0	68.0	66.0	65.5	64.5
27	63.5	63.0	70.0	70.0	66.8	66.5
28	60.0	60.0	72.0	70.5	66.0	65.3
29	64.0	64.0	68.0	68.0	66.0	66.0
30	60.0	62.0	73.0	72.5	66.5	67.3
31	58.0	58.0	80.0	76.0	69.0	67.0
June 1	67.0	65.0	79.0	77.0	73.0	71.0
2	68.0	67.0	82.0	80.0	75.0	73.5
3	67.0	67.0	84.0	82.5	75.5	74.8
4	70.0	69.5	85.0	84.0	77.5	76.8
5	72.0	71.0	76.0	79.0	74.0	75.0
6	70.0	69.0	76.5	75.0	73.3	72.0
7	67.5	67.0	78.0	76.0	72.8	71.5
8	61.0	62.0	77.0	76.0	69.0	69.0
9	58.0	59.0	68.0	67.0	63.0	63.0
10	61.0	63.0	69.0	68.0	65.0	65.5
11	60.5	62.5	62.0	63.0	61.3	62.8
12	60.0	61.0	74.0	71.0	67.0	66.0
13	62.0	64.0	76.0	73.5	69.0	68.8
14	65.0	65.0	83.0	79.0	74.0	72.0

[1]This mean is the average of the temperatures for the particular depths at 7:00 a. m. and 5:20 p. m. for each day.

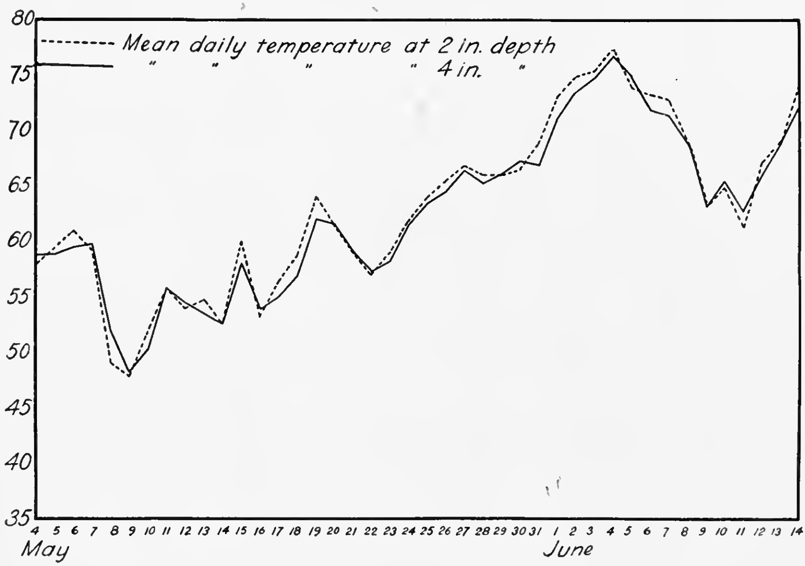


CHART 7.—SOIL TEMPERATURES FROM MAY 14 TO JUNE 14, 1923, UNIVERSITY SOUTH FARM (Table 9)

FIG. 36.—CORN FROM DIPLODIA-INFECTED SEED (LEFT) AND FROM CORN FROM GOOD SEED (RIGHT)

An early planted experimental series on University Roland field, Urbana. Corn grown from Diplodia-infected seed is affected very adversely by early planting in rather cold soil.

TABLE 10.—SOIL MOISTURE FROM MAY 2 TO JUNE 13, 1923, UNIVERSITY SOUTH FARM, URBANA (TABLE 8)

Mean percentages based on dry weight

Date of planting	Number of samples	Mean percentage of soil moisture
		perct.
May 2	14	28.72 ± 0.36
3	13	28.44 ± 0.22
4	14	27.43 ± 0.27
5	14	26.91 ± 0.30
8	14	28.20 ± 0.29
11	14	29.06 ± 0.28
14	14	28.12 ± 0.22
17	13	31.10 ± 0.31
20	14	28.40 ± 0.54
23	14	27.73 ± 0.38
26	14	34.20 ± 0.42
29	14	29.07 ± 0.26
June 1	14	28.18 ± 0.41
4	14	27.64 ± 0.36
7	14	26.03 ± 0.28
10	14	27.30 ± 0.44
13	14	26.92 ± 0.32

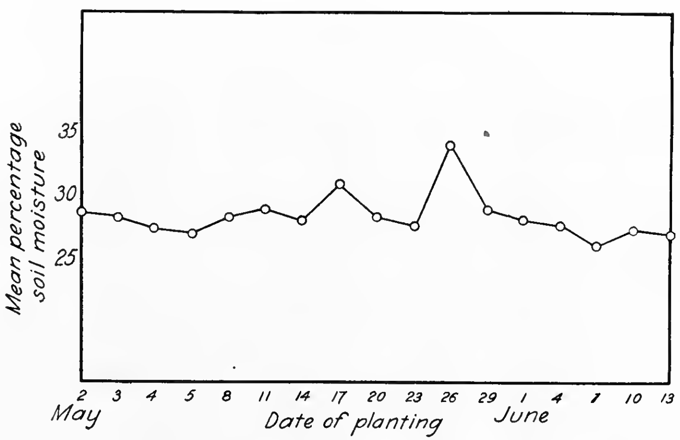


CHART 8.—PERCENTAGE OF SOIL MOISTURE FROM MAY 2 TO JUNE 12, 1923, UNIVERSITY SOUTH FARM (Table 10)

and the late plantings of scutellum-rotted seed yielded at a much lower rate than the two plantings at intermediate dates. Corn from Diplodia-infected seed yielded the least in the early plantings and the most in the late plantings.

Reductions in yield of corn from Diplodia-infected seed, as compared with corn from good seed, are usually greatest in the early planting and gradually decrease in subsequent plantings. The exception to this general statement occurs whenever a planting is accompanied by high moisture, in which event the yields may be reduced even more than in the earliest planting.

TABLE 11.—MEAN SOIL TEMPERATURES FOR FOURTEEN DAYS FOLLOWING EACH PLANTING (TABLE 8), UNIVERSITY SOUTH FARM, URBANA

Taken at a depth of 2 inches

Date of planting	Mean minimum soil temperature	Mean maximum soil temperature	Mean soil temperature
	°*F*	°*F*	°*F*
May 2	50.3	60.2	55.3
May 14	55.2	64.6	59.9
May 21	59.9	72.3	66.1
May 31	64.4	76.2	70.3

Similar data from experimental plots at Ontario Parish, near Oneida, Illinois, are reported in Table 13 and Chart 11; soil temperature records kept during the experiment are given in Table 14 and Chart 12. These data, together with many other data not herein reported, indicate that on most soils of the corn belt very early plantings of inferior seed, including infected seed, are likely to result in unsatisfactory field stands (Figs. 35 and 36). They also indicate that late plantings of scutellum-rotted seed yield much less than intermediate plantings. *Good seed of strong vitality and free from infection will grow under a wider range of temperature and moisture and can be planted with safety much earlier than infected seed or seed affected with scutellum rot.*

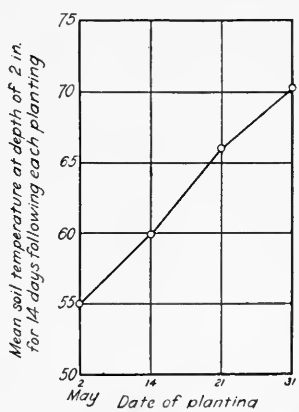


CHART 9.—MEAN SOIL TEMPERATURES FOR FOURTEEN DAYS FOLLOWING EACH PLANTING, UNIVERSITY SOUTH FARM, URBANA, 1923 (Table 11)

A combination of high temperature and high humidity during the maturation of the corn crop favors the development of certain ear rots, particularly Diplodia, in disease-susceptible strains of corn. There are strains of corn, however, which are affected much less than others by ear rots under the same unfavorable conditions. Where all conditions are ideal for corn, no ear rots may develop on the ear-rot susceptible strains, but such conditions seldom prevail.

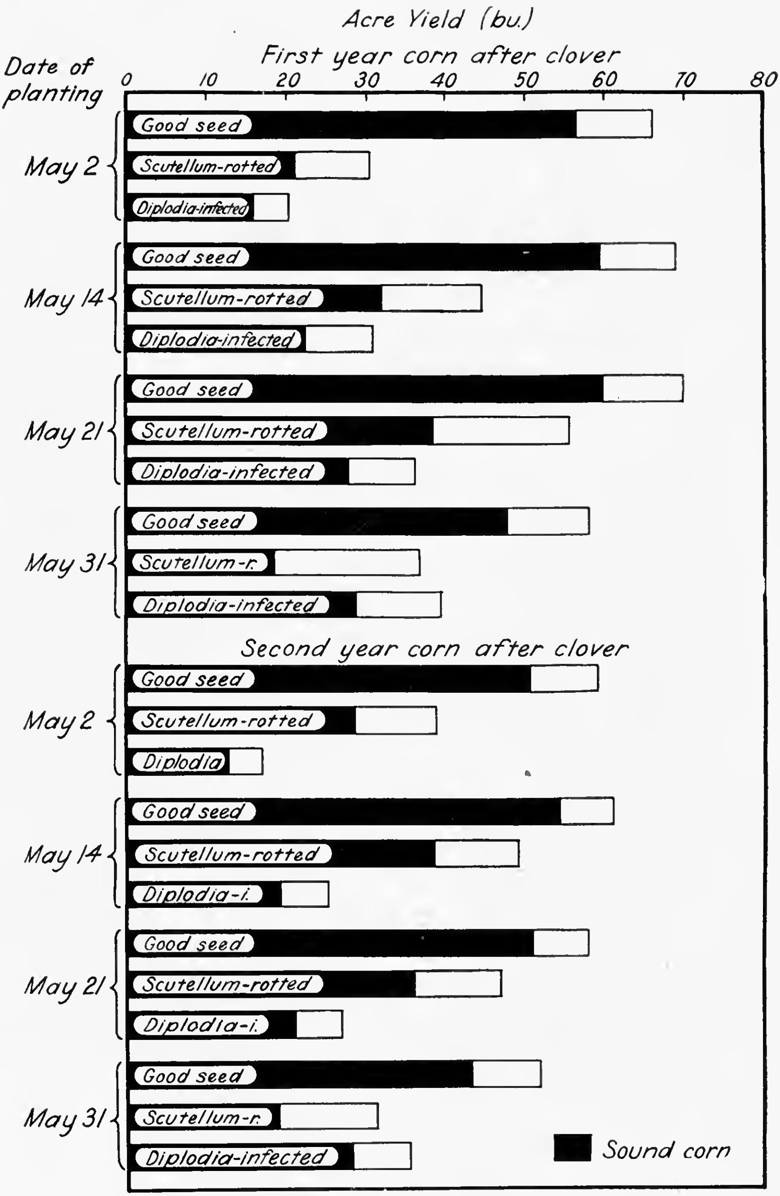


CHART 10.—YIELDS FROM SCUTELLUM-ROTTED SEED AND FROM DIPLODIA-INFECTED SEED PLANTED AT FOUR DIFFERENT DATES, (Table 12)

The early and late plantings from scutellum-rotted seed yielded at a much lower rate than the two plantings at intermediate dates. Corn from Diplodia-infected seed yielded the least in the early plantings and most in the late plantings.

TABLE 12.—INFLUENCE OF DATE OF PLANTING ON YIELD OF CORN FROM GOOD SEED, FROM SCUTELLUM-ROTTED SEED, AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on the North-Central rotation of the University South Farm, Urbana, 1923

Date of planting	Character of seed	Number of replications	Acre yield		Reduction in sound corn following use of—			
			Total	Sound	Scutellum-rotted seed		Diplodia-infected seed	
			First Year Corn after Clover					
			bu.	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
May 2	Good	8	66.1 ± 1.0	56.4 ± 1.2				
	Scutellum-rotted	4	30.4 ± 2.3	21.1 ± 2.9	35.3 ± 3.1	62.6		
	Diplodia-infected	4	20.2 ± 0.9	15.8 ± 1.0			40.6 ± 1.6	72.0
May 14	Good	8	68.9 ± 0.8	59.4 ± 0.9				
	Scutellum-rotted	4	44.5 ± 2.2	31.8 ± 2.6	27.6 ± 2.7	46.5		
	Diplodia-infected	4	30.9 ± 1.9	22.3 ± 2.2			37.1 ± 2.4	62.5
May 21	Good	8	69.8 ± 1.2	59.9 ± 1.3				
	Scutellum-rotted	4	55.3 ± 1.7	38.3 ± 1.7	21.6 ± 2.1	36.1		
	Diplodia-infected	4	36.1 ± 3.5	27.6 ± 3.8			32.3 ± 4.0	53.9
May 31	Good	8	57.9 ± 1.4	47.6 ± 1.8				
	Scutellum-rotted	4	36.7 ± 1.6	18.4 ± 0.9	29.2 ± 2.0	61.3		
	Diplodia-infected	4	39.3 ± 3.1	28.7 ± 3.5			18.9 ± 3.9	39.7
			Second Year Corn after Clover					
			bu.	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
May 2	Good	6	59.1 ± 0.9	50.4 ± 1.4				
	Scutellum-rotted	3	38.8 ± 0.7	28.6 ± 1.3	21.8 ± 1.9	43.3		
	Diplodia-infected	2	17.0 ± 0.5	12.9 ± 0.5			37.5 ± 1.5	74.4
May 14	Good	8	61.0 ± 1.4	53.5 ± 1.8				
	Scutellum-rotted	4	49.1 ± 1.9	38.4 ± 1.3	15.1 ± 2.2	28.2		
	Diplodia-infected	3	25.2 ± 1.1	19.2 ± 0.7			34.3 ± 1.9	64.1
May 21	Good	8	57.9 ± 1.4	50.8 ± 1.2				
	Scutellum-rotted	4	46.8 ± 0.5	35.8 ± 0.9	15.0 ± 1.5	29.5		
	Diplodia-infected	4	27.0 ± 0.9	21.2 ± 1.1			29.6 ± 1.6	58.3
May 31	Good	8	51.8 ± 1.5	43.3 ± 1.7				
	Scutellum-rotted	4	31.2 ± 4.1	18.9 ± 3.9	24.4 ± 4.2	56.4		
	Diplodia-infected	4	35.3 ± 3.4	28.2 ± 3.3			15.1 ± 3.7	34.9

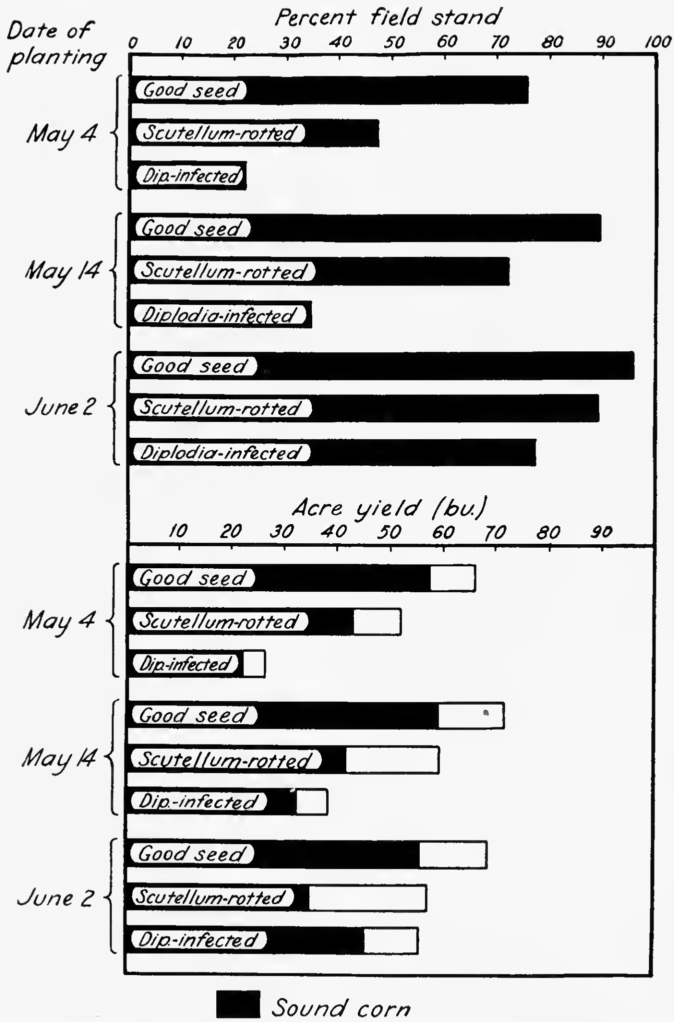


CHART 11.—YIELDS FROM GOOD SEED, SCUTELLUM-ROTTED SEED, AND FROM DIPLODIA-INFECTED SEED PLANTED AT THREE DIFFERENT DATES (Table 13 and Chart 12)

Altho the field stands of corn from scutellum-rotted seed increased with the advance in the date of planting, the yield of sound corn from such seed decreased with the advance in date of planting. Both field stand and yield of sound corn from Diplodia-infected seed increased with the advance in date of planting.

TABLE 13.—INFLUENCE OF DATE OF PLANTING ON FIELD STAND AND YIELD FROM GOOD SEED, FROM DIPLODIA-INFECTED SEED, AND FROM SEED BADLY AFFECTED WITH SCUTELLUM ROT

Yellow dent corn grown on brown silt loam, Ontario Parish, near Oneida, 1923

Date of planting	Character of seed	Number of replications	Field stand	Acre yield	
				Total	Sound
			perct.	*bu.*	*bu.*
May 4	Good.	9	75.8 ± 1.7	66.1 ± 1.6	57.5 ± 1.4
	Scutellum-rotted	6	47.5 ± 1.9	52.2 ± 2.1	43.3 ± 2.2
	Diplodia-infected	6	22.1 ± 1.5	26.6 ± 1.5	22.7 ± 1.5
May 14	Good.	9	89.8 ± 1.2	71.9 ± 1.7	59.2 ± 1.9
	Scutellum-rotted	6	72.1 ± 1.5	59.3 ± 1.0	42.0 ± 0.9
	Diplodia-infected	6	34.3 ± 1.7	38.6 ± 1.4	32.5 ± 1.3
June 2	Good.	9	95.9 ± 0.8	68.6 ± 1.6	55.9 ± 2.4
	Scutellum-rotted	6	89.3 ± 1.1	57.3 ± 1.6	35.2 ± 2.4
	Diplodia-infected	6	76.8 ± 1.7	56.3 ± 1.6	45.7 ± 2.4

FIG. 37.—SCUTELLUM-INFECTED PLANTS AFFECTED BY DROUTH

Note curling and dying of tips of leaves of plants from scutellum-rotted seed (right) and healthy appearance of plants from good seed (left) under identical drouth conditions. Planted in heavily infested brown silt loam, near Bloomington. Corn plants grown from infected seed or from a strain susceptible to root rot and having partially rotted root systems nearly always suffer first from drouth.

TABLE 14.—MEAN DAILY SOIL TEMPERATURES AND DAILY RAINFALL FROM MAY 6 TO JUNE 11, 1923 (TABLE 13)

Soil temperatures taken at a depth of four inches, Ontario Parish, near Oneida

Date	Soil temperature	Rainfall	Date	Soil temperature	Rainfall
	°F.	*inches*		°F.	*inches*
May 6.....	54.0	....	May 26.....	62.5	....
7.....	55.5	....	27.....	63.5	....
8.....	51.3	.05	28.....	64.5	.32
9.....	51.3	....	29.....	66.5	....
10.....	51.5	....	30.....	69.5	....
11.....	54.2	1.90	31.....	69.5	....
12.....	53.9	....	June 1.....	73.0	....
13.....	52.6	....	2.....	73.3	....
14.....	52.0	....	3.....	74.0	....
15.....	53.2	....	4.....	74.0	.03
16.....	54.1	....	5.....	74.0	....
17.....	54.9	....	6.....	73.5	....
18.....	55.7	....	7.....	71.5	....
19.....	59.0	....	8.....	70.0	....
20.....	59.3	....	9.....	63.3	....
21.....	59.2	.31	10.....	63.5	....
22.....	58.9	....	11.....	63.0	.52
23.....	58.5	....			
24.....	59.2	....			
25.....	60.5	....			

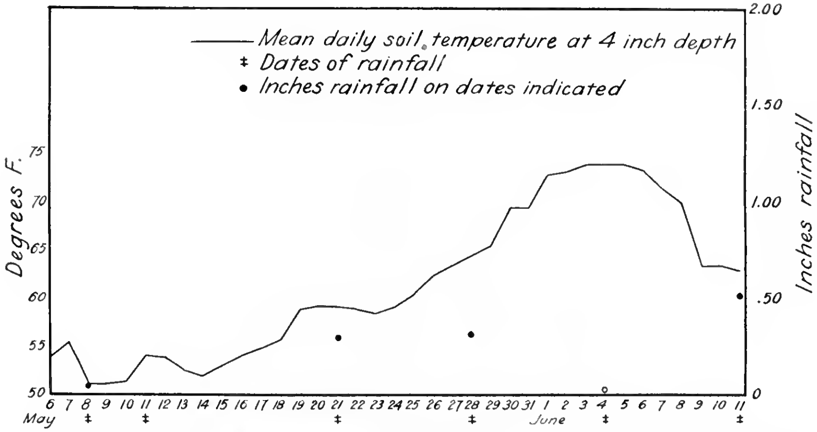


CHART 12.—SOIL TEMPERATURES AND RAINFALL AT ONTARIO PARISH, 1923 (Table 14)

SOIL MOISTURE A HIGHLY IMPORTANT FACTOR

The percentage of moisture present in the soil frequently is the most important single factor influencing the behavior of diseased or disease-susceptible corn. In the experiment reported in Table 6, high soil moisture probably was as important an influencing factor as temperature, especially in the last planting. When the moisture content is below optimum for plant growth, corn plants are unable to carry on their normal metabolism. Corn plants grown from infected seed or from a strain susceptible to root rot and having partially rotted

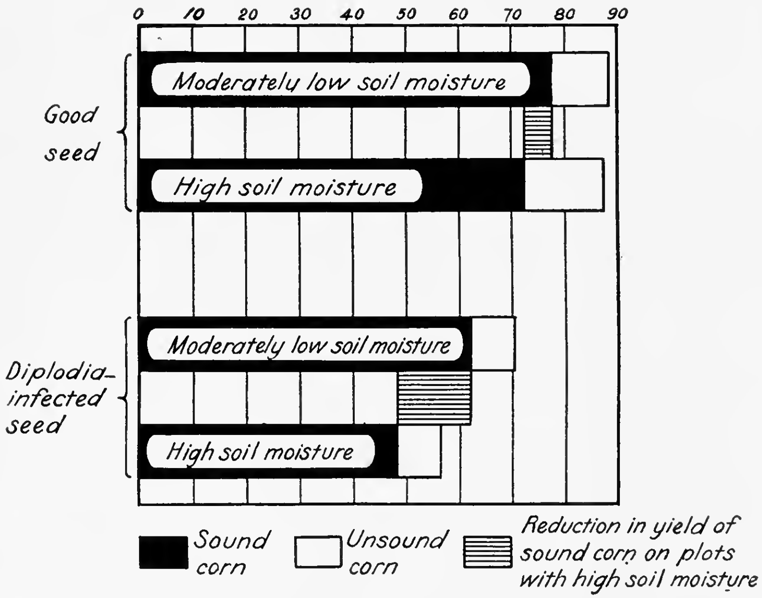


CHART 13.—YIELDS FROM DIPLODIA-INFECTED SEED PLANTED UNDER HIGH AND UNDER MODERATELY LOW SOIL MOISTURE CONDITIONS (Table 15)

Planting at a time of high soil moisture, as compared with moderately low soil moisture, results in greater reductions in yields of sound corn from Diplodia-infected seed than from good seed. This is especially true under moderate to high temperature conditions.

root systems are the first to suffer from the ill effects of a drouth (Fig. 37). On the other hand, strains of corn resistant to root rot, especially resistant strains with extensive and efficient root systems, may not be affected if the drouth does not continue too long. Under such unfavorable conditions of soil moisture as frequently obtain during July and August, differences between healthy and diseased corn may be pronounced, and often result in wide differences in yield of grain at the end of the season.

TABLE 15.—INFLUENCE OF A HIGH AND A MODERATELY LOW PERCENTAGE OF SOIL MOISTURE DURING THE FIRST TEN DAYS FOLLOWING PLANTING, ON THE YIELD OF CORN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn planted June 2, 1922, on brown silt loam of high fertility, Bloomington

Character of seed	Number of plots	Mean acre yields on plots with— Moderately low soil moisture	Mean acre yields on plots with— High soil moisture	Reduction in yield on plots with high soil moisture	Odds
Total Yield					
		bu.	*bu.*	*bu.*	
Good	6	88.5	87.8	0.7	1:1
Diplodia-infected	6	70.9	56.5	14.4	640:1
Sound Corn					
Good	6	77.3	73.5	3.8	7:1
Diplodia-infected	6	62.6	48.3	14.3	219:1

Romyn,[83] a graduate student at the University of Illinois in 1920-1922, in discussing preliminary trials conducted to determine the optimum soil moisture for growing corn in pots in summer at a temperature of 32° to 37° C., stated that "the percentage of water in the disease-free pots can be reduced to 40 percent without markedly

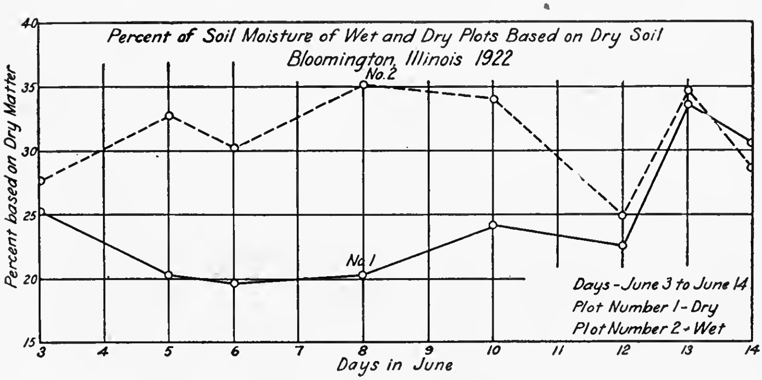


CHART 14.—PERCENTAGE OF SOIL MOISTURE FROM JUNE 3 TO JUNE 14, 1922, BLOOMINGTON (Table 15)

affecting the yield, but a decrease to 40 percent in the diseased pots brings about a distinct decrease in yield."

The percentage of soil moisture present at planting time and for the first week or ten days following planting may be the most important environing factor in determining the extent of injury in corn grown from Diplodia-infected seed, at least where the soil temperature is comparatively high. Data bearing on this relation of environment to parasitism by Diplodia are given in Table 15 and Chart 13. These data are from an experiment in which all the corn was planted on the same day, June 2, 1922. The following day half of the plots were watered uniformly with a hose. They were kept wet by frequent sprinklings until the twelfth day after planting, when there was a heavy rain. No further attempt was made to control soil moisture. Soil moisture and temperature records for the period are presented in Charts 14 and 15. Differences in the comparative vigor of the corn grown from good seed and from Diplodia-infected seed on the plots differing in soil moisture are illustrated in Fig. 38. Where good seed was used there was little difference in total yield of corn from the wet and the dry plots. In yield of sound corn the difference of 3.8 bushels in favor of the dry plots with odds of 7 to 1, also is not significant. However, the corn grown from Diplodia-infected seed showed a reduction of 14.4 bushels per acre in total yield and 14.3 bushels in yield of sound corn, with odds of 640 to 1 and 219 to 1, respectively, on the plots that were kept wet for twelve days following planting.

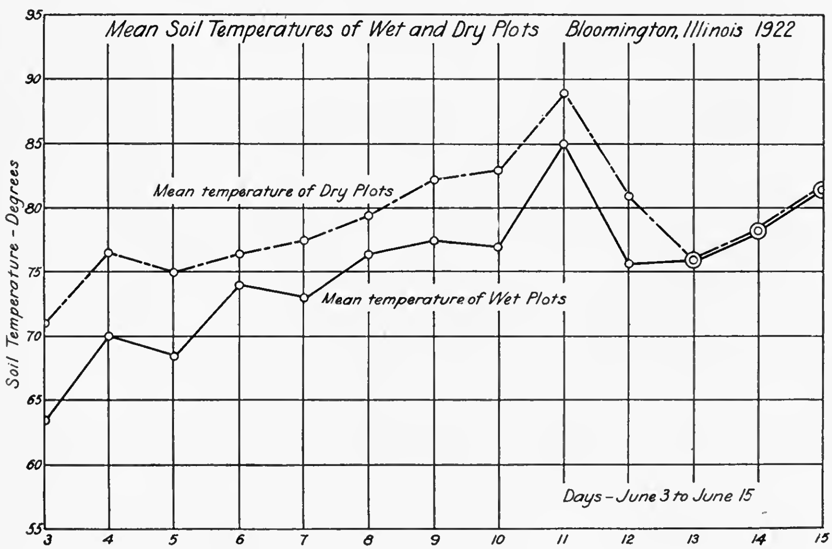


CHART 15.—SOIL TEMPERATURES FROM JUNE 3 TO JUNE 15, 1922, BLOOMINGTON (Table 15)

In general it may be said that planting at a time of high soil moisture, as compared with moderately low soil moisture, results in greater reductions in yield of sound corn from Diplodia-infected seed than from good seed. This is especially true under moderate to high temperature conditions.

FIG. 38.—EFFECT OF SOIL MOISTURE ON DIPLODIA INJURY

Corn from good seed (left) and from Diplodia-infected seed (right) on plots differing widely in soil moisture for the first twelve days following planting, near Bloomington. Note the greatly reduced stand and reduced vigor of corn from Diplodia-infected seed on the plots with high soil moisture content. Where good seed was used there was little difference in total yield of corn from the wet and the dry plots.

INFLUENCE OF SOIL AERATION

It is a well established fact that aeration is essential to the productivity of the soil. Lack of acration, usually following imperfect drainage and poor cultivation, results in the accumulation of carbon dioxid and the formation of reductive fermentation. Such conditions usually are injurious to corn plants, particularly if they continue long enough

TABLE 16.—INFLUENCE OF SOIL AERATION ON GROWTH OF PLANTS FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED[1]

Yellow dent corn grown in pots, Urbana, 1922

Frequency of aeration	Character of seed	Number of pots	Mean total air-dry weight of plants	Difference in weight of plants grown from good seed and from Fusarium-infected seed	
			gms.	*gms.*	*perct.*
Daily.......	Good...............	4	8.00		
	Fusarium-infected....	4	7.51	0.49	6.1
Every 2 days	Good...............	4	10.11		
	Fusarium-infected....	4	5.73	4.38	43.3
Every 4 days	Good...............	4	9.01		
	Fusarium-infected....	4	4.17	4.84	53.7
Every 8 days	Good...............	4	8.68		
	Fusarium-infected....	4	3.81	4.87	56.1
None.......	Good...............	4	9.74		
	Fusarium-infected....	4	2.84	6.90	70.8

[1]Unpublished data of E. A. Romyn, University of Illinois.

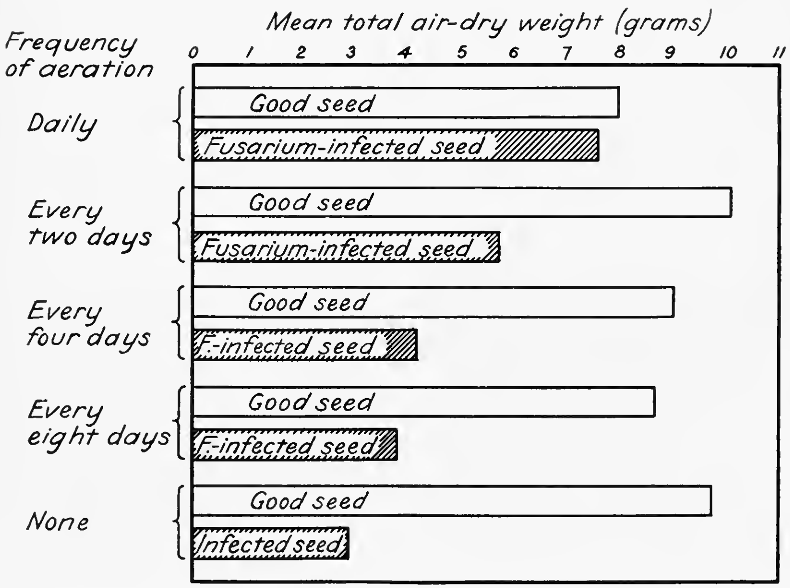


CHART 16.—FUSARIUM INJURY AS AFFECTED BY SOIL AERATION (Table 16)

Corn from Fusarium-infected seed was affected adversely by a lack of frequent aeration, whereas corn from good seed was not injured by the same unfavorable conditions.

to form a metallic solution of ferrous compounds,[38] which are very toxic and "are commonly regarded as one cause of the sterility of badly aerated soils."[86, page 84] Corn grown from infected and disease-susceptible seed is the first to be injured by such unfavorable conditions. However, if the lack of drainage and aeration persist, the disease resistance of corn from good seed also may be broken down. Proper soil aeration not only facilitates the complete oxidation of only partially oxidized substances in the soil that may be toxic, especially to corn plants from infected seed and to plants very susceptible to injury under such conditions, but also aids in preventing the formation of such substances.

Romyn,[83] working with good seed and Fusarium-infected seed, grew plants in sealed pots in a greenhouse maintained at a temperature of 20° to 21° C. The pots, containing sand and a nutrient solution, were divided into series which were aerated at intervals of twenty-four hours, two days, four days, and eight days, respectively. One series received no aeration. Summarized data from two experiments conducted at different dates are given in Table 16 and Chart 16. Romyn comments as follows:

"It appears that once a pot is sealed, the amount of artificial aeration it receives makes no significant difference in the yield of plants. In both experiments the disease-free plants receiving no aeration yielded as well as those aerated daily.

"The amount of aeration does, however, make a difference in the development of the fungus. The progressively decreasing yields of diseased corn with the fewer aerations can be attributed to an increasing virulence of the disease. Tho the plants in the frequently aerated pots also were diseased, they grew more vigorously, while the progress of the pathogene was retarded."

These interesting data (Table 16) contribute to a proper interpretation of the field performance of corn grown from good seed and from diseased seed on soil poorly drained and hence poorly aerated.

EFFECT OF AMOUNT OF PLANT-FOOD MATERIALS IN SOIL SOLUTION

That it is important to maintain the permanent fertility of the soil is an established fact. A lack of any of the essential plant-food materials is certain to result in a decreased yield. Altho the problems of soil fertility and corn diseases are closely interrelated, they constitute two distinct groups of problems. The soil fertility problem obviously cannot be solved by seed selection and breeding alone; neither can the corn disease problem be controlled entirely by soil treatment and soil management.

The significance of this situation can better be appreciated by a careful study of the data presented in Table 17. It will be observed that there is a substantial and consistent increase in yield on the plots where manure, limestone, and rock phosphate have been applied. Yet in spite of the fact that the majority of these treated plots represent the best soil treatment and soil management known at the present time on farms in central Illinois, there is a significant difference in yield between the corn grown from good seed and that grown from diseased seed of the same strain under what would ordinarily be termed the most favorable soil conditions. Altho certain of the corn rot diseases may be controlled largely by soil treatments, there are other corn rot diseases the injury from which is lessened only slightly by the same treatments. As would be expected, the highest average yields were obtained with good seed on properly treated soil. The average yield of corn from diseased seed on the treated plots was only slightly better than the yield of corn from good seed on the no-treatment plots, 66.7 bushels per acre compared with 66.2 bushels.

For a soil to be productive it is necessary not only that the soil solution should contain all the essential plant-food materials, but that all necessary nutrients should be present in their proper proportion, a condition which has been designated as "physiological balance." An excess of some one plant-food material may be as detrimental as a deficiency. Following is a discussion of these various elements of the soil and the part that each plays in plant nutrition.

Nitrogen Excess or Deficiency

Altho an excess of nitrogen seldom is a serious problem on the farms of the corn belt, there is experimental evidence that too much nitrogen favors the development of at least two of the corn rot diseases. Nitrogen starvation causes a marked stunting and a yellowing of the entire foliage. A deficiency of this element is so common an occurrence that it presents one of the greatest problems in American agriculture.

Importance of Phosphorus

The importance of the element phosphorus in plant nutrition has received much attention. Thatcher[103] makes the following summarized statement:

"Abundance of available phosphorus early in the plant's life greatly stimulates root growth, and later on it undoubtedly hastens the ripening process; hence this element seems to act as the exact antithesis of nitrogen."

Large areas of Illinois soils are deficient in phosphates, and the application of phosphates on such soils, together with proper soil management, has been found to result in increased yields of improved quality.

Corn grown from good seed and from infected seed differs greatly in its response to an increase of available phosphates in the

TABLE 17.—INFLUENCE OF MANURE, LIMESTONE, AND ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED SEED

Brown silt loam on various fields in Illinois, 1919-1922

Year	Location (Illinois)	Character of seed	Acre yield: No treatment	Acre yield: Manure, limestone, rock phosphate
			bu.	*bu.*
1919	Urbana..........	Good..................	70.4	97.4
		Scutellum-rotted.........	56.6	84.2
1920	Bloomington......	Good..................	76.1	77.0
		Scutellum-rotted.........	47.4	63.8
1920	Bloomington......	Good..................	77.0	80.1
		Scutellum-rotted.........	55.6	66.5
1920	Bloomington......	Good..................	85.7	91.7
		Scutellum-rotted.........	69.7	75.5
1920	Urbana..........	Good..................	103.8	110.4
		Diplodia-infected.........	60.7	90.3
1920	Urbana..........	Good..................	....	80.8
		Scutellum-rotted.........	....	68.1
1921	Urbana..........	Good..................	....	100.7
		Scutellum-rotted.........	....	90 9
1921	Urbana..........	Good..................	....	90.5
		Scutellum-rotted.........	....	77.0
1921	Bloomington......	Good..................	64.3	74.7
		Scutellum-rotted.........	57.2	57.7
1921	Bloomington......	Good..................	64.4	75.2
		Scutellum-rotted.........	57.9	60.9
1921	Bloomington......	Good..................	67.4	74.1
		Diplodia-infected.........	53.0	51.5
1921	Bloomington......	Good..................	65.7	77.5
		Fusarium-infected........	58.5	70.8
1921	Bloomington......	Good..................	67.4	74.1
		Fusarium-infected........	60.6	66.5
1922	Bloomington......	Good..................	....	100.0
		Scutellum-rotted.........	....	95.6
1922	Urbana..........	Good..................	....	59.2
		Scutellum-rotted.........	....	57.5
1922	Urbana..........	Good..................	....	56.1
		Scutellum-rotted.........	....	44.7
1922	Urbana..........	Good..................	61.7	67.1
		Diplodia-infected.........	39.5	44.0
1922	Urbana..........	Good..................	25.8	39.3
		Fusarium-infected........	22.9	38.2
1922	Urbana..........	Good..................	48.7	71.5
		Fusarium-infected........	49.8	68.7
1922	Urbana..........	Good..................	49.0	75.6
		Fusarium-infected........	44.5	77.3
1922	Urbana..........	Good..................	....	58.3
		Fusarium-infected........	....	51.5
	Grand average.....	Good..................	66.2	77.7
		Diseased...............	52.4	66.7

TABLE 18.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED

Yellow dent corn grown on brown silt loam, part of the plots receiving organic manure only and part receiving organic manure and rock phosphate, North-Central and South-Central rotations, University South Farm, 1922

Rotation	Character of seed	Acre yield on plots receiving organic manure	Effect of rock phosphate in addition to organic manure	
			Increase	Decrease
		Total Yield		
		bu.	*bu.*	*bu.*
Corn, corn, spring grains, clover....	Good.............	59.6	2.4	....
	Fusarium-infected..	50.8	12.0	....
Corn, corn, corn, soybeans........	Good.............	35.0	4.9	....
	Fusarium-infected..	30.5	7.3	....
		Sound Corn		
		bu.	*bu.*	*bu.*
Corn, corn, spring grains, clover....	Good.............	49.3	4.3	....
	Fusarium-infected..	37.7	18.4	....
Corn, corn, corn, soybeans........	Good.............	27.6	6.3	....
	Fusarium-infected..	21.1	10.4	....

soil, the increase in yield of corn from Fusarium-infected seed being much greater than the increase from good seed. Typical examples of such increases are shown in Tables 18 and 19 and Chart 17. The yields of sound corn from the Fusarium-infected seed reported in Table 18 were increased 18.4 and 10.4 bushels per acre, respectively, in the two rotations, by the application of rock phosphate, while the yields from good seed were increased only 4.3 and 6.3 bushels, respectively. The following year on the same plots (Table 19) the acre yield of sound corn from Fusarium-infected seed was increased from 43.5 bushels on the plots receiving manure only to 49.3 bushels on the phosphated plots, or an increase of 5.8 bushels. The acre yield of sound corn from good seed was increased only 0.7 bushel by the same treatment. On the plots receiving organic manure only, corn from Fusarium-infected seed yielded 8.0 bushels less, with odds greater than 9999 to 1, than corn from good seed, while on the plots receiving rock phosphate the difference in yield was only 2.9 bushels, with odds of 39 to 1.

Data in Table 20 also show that disease-susceptible corn on phosphated soil apparently may be highly resistant to the particular disease under experimentation and may yield approximately as much as a good-seed selection. On adjacent plots where the supply of available phosphates is less the decrease in yield may be very pronounced.

TABLE 19.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED

Yellow dent corn planted May 14, 1923, on brown silt loam, part of the plots receiving organic manure only and part receiving manure and rock phosphate, North-Central and South-Central rotations, University South Farm, Urbana

Soil treatment	Character of seed	Number of replications	Mean acre yield		Reduction in sound corn following use of Fusarium-infected seed		Odds
			Total	Sound			
			bu.	*bu.*	*bu.*	*perct.*	
Organic manure	Good seed.	16	59.1	51.5			
	Fusarium-infected.	16	51.5	43.5	8.0	15.5	>9999:1
Organic manure and rock phosphate........	Good seed.	16	60.1	52.2			
	Fusarium-infected.	16	56.1	49.3	2.9	5.6	39:1

The effects of applications of phosphate on the yields of corn grown from good and from infected seed are not always so pronounced as the data in Tables 18, 19, and 20 would seem to indicate, even on soils of the same general type and of apparently equal fertility. Data from forty-two experiments located on brown silt loam at various points in central Illinois and covering a period of two years are summarized in Table 21. It will be observed that corn from good seed did not always give a significant increase in yield on the phosphated plots. Obviously, in many instances, the corn from good seed, with its extensive healthy root systems, was able to get a sufficient supply of phosphates from the soil that received no additional phos-

TABLE 20.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM DISEASE-SUSCEPTIBLE SEED

Yellow dent corn grown on infested brown silt loam, part of the plots receiving limestone only and part receiving both limestone and rock phosphate, near Bloomington, 1920.

Character of seed	Yield of plots receiving limestone only	Effect of rock phosphate in addition to limestone	
		Increase	Decrease
Total Yield			
	bu.	*bu.*	*bu.*
Good....................	81.3	....	0.3
Disease-susceptible.......	70.6	6.9	....
Sound Corn			
	bu.	*bu.*	
Good....................	76.1	0.9	....
Disease-susceptible.......	65.0	8.4	....

phates. In interpreting the responses of healthy corn to application of phosphate, differences in various strains of corn should be considered. There is evidence that certain strains, on account of their extensive and fibrous root systems, are more efficient in utilizing limited supplies of this plant-food element than other strains that appear equally healthy.

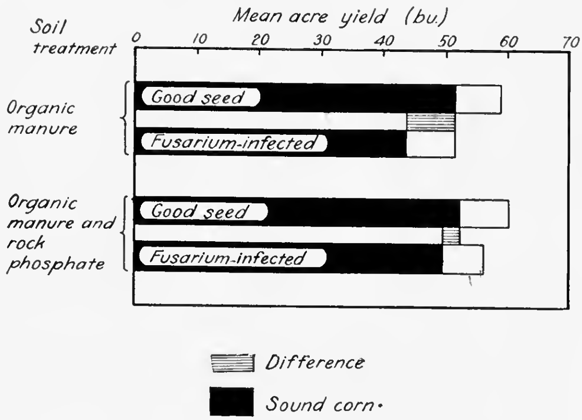


CHART 17.—YIELDS FROM FUSARIUM SEED AS INFLUENCED BY PHOSPHATES (Table 19)

The yield of corn grown from Fusarium-infected seed is greatly increased by an application of phosphate to the soil.

The ability of corn from good seed to respond favorably to applications of phosphate is further conditioned by date of planting and other important factors which are not within the province of the present bulletin.

Corn grown from scutellum-rotted seed was benefited more by the application of phosphate than was corn from good seed. The acre yield of sound corn from good seed was increased 3.5 bushels, with odds of only 18 to 1, while under the same conditions the yield of sound corn from scutellum-rotted seed was increased 6.6 bushels, with odds of 69 to 1, which are significant from the standpoint of odds of probability.

Altho there were instances where corn grown from Diplodia-infected seed was benefited markedly by applications of phosphate, there were other instances where the virulence of the disease apparently was increased by the same treatment, a typical example of which is given in Table 22. In the planting on May 8 there was a substantial increase in the yield of corn from Diplodia-infected seed on the phosphated plot, but in the later plantings there were slight decreases. Thus, on the whole, injury and loss in either total yield

TABLE 21.—SUMMARY OF DATA SHOWING THE INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED SEED

Corn grown on brown silt loam at various points in central Illinois, 1921, 1922

Years represented	Number of counties represented	Number of experiments represented	Character of seed	Acre yield		Increase on phos-phated plots	Odds
				No treat-ment	Phos-phated		
Total Yield							
				bu.	*bu.*	*bu.*	
2 (1921-22)	4	13	Good	59.6	63.9	4.3	62:1
			Scutellum-rotted	51.4	56.0	4.6	65:1
2 (1921-22)	4	10	Good	57.9	61.3	3.4	22:1
			Diplodia-infected	39.7	43.2	3.5	10:1
2 (1921-22)	4	10	Good	58.1	59.4	1.3	4:1
			Fusarium-infected	48.9	54.1	5.2	1427:1
1 (1922)	2	9	Good	63.4	65.0	1.6	3:1
			Starchy	53.8	61.1	7.3	384:1
Sound Corn							
2 (1921-22)	4	13	Good	50.4	53.9	3.5	18:1
			Scutellum-rotted	41.0	47 6	6.6	69:1
2 (1921-22)	4	10	Good	49.1	53.8	4.7	41:1
			Diplodia-infected	32.6	36.9	4.3	10:1
2 (1921-22)	4	10	Good	50.4	52.6	2.2	10:1
			Fusarium-infected	40.1	47.8	7.7	1110:1
1 (1922)	2	9	Good	52.4	57.7	5.3	3332:1
			Starchy	43.0	49.2	6.2	109:1

TABLE 22.—INFLUENCE OF ROCK PHOSPHATE ON YIELD FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam, part of the plots receiving no treatment and others receiving rock phosphate, Ontario Parish, near Oneida, 1922

Date of planting	Character of seed	Acre yield of sound corn on no-treatment plots	Effect of rock phosphate on yield of sound corn	
			Increase	Decrease
		bu.	*bu.*	*bu.*
May 8	Good	69.8	....	2.6
	Diplodia-infected	50.2	13.0	....
May 16	Good	72.8	....	4.1
	Diplodia-infected	53.9	....	4.9
May 29	Good	68.3	....	0.2
	Diplodia-infected	54.0	....	4.5

or yield of sound corn from Diplodia-infected seed were not significantly reduced by applications of phosphate (Table 21).

Data obtained up to the present time indicate that lack of abundance of available phosphates may be an important predisposing factor with corn grown from Fusarium-infected seed. In the case of corn from good seed in this particular series of experiments (Table 21), neither the total yield nor the yield of sound corn was increased appreciably by applications of phosphate, the increases being only 1.3 and 2.2 bushels per acre, respectively. On the other hand, both total yields and yields of sound corn from Fusarium-infected seed from the same strains of corn were significantly increased, the increases being 5.2 and 7.7 bushels per acre, respectively, with markedly high odds of probability in each case.

Since kernel starchiness indicates susceptibility to the corn rot diseases, as will be developed later in this bulletin, the response of corn from such seed to applications of phosphate is very suggestive (Table 21). Total yield of corn from good seed was increased only 1.6 bushels per acre on the phosphated plots, with odds of only 3 to 1, while the total yield of corn from starchy seed in the same test was increased 7.3 bushels, with odds of 384 to 1.

The results of Romyn,[83] from pot experiments conducted with the same seed lots that were used in experiments reported in Tables 18 and 19, seem to indicate that corn from Fusarium-infected seed may require more phosphate than is required by corn from good seed. In determining the hydrogen-ion concentration of the nutrient solution in the pots, Romyn found that the pots containing plants from Fusarium-infected seed were a little less acid than those growing plants from good seed. This difference also was brought out by comparing in like manner the nutrient solutions in pots containing plants grown from good seed, but in a number of which some of the plants were diseased. In general the nutrient solutions in the pots containing the greatest number of diseased plants were less acid in reaction than those containing few or no diseased plants. A summary of Romyn's results is presented in Table 23. His comments and interpretation are as follows:

"Altho the data are limited, they seem to indicate a larger absorption of the anions, or acid radicals, in the nutrient solution by the diseased corn. The possibility that this difference in hydrogen-ion concentration is due to a larger excretion of carbon dioxid by the good seed roots can be dismissed for two reasons. In the first place, any accumulation of carbon dioxid in the pots would have diminished the root growth in those pots in Experiments 4 and 5 which were aerated only at long intervals—this did not happen. Clements,[12] in a recent symposium on aeration, summarizes the work of a number of investigators which supports this contention. Secondly, the sweep of air thru the pots in the taking of the samples

TABLE 23.—INFLUENCE OF PLANTS FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED ON THE HYDROGEN-ION CONCENTRATION OF THE SOIL SOLUTION[1]

Yellow dent corn grown in pots, Urbana, 1922

Lime treatment	Character of seed	Number of pots	Mean hydrogen-ion concentration in p_H values	Difference in p_H value between pots containing corn from good and from infected seed	Odds
None......	Good..............	11	5.622		
	Fusarium-infected...	11	5.737	0.115	107:1
Limed.....	Good..............	11	5.866		
	Fusarium-infected...	11	5.943	0.077	25:1

[1]Unpublished data of E. A. Romyn, University of Illinois.

would probably have equalized the carbon dioxid saturation in all the solutions drawn off.

"It is not possible to say which of the anions has been absorbed, but as the acidity of the solution is due to the H_2PO_4 ion of the KH_2PO_4, it seems very likely that this ion has been absorbed for the purpose of supplying either extra P or an acid radical to the diseased plants.

"In interpreting these results, the effect of the sand itself on the pH of the nutrient solution should be taken into account. Both Shive[93] and Hoagland[39] have reported that the hydrogen-ion concentration of a nutrient solution is markedly affected by the addition of quartz sand. Both these workers, however, washed their sand carefully (Hoagland taking the further precaution of treating the sand with HCL) and thoroly flooded the sand at each change of nutrient solution. The sand in this experiment was not washed or so extensively irrigated and an effect of some alkaline reacting materials was noticed. But as this initial effect would be practically overcome by the end of the growth period and would affect both strains in the same way, it does not interfere with the comparative value of the hydrogen-ion concentration of the final solutions drawn off."

The data of Tables 15 to 20 indicate not only that a lack of an abundant phosphate supply may be an important factor predisposing corn to disease, but also that seed infection and seed condition are factors that deserve careful attention in studying any physiological problem relating to phosphate nutrition of corn.

Potassium and Disease Susceptibility

Thatcher[103] summarizes the rôle of potassium in plant nutrition as follows:

"The popular expression that 'potash makes sugars and starch' is a surprisingly accurate description of the rôle of this element in plant metabolism. Either the photosynthesis of starch, or the changes necessary to its translocation (it is not yet certain which) is so dependent upon the presence of potassium in the cell sap that the whole process stops at once if an insufficient supply is present. . . . The grains of the cereal crops become shrunken as a result of potassium starvation; and are plump and well-filled with starch in the endosperm when sufficient potassium is available for the crop's needs."

The relation of potassium starvation to disease susceptibility has been studied by a number of investigators. Russell[86] summarizes the results at Rothamsted as follows: "The vigor and healthiness of the plant are the first to suffer in a bad season, or to succumb to disease."

TABLE 24.—SUMMARY OF DATA SHOWING THE INFLUENCE OF POTASSIUM SULFATE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED AND DISEASE-SUSCEPTIBLE SEED

Grown on brown silt loam of medium fertility, Bloomington, 1923

Number of experiments	Character of seed	Acre yield: No treatment	Acre yield: Treated with potassium sulfate	Increase on potassium sulfate plots	Odds
	Total Yield				
		bu.	*bu.*	*bu.*	
4	Good	67.0	68.0	1.0	3:1
4	Scutellum-rotted	62.0	66.2	4.2	9:1
4	Diplodia-infected	51.4	48.7	−2.7	5:1
4	Fusarium-infected	64.1	66.9	2.8	3:1
	Sound Corn				
4	Good	46.2	46.6	0.4	1:1
4	Scutellum-rotted	30.2	39.1	8.9	141:1
4	Diplodia-infected	31.5	34.2	2.7	11:1
4	Fusarium-infected	38.9	49.4	10.5	66:1

Data showing the effect of applications of potassium sulfate on the yield of corn grown from good seed and from diseased seed are given in Table 24. The soil on which this experiment was located had not grown a leguminous crop for several years. The supply of decaying organic matter was rather low. Under such conditions a deficiency of available potassium salts might exist. Corn from good seed was not affected either in total yield or in yield of sound corn by applications of potassium sulfate. However, the quality of the yield from both scutellum-rotted and Fusarium-infected seed was significantly improved, the increases in sound corn being 8.9 and 10.5 bushels per acre, with odds of 141 to 1, and 66 to 1, respectively. Corn from Diplodia-infected seed apparently was not benefited in any way by the same applications of potassium sulfate. In other soil experiments where the soil was well supplied with decaying organic matter and available phosphates, no such benefits from the addition of potassium salts were observed.

INJURIOUS CONSTITUENTS IN SOIL SOLUTION

Toxic Substances

The problem of organic and inorganic constituents in the soil which are injurious to plants has received much attention, both in the United States and in other countries. There seems to be fairly conclusive evidence that toxic substances may form in poorly drained and poorly aerated soils and in soils lacking calcium carbonate, or lime. The active agencies in producing so-called "sour" or "acid" soils have been the subject of much study. The toxic properties of acid soils may result either from the presence of true acids in the soil or from a lack of basicity.[86] In the latter case soluble aluminum and ferrous salts, and in certain instances manganese, are believed to be largely responsible for the toxic effect of such soils upon plant growth.

Soluble aluminum compounds do not form readily in soils well supplied with lime and available phosphates. Moreover, applications of limestone in proper amounts change these soluble compounds into insoluble and non-acid forms. Connor[13] and others expressed the belief that the beneficial effects of applications of available phosphates are due as much to their rendering the aluminum salts insoluble as to the extra supply of available phosphate they furnish.

Hoffer and Carr[42] found that root rots of corn were more severe "in soils notable for their deficiencies in lime and available phosphates than in other soils," and showed that the absorption and accumulation of iron and aluminum salts in the nodal tissues resulted in a purplish brown discoloration followed by a disintegration of the affected tissues (Fig. 39). The accumulation of these metallic salts also resulted in a clogging of large numbers of the vascular bundles. In a later publication Hoffer and Trost[43] made the following statement:

"The accumulation of iron and aluminum compounds in the nodal tissues of corn plants is affected by conditions in the soil as well as the genetical composition of the strain of corn. The accumulations of aluminum in the plants are associated with retarded growths and increased susceptibility of certain strains to root rots. . . . When iron compounds gradually accumulate in the nodal tissues of the plants, the growth of the stalks may be little affected, but the disintegrations of the nodal tissues are accompanied by increased susceptibilities of the plants to root rot."

The reaction of the soil solution, in addition to being an important factor in determining the availability of phosphates and other essential plant food materials, has a pronounced influence on the behavior of parasitic soil fungi.

Limestone as a Corrective for Toxicity

Experiments were begun early in these investigations to determine the influence of various applications of limestone on the development

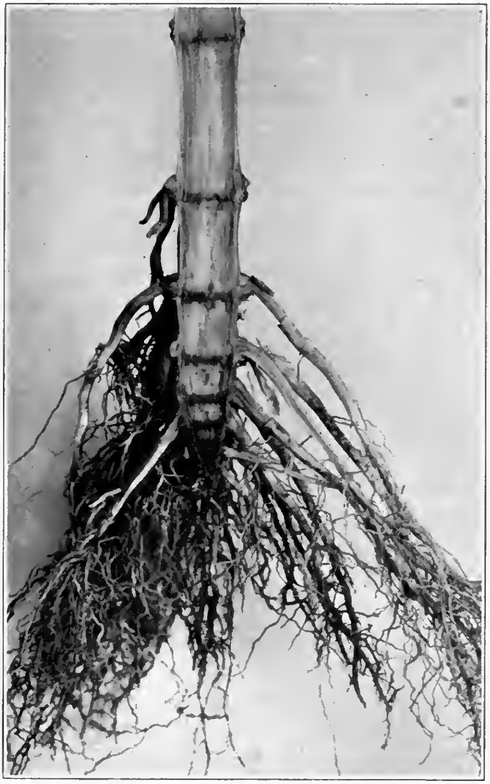


FIG. 39.—FERROUS IRON POISONING
Note the badly discolored nodes.

of certain of the corn rot diseases. Data from the University Roland Field, Urbana, showing the influence of applications of limestone and manure on the development of corn from good seed and from Diplodia-infected seed, are presented in Table 25. Altho the corn from good seed was benefited by the applications in every case, the corn from Diplodia-infected seed was little better on the treated plots than on the untreated plots.

Date of planting apparently is a very important factor in the comparative development of Diplodia-infected corn on limed and on unlimed soil (Tables 26 and 27). In the experiment reported in Table 26, it will be noted that in the first planting on

TABLE 25.—INFLUENCE OF DIFFERENT AMOUNTS OF LIMESTONE ON YIELD FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam, some of the plots receiving no treatment and others manure and limestone, University Roland Field, Urbana, 1922

Character of seed	Yield on no-treatment plots	Effect of different treatments on acre yield			
		10 tons manure 4 tons limestone		10 tons manure 8 tons limestone	
		Increase	Decrease	Increase	Decrease
		Total Yield			
	bu.	*bu.*	*bu.*	*bu.*	*bu.*
Good seed..........	59.0	7.1	....	9.2	....
Diplodia-infected....	39.9	0.6	....	2.9	....
		Sound Corn			
Good seed..........	48.5	10.0	....	11.0	....
Diplodia-infected....	30.1	2.3	....	3.5	....

May 7 there was an increase in both total yield and yield of sound corn from Diplodia-infected seed for each of the three rates of application of lime. In the plots where limestone was applied at the rate of 12 tons per acre, corn from Diplodia-infected seed yielded 9.8 bushels less than corn from good seed, altho there was practically no increase in yield of sound corn from this treatment. In the last planting there was a decided decrease in yield from Diplodia-infected seed on all the limed plots.

Similar data from experimental plots near Oneida are given in Table 27 and Chart 18. In the first planting there was an increase of 10.2 bushels per acre in yield of sound corn from Diplodia-infected seed, but in the last planting there was a decrease of 13.7 bushels. These data indicate that both date of planting and soil reaction are important environing factors in the development of corn from Diplodia-infected seed.

Summarized data of all the experiments on the relation of liming to certain of these diseases are reported in Table 28. The experiments were located on fields that were representative of the large areas of brown silt loam in central Illinois. At no place was there a significant increase in yield of corn from good seed on the limed plots. Of the

TABLE 26.—INFLUENCE OF DIFFERENT AMOUNTS OF LIMESTONE ON YIELD OF CORN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam, part of the plots receiving no treatment and others receiving different applications of limestone, near Bloomington, 1921

Date of planting	Character of seed	Yield on no-treatment plots	Effect of different applications of limestone on acre yield					
			4 tons		8 tons		12 tons	
			Increase	Decrease	Increase	Decrease	Increase	Decrease
			Total Yield					
		bu.	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
May 7	Good	73.6	....	2.3	2.4	....	3.3	....
	Diplodia-infected	42.8	6.6	....	14.0	....	24.3	....
May 14	Good	69.5	....	0.5	6.5	....	8.8	....
	Diplodia-infected	53.3	5.4	....	3.7	....	3.1	....
May 21	Good	71.2	....	9.3	7.6	....	13.0	....
	Diplodia-infected	58.2	....	1.1	4.5	....	8.4	....
May 30	Good	82.7	....	3.2	10.0	....	3.4	....
	Diplodia-infected	54.4	....	7.2	....	9.0	....	4.5
			Sound Corn					
May 7	Good	52.3	....	3.9	0.3	....	4.1	....
	Diplodia-infected	32.5	6.2	....	8.1	....	0.5	....
May 14	Good	47.7	....	2.9	10.8	....	15.2	....
	Diplodia-infected	38.2	....	0.9	....	4.6	....	2.2
May 21	Good	47.5	....	0.4	5.3	....	10.5	....
	Diplodia-infected	40.8	1.3	....	6.6	....	....	7.3
May 30	Good	57.6	....	7.6	5.9	....	11.5	....
	Diplodia-infected	35.9	....	5.1	....	3.8	....	4.6

TABLE 27.—INFLUENCE OF LIMESTONE ON YIELD OF CORN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Yellow dent corn grown on brown silt loam, part of the plots receiving no treatment and part receiving limestone, Ontario Parish, near Oneida, 1922

Date of planting	Character of seed	Yield on no-treatment plots	Effect of 4 tons of limestone on acre yield	
			Increase	Decrease
		Total Yield		
		bu.	*bu.*	*bu.*
May 8	Good	72.4	4.3	....
	Diplodia-infected	56.1	5.9	....
May 16	Good	79.2	....	....
	Diplodia-infected	61.6	....	8.5
May 29	Good	74.4	....	3.2
	Diplodia-infected	60.7	....	15.7
		Sound Corn		
May 8	Good	66.4	3.5	....
	Diplodia-infected	49.7	10.2	....
May 16	Good	74.4	1.6	....
	Diplodia-infected	56.3	....	9.6
May 29	Good	69.3	....	3.6
	Diplodia-infected	52.8	....	13.7

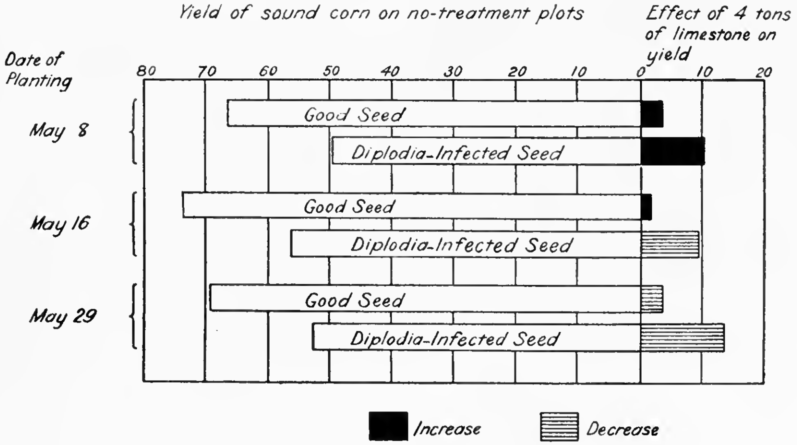


CHART 18.—DIPLODIA INJURY AS INFLUENCED BY LIMESTONE (Table 27)

In the early planting liming increased the yield of sound corn both from good seed and from Diplodia-infected seed. In the later plantings, however, it reduced the yields except for an insignificant increase in corn from good seed.

TABLE 28.—SUMMARY OF DATA SHOWING THE INFLUENCE OF LIMESTONE ON YIELD FROM GOOD SEED AND FROM VARIOUS LOTS OF DISEASED AND DISEASE-SUSCEPTIBLE SEED

Corn grown on brown silt loam at various points in central Illinois, 1919 to 1922

Number of years represented	Number of counties represented	Number of experiments represented	Character of seed	Mean acre yield		Increase in yield on limed plots	Odds
				No treatment	Limed		
				bu.	*bu.*	*bu.*	
4 (1919-22)	7	17	Good.......	67.9	70.1	2.2	5:1
			Scutellum-rotted.....	57.4	62.0	4.6	191:1
3 (1920-22)	6	12	Good.......	78.2	79.1	0.9	4:1
			Diplodia-infected...	53.9	57.7	3.8	6:1
2 (1921-22)	6	6	Good.......	64.9	66.6	1.7	1:1
			Fusarium-infected...	57.3	61.0	3.7	14:1
1 (1922)	3	6	Good.......	75.6	77.1	1.5	7:1
			Starchy.....	68.4	69.5	1.1	3:1

different diseased composites, corn from scutellum-rotted seed was the only one to show a significant increase in yield for the limed plots, the increase being 4.6 bushels per acre, with odds of 191 to 1, as contrasted with an increase of 2.2 bushels, with odds of 5 to 1, in the corn from good seed.

INFLUENCE OF CROP SEQUENCE

Previous cropping, or crop sequence, is one of the most important environing factors determining the extent of injury caused by corn rot diseases. In the experiments reported in Table 29 the comparisons were made in the same or closely adjacent fields of the same soil type and as nearly alike in all other factors as possible. In no case was there a difference of more than one day in date of planting. Where corn followed corn or wheat the reduction in acre yield from scutellum-rotted seed was significantly greater in every instance than where corn followed a legume, prairie sod, or oats. In the experiment at Bloomington in 1920 there was a difference of 14.1 bushels in acre yield between corn from good seed and from scutellum-rotted seed where corn followed clover, but in the same field where corn followed badly scabbed spring wheat the difference was 33.1 bushels. Results in 1921 were very similar. There was a reduction of 11.8 bushels in acre yield of sound corn on the virgin soil field, but a reduction of 31.3 bushels just across the fence on soil that had been in grain crops the preceding years. At Peoria, in 1921, the difference in the yield of corn from good seed and from scutellum-rotted seed was

TABLE 29.—INFLUENCE OF CROP SEQUENCE ON YIELD FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED

Yellow dent corn grown at various points in Illinois, 1920 to 1922

Experiment No.	Year	Location (Illinois)	Crop sequence	Seed lot No.	Character of seed	Acre yield		Reduction in sound corn grown from scutellum-rotted seed	
						Total	Sound		
						bu.	*bu.*	*bu.*	*perct.*
1	1920	Bloomington.....	Wheat, clover, clover............	1	Good...........	88.7	85.0		
				2	Scutellum-rotted .	76.5	70.9	14.1	16.6
	1920	Bloomington.....	Wheat, corn, spring wheat (scabbed)	1	Good...........	81.8	75.4		
				2	Scutellum-rotted .	57.9	42.3	33.1	43.9
2	1921	Bloomington.....	Virgin prairie sod...............	3	Good...........	94.3	72.3		
				4	Scutellum-rotted .	89.5	60.5	11.8	16.3
	1921	Bloomington.....	Corn, oats, wheat..............	3	Good...........	87.0	63.7		
				4	Scutellum-rotted .	67.9	32.4	31.3	49.1
3	1921	Peoria...........	Oats, wheat, clover.............	5	Good...........	74.6	56.7		
				6	Scutellum-rotted .	72.2	51.6	5.1	9.0
	1921	Peoria...........	Corn, corn, corn................	5	Good...........	81.7	65.8		
				6	Scutellum-rotted .	68.3	53.1	12.7	19.3
4	1922	Cambridge......	Oats, corn, oats................	7	Good...........	66.4	62.2		
				8	Scutellum-rotted .	63.9	59.9	2.3	3.7
	1922	Cambridge......	Corn, corn, corn................	7	Good...........	66.0	62.3		
				8	Scutellum-rotted .	59.2	55.1	7.2	11.6

FIG. 40.—INFLUENCE OF CROP ROTATION ON INJURY FROM SCUTELLUM ROT

Rows on the left are from scutellum-rotted seed; those on the right are from good seed. Above, first year corn after a legume in a rotation of soybeans, corn, corn, corn. Below, first year corn after a legume in a rotation of clover, corn, corn, wheat. Soil treatments have been the same in each rotation and the date of planting was the same. University South Farm, Urbana.

Corn from good seed responded better to more favorable conditions in crop rotations than did corn from scutellum-rotted seed. Data from these rotations up to the present time indicate that crop rotation is as important a factor in determining yield of corn as are soil treatments.

TABLE 30.—SUMMARY OF THREE YEARS' DATA SHOWING YIELDS FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED ON THREE STANDARD CROP ROTATIONS

Yellow dent corn grown on the University South Farm, Urbana, 1920 to 1922

Name of rotation	Crop sequence	Years since legume	Character of seed	Acre yield		Reduction in sound corn following use of scutellum-rotted seed	
				Total	Sound		
				bu.	*bu.*	*bu.*	*perct.*
Northwest	Potatoes, corn, soybeans, alfalfa	2	Good	76.1	63.6		
			Scutellum-rotted	65.9	49.9	13.7	21.5
North-Central	Corn, corn, spring grains, clover	1	Good	71.3	64.6		
			Scutellum-rotted	60.3	51.5	13.1	20.3
North-Central	Corn, corn, spring grains, clover	2	Good	65.6	56.9		
			Scutellum-rotted	57.6	47.9	9.0	15.8
South-Central	Corn, corn, corn, soybeans	1	Good	53.8	47.0		
			Scutellum-rotted	46.9	39.9	7.1	15.1
South-Central	Corn, corn, corn, soybeans	2	Good	46.9	40.9		
			Scutellum-rotted	42.7	35.4	5.5	13.4
South-Central	Corn, corn, corn, soybeans	3	Good	40.0	30.0		
			Scutellum-rotted	34.1	27.3	2.7	9.0

5.1 bushels per acre where corn followed clover and 12.7 bushels where corn followed corn. Results at Cambridge the following year were similar.

FIG. 41.—INFLUENCE OF CROP SEQUENCE ON INJURY FROM SCUTELLUM ROT

The reduction in yield of sound corn from scutellum-rotted seed (right) as compared with the yield from good seed (left) was very much greater in the field where corn followed soybeans in a rotation of corn, corn, corn, soybeans (below) than where it was the third year of corn in the same rotation (above) (Table 30). Of the environing factors affecting the development of the different corn rot diseases, the problem of crop rotation and crop sequence takes a place second to no other under conditions existing at the present time in central Illinois.

Since 1920, plantings of good seed and various lots of diseased seed have been made in three long-time rotations on the University South Farm, Urbana. A summary of three years' field data from good seed and from scutellum-rotted seed is presented in Table 30. In the Northwest rotation the acre yields of sound corn averaged 63.6 bushels and 49.9 bushels, respectively, showing a reduction of 13.7 bushels due to scutellum-rotted seed. Soil treatments on the North-Central and the South-Central rotations have been the same since the rotations were started in 1907. They have consisted of an application of rock phosphate at the rate of 2,000 pounds per acre every four years.

Data from these rotations up to the present time indicate that crop rotation is as important a factor in determining yield of corn as are soil treatments (Fig. 40). Corn from good seed responded better to the more favorable conditions in each rotation than did corn from scutellum-rotted seed. Of the environing factors affecting the development of the different corn rot diseases under discussion in this bulletin, the problem of *crop rotations* (Fig. 40) and *crop sequence* (Fig. 41) takes a place second to no other under conditions existing at the present time in central Illinois.

GENETIC FACTORS

From the data and discussion presented up to this point it is evident (1) that pathogenic bacteria and fungi are capable of causing diseases of great economic importance to the corn crop under conditions usually existing in the corn belt, and (2) that such environing factors as soil temperature, soil moisture, soil aeration, available plant food materials, soil toxicity, and crop sequence exercise a strong influence on the development and expression of disease.

However, the extent to which the corn plant is affected by either parasitic or environing factors depends largely on the inherent qualities, or genetic composition, of the particular corn plant in question. Certain strains of corn, on account of their superior inherent qualities, are able to develop and function normally under a wide range of environmental conditions, while other strains vary greatly in their susceptibility to injury when grown in association with the same environmental and parasitic factors. Differences in genetic factors seem to be the only logical explanation for these variations.

A large number of genetic characters, including abnormalities, chlorophyll deficiencies, and seed characters, have received much attention by a number of investigators, a summary of whose work has been given by Lindstrom[62] and by Wallace and Bressman.[112] In addition to the work on individual genetic factors, certain linkage groups have been established. The relation of all these known factors to disease resistance and productiveness of seed corn has not been determined, but it is common observation that corn containing many weak and undesirable characters is not likely to yield satisfactorily. In addition to the heritable characters already known there undoubtedly are many other characters which are very important in determining the behavior of a strain of corn and its ability to resist disease and injury from unfavorable environments. Hoffer and Carr[42] suggested that selective absorption by individual corn plants may prove to be a very important heritable character. Hoffer and Trost[43] later published data which gave support to this suggestion. Holbert and Koehler[49] showed that inbred strains differ greatly in the character and extent of their root systems. Certain strains, apparently independent of any parasitic factors, have such a limited and inefficient root system (Fig. 42) that they are unable to function normally during the hot days of July and August, when the soil moisture is low (Fig. 43).

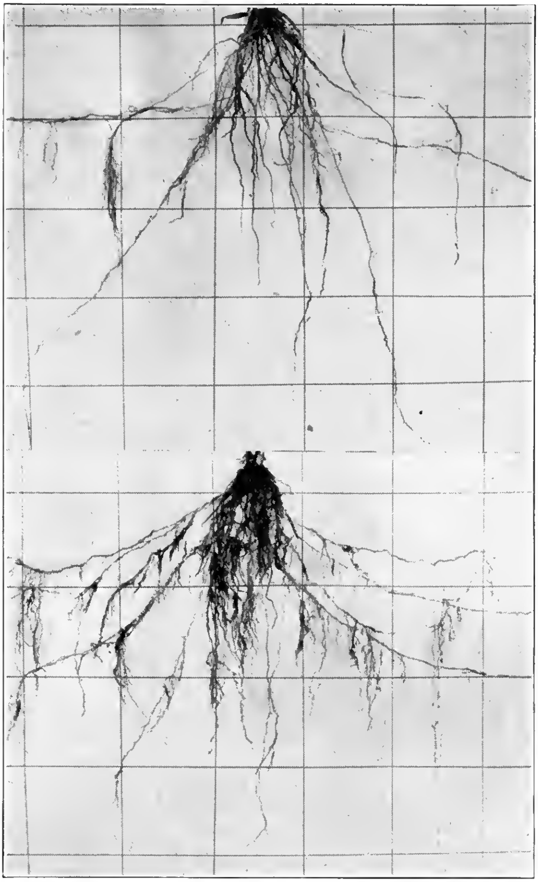


FIG. 42.—HERITABLE DIFFERENCES IN EXTENT AND CHARACTER OF ROOT SYSTEMS

Representative root systems of two inbred strains of dent corn. The one illustrated above is susceptible to leaf firing; the lower one is highly resistant to both leaf firing and root rot. Note difference in character and extent of the two root systems.

Other strains not only have fewer roots and a lower ratio of tops to roots, but are very susceptible to a rotting of the roots and to injury from inoculation with *Gibberella saubinetii* (Fig. 44). Data illustrating this behaviour are given in Tables 31 and 32. In the two unrelated strains reported in Table 31,

TABLE 31.—VARIATION OF TWO UNRELATED INBRED STRAINS IN MEASUREMENTS AND WEIGHT OF STALKS AND IN WEIGHT OF ROOTS; ALSO IN SUSCEPTIBILITY TO INOCULATION WITH *G. saubinetii*

Strong-rooted and weak-rooted strains planted May 22, 1923, in barrels containing brown silt loam. The plants for measuring and weighing were washed out on July 19 to 23, near Bloomington, 1923

Character of strain	Pedigree	Number of plants	Mean height	Mean circum-ference	Mean total number of roots	Mean air-dry weight		Ratio of wt. of tops to wt. of roots	Mean plant yield of grain, Sept. 28 (40 plants)	
						Tops	Roots		Un-inocu-lated	Inoculated with *Gibberella saubinetii*
			in.	*in.*		*gms.*	*gms.*		*lbs.*	*lbs.*
Strong-rooted. . .	A-1-1-2-R-3-2. .	10	58.5	3.3	49.4	95.5	79.6	1:0.83	0.575	0.549
Weak-rooted. . . .	B-1-1-1-R-8-2. .	10	54.0	2.3	32.4	64.1	42.2	1:0.66	0.428	0.328
Difference.			4.5	1.0	17.0	31.4	37.4	0.17	0.147	0.221
Odds.			132:1	88:1	>9999:1	216:1	908:1	87:1		

differences in height, circumference at base of plant, total number of roots, and air-dry weights of tops and roots were all significant. The ratio of tops to roots in the good strain (A-1-1-2-R-3-2) was 1 to 0.83, while in the weak-rooted strain (B-1-1-1-R-8-2) it was 1 to 0.66 (Fig. 45). This difference in the two ratios was fairly consistent for the plants studied, the odds being 87 to 1. Uninoculated plants pro-

FIG. 43.—SUSCEPTIBILITY (Left) AND RESISTANCE (Right) TO INJURY FROM DROUTH

Certain strains, apparently independent of any parasitic factors, have such a limited and inefficient root system that they are unable to function normally during the hot days of July and August under conditions of low soil moisture.

duced a mean plant yield of 0.575 and 0.428 pound, respectively, while inoculated plants yielded 0.549 and 0.328 pound, respectively. Thus the yield of the good strain was reduced only 0.026 pound per plant by the inoculation, while the yield of the weak-rooted strain was reduced 0.10 pound per plant.

The two strains reported in Table 32 were very closely related. In 1922 they differed greatly in pulling resistance, the resistance of

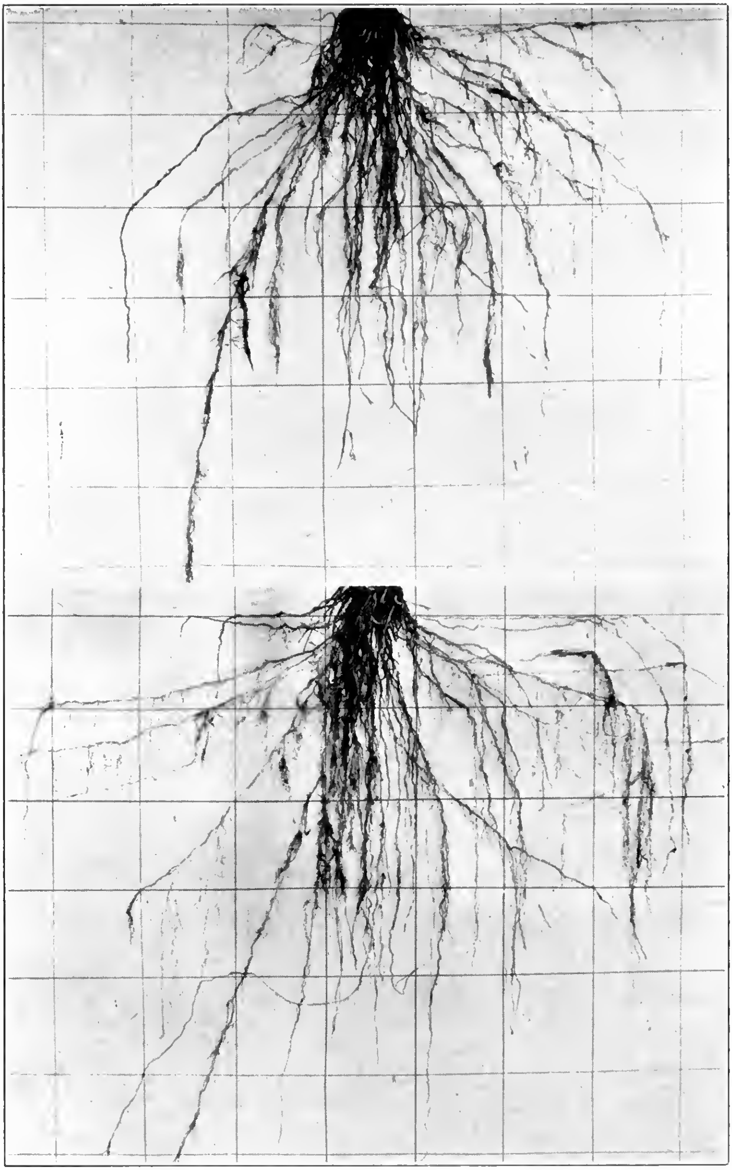


FIG. 44.—HERITABLE DIFFERENCES IN ROOT SYSTEMS

Representative root systems of two inbred strains of dent corn, one of which (above) is susceptible to root rot and the other (below) highly resistant. Note the difference in extent and branching of the lateral roots.

FIG. 45.—DIFFERENCE IN RATIO OF TOPS TO ROOTS

Representative plants of the two unrelated inbred strains. At the left, strain A-1-1-2-R-3-2; at the right strain B-1-1-1-R-8-2 (Table 31). Note difference in number of roots as well as in mass.

TABLE 32.—VARIATION OF TWO CLOSELY RELATED INBRED STRAINS IN RESISTANCE TO VERTICAL PULL AND IN SUSCEPTIBILITY TO INJURY FROM *Gibberella saubinetii*

Yellow dent corn grown from nearly disease-free horny seed planted May 22, 1923, on brown silt loam on which corn had been grown the previous year, near Bloomington.

Character of strain	Pedigree in 1922	Number of plots	Mean resistance to vertical pull		Acre yield			
			Parent plants, 1922	Progeny, 1923	Uninoculated	Inoculated	Reduction	Odds
			lbs.	*lbs.*	*bu.*	*bu.*	*bu.*	
Strong-rooted	B-1-1-1-1-7	4	364.0	280.6	54.9	52.8	2.1	3:1
Weak-rooted	B-1-1-1-1-8	4	120.0	147.6	40.8	25.3	15.5	71:1

TABLE 33.—VARIATION IN SUSCEPTIBILITY TO ROOT ROT OF TWO INBRED STRAINS HAVING THE SAME NUMBER OF MAIN ROOTS

Seed from a good strain and from a strain susceptible to leaf firing and root rot, planted May 22, 1923, in barrels containing brown silt loam. The plants for measuring and weighing were washed out on July 21 to 25, Bloomington

Character of strain	Pedigree	Number of plants	Mean height	Mean circumference	Total number of roots	Percentage of rotted and partially rotted roots (July 21-25)	Mean air-dry weight		Ratio of wt. of tops to wt. of roots	Mean plant yield of grain, Sept. 28 (40 plants)
							Tops	Roots		
			in.	*in.*		*perct.*	*gms.*	*gms.*		*lbs.*
Good	G-4-2-1	10	64.8	2.8	46.5	1.5	119.5	101.7	1:0.85	0.607
Susceptible to both leaf firing and root rot	G-4-4-1	10	63.5	2.3	45.7	24.0	71.3	44.2	1:0.62	0.251
Difference			1.3	0.5	0.8	22.5	48.2	67.5	0.21	0.356
Odds					1:1	344:1	4999:1	554:1	35:1	

one being 364 pounds and that of the other 120 pounds. In 1923 the mean resistance was 280.6 pounds for the one and 147.6 pounds for the other (Fig. 46). The weaker rooted strain (B-1-1-1-1-8) not only yielded less in the uninoculated plots, but was much more susceptible to injury from inoculation, the reduction in yield being 15.5 bushels per acre with odds of 71 to 1, as compared with a reduction in the strong-rooted strain (B-1-1-1-1-7) of only 2.1 bushels with odds of 3 to 1.

FIG. 46.—HERITABLE DIFFERENCES IN ANCHORAGE OF CORN PLANTS

A weak-rooted inbred strain growing between corn from a strong-rooted inbred strain which was closely related (Table 32).

On the other hand, strains of corn with the same total number of main roots may differ greatly in their resistance to root rot (Figs. 47 and 48). In the more strongly rooted strain (G-4-2-1) reported in Table 33, only 1.5 percent of the main roots were rotted on July 21, while in the strain susceptible to leaf firing and root rot (G-4-4-1), 24.0 percent of the main roots were rotted. The difference of 0.8 in number of main roots was not significant. However, there were marked differences in number of fibrous roots (Fig. 49). The ratio

FIG. 47.—SUSCEPTIBILITY AND RESISTANCE TO ROOT ROT

Portions of two root systems, the one on the left being very susceptible to root rot and the other highly resistant.

of tops to roots in the good strain was 1 to 0.85, while in the susceptible strain this ratio was 1 to 0.62. During the latter part of the growing season there was much firing of the lower leaves in the susceptible strain, and by the middle of September practically all the roots were rotted. This difference in the two strains in resistance and susceptibility to root rot was reflected in the yield of grain. The good strain yielded 0.607 pound per plant, while the susceptible strain yielded only 0.251 pound.

In general it has been found that weak-rooted strains, when compared with better rooted strains, are more likely to lodge and are lower in grain production (Fig. 50), owing in part to being more susceptible to injury from unfavorable environment and in part to parasitic factors, as is shown by data presented in Table 34. The final field stands of strong-rooted and weak-rooted strains in the uninoculated plots were practically the same, 90.2 and 90.0 percent, respectively. The mean yield of the strong-rooted strains was 64.5 bushels per acre, while that of the weak-rooted was 38.8 bushels.

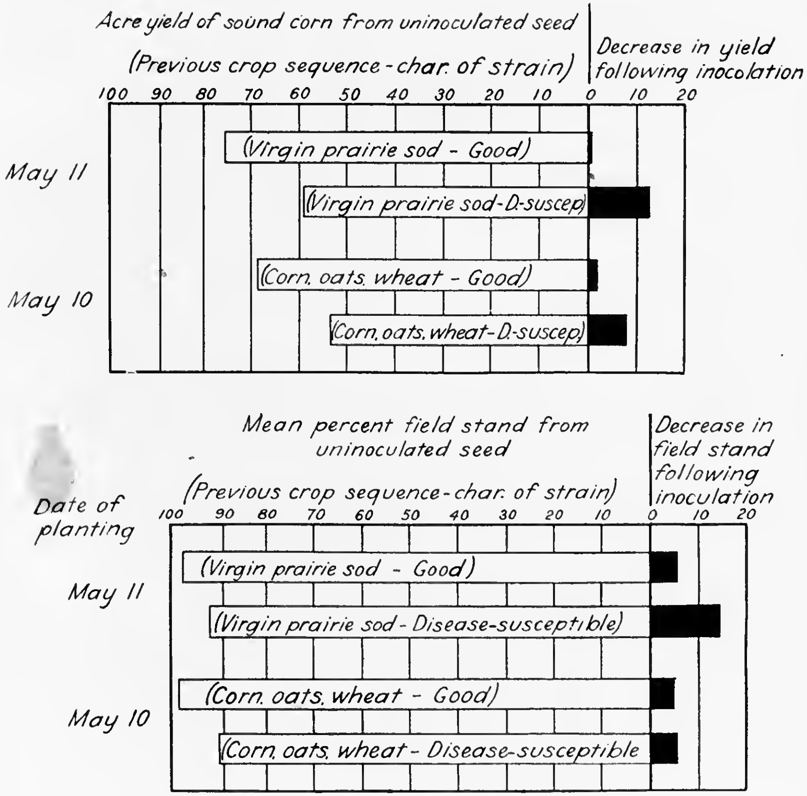


CHART 19.—DISEASE RESISTANCE IN OPEN-POLLINATED STRAINS
(Table 35)

The yields from the open-pollinated strain selected for disease resistance and planted in clean soil and in infested soil were only slightly reduced by inoculation with *G. saubinetii*. The yields from a susceptible strain under like conditions were significantly reduced on both clean and infested soil. Also, the only significant reduction in field stand following inoculation occurred where seed of susceptible strains was used.

TABLE 34.—VARIATIONS OF STRONG-ROOTED AND WEAK-ROOTED STRAINS IN YIELD FOLLOWING INOCULATION WITH *Gibberella saubinetii*

Inbred strains of yellow dent corn planted May 22, 1923, on brown silt loam on which corn had been grown the previous year, near Bloomington

Character of strain	Number of strains in experiment	Resistance to vertical pull in uninoculated plots		Field stand on uninoculated plots	Plant height 45 days after planting	Mean acre yield of uninoculated plots	Reduction following inoculation	Odds
		Parent plants, 1922	Progeny, 1923					
		lbs.	*lbs.*	*perct.*	*inches*	*bu.*	*bu.*	
Strong-rooted	18	383.0	304.0	90.2	36.8	64.5	4.7	81:1
Weak-rooted	18	133.0	175.7	90.0	32.8	38.8	10.4	>9999:1
Difference		250.0	128.3	0.2	4.0	25.7		
Odds		>9999:1	>9999:1	2:1	526:1	>9999:1		

TABLE 35.—VARIATION IN FIELD STAND AND YIELD FROM DISEASE-SUSCEPTIBLE AND FROM DISEASE-RESISTANT STRAINS, FOLLOWING INOCULATION WITH *Gibberella saubinetii*

Open-pollinated yellow dent corn grown on two fields of brown silt loam, near Bloomington, 1921

Previous crop sequence 1918, 1919, 1920	Character of strain	No. of plots	Mean percentage field stand				Mean total acre yield				Mean acre yield of sound corn			
			Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds	Uninoculated	Inoculated	Reduction	Odds
			perct.	*perct.*			*bu.*	*bu.*	*bu.*		*bu.*	*bu.*	*bu.*	
Virgin prairie sod	(*Pl. May 11*) Good	8	97.8	92.4	5.4	665:1	93.5	91.7	1.8	5:1	75.5	75.2	0.3	1:1
	Disease-susceptible	8	92.5	78.5	14.0	3332:1	83.9	69.1	14.8	713:1	59.1	46.6	12.5	1249:1
Corn, oats, wheat	(*Pl. May 10*) Good	8	98.6	93.6	5.0	262:1	87.1	85.8	1.3	3:1	68.8	67.1	1.7	3:1
	Disease-susceptible	8	90.8	85.4	5.4	43:1	76.2	71.2	5.0	127:1	53.6	45.6	8.0	117:1

Inoculation with *Gibberella saubinetii* reduced the mean yield of the strong-rooted strains 4.7 bushels per acre, while it reduced the mean yield of the weak-rooted strains 10.4 bushels. In the former case the odds were 81 to 1; in the latter they were more than 9999 to 1.

Altho variations in disease resistance are greater in open-pollinated corn than in uniform inbred strains, *yet there are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection.* Table 35 and Chart 19 present data from an inoculation experiment in which

FIG. 48.—HEALTHY AND ROTTED ROOTS

Representative roots from a strain highly resistant to root rot (left) and from a strain susceptible to root rot (right).

disease-sueeptible open-pollinated strains were compared with an open-pollinated strain that had been selected for disease resistance for a number of years. The field plantings were made under conditions which Dickson has shown to be favorable for injury from *G. saubinetii.* Inoculation with this organism in plantings following virgin prairie sod, reduced the mean total yield of corn from susceptible strains 14.8 bushels per acre, with odds of 713 to 1, while under the same conditions it reduced the total yield of the corn from the good seed only

FIG. 49.—HERITABLE DIFFERENCES IN CHARACTER OF ROOT SYSTEMS (Table 33)

Representative plants of two inbred strains.

1.8 bushels per acre, with odds of 5 to 1. With the good strain in this experiment there was practically no reduction in the yield of sound corn following inoculation, but with the disease-susceptible strains there was a reduction of 12.5 bushels per acre, with odds of 1249 to 1.

Results from the plantings following wheat were in accord with the foregoing results from the planting following virgin sod, tho the reductions in the disease-susceptible plots were not so pronounced.

Complete resistance or immunity to a majority of the corn rot diseases seems possible only by the recombination of two or more highly resistant and reasonably productive inbred strains which nick

FIG. 50.—HERITABLE DIFFERENCES IN ANCHORAGE OF CORN PLANTS

Certain inbred strains of corn are weakly anchored and consequently blow down easily. Other strains are well anchored and are able to withstand all ordinary wind and rain storms. The performance of such strains has been found to be consistent over a period of years as reported by Koehler, Dungan, and Holbert. Bloomington.

TABLE 36.—COMPARATIVE FIELD PERFORMANCE OF CORN GROWN FROM A GOOD SELECTION OF OPEN-POLLINATED SEED AND FROM FIRST-GENERATION HYBRID SEED OF COMPATIBLE DISEASE-RESISTANT INBRED STRAINS DERIVED FROM THIS SAME OPEN-FERTILIZED STRAIN, BLOOMINGTON, 1923

Nature of corn	Number of plots	Percentage field stand	Percentage of plants			Percentage of ears		Acre yield	
			Inclined over 30°	Smutted	Barren	Rotted	Immature	Total	Sound
		perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*bu.*	*bu.*
Open-pollinated...	10	88.5 ± 1.0	12.8 ± 1.3	2.5 ± 0.4	14.2 ± 1.1	3.3 ± 0.6	0.6 ± 0.2	90.5 ± 1.0	85.9 ± 0.5
F_1 of disease-resistant inbred strains	10	94.7 ± 0.2	0.1 ± 0.3	0.1 ± 0.3	0.0	1.8 ± 0.5	3.9 ± 1.3	117.2 ± 1.6	110.5 ± 2.9

together in a compatible way, an illustration of which is given in Table 36 and Figs. 51, 52, and 53. These data, as well as those reported in Tables 31 to 35 inclusive, indicate that genetic factors are as important as environmental factors (Table 4) in determining resistance to Gibberella root rot and seedling blight disease.

In comparing good open-pollinated corn with this first-generation cross reported in Table 36, it will be noted that the percentage of inclined plants was reduced from 12.8 percent to 0.1 percent in the cross, and the percentage of smutted plants from 2.5 to 0.1 percent.

FIG. 51.—A GOOD FIRST GENERATION CROSS (LEFT) AND A POOR ONE (RIGHT)

First-generation crosses between inbred strains vary greatly in their ability to stand erect during strong wind storms. Many crosses are very inferior to the original variety, while a few are decidedly superior in every respect. The cross on the left is illustrated also in Figs. 52 and 53 (Table 36).

The total yield was increased from 90.5 ± 1.0 bushels per acre in the open-pollinated corn to 117.2 ± 1.6 bushels in the first-generation cross. The yield of sound corn was increased from 85.9 ± 0.5 bushels per acre to 110.5 ± 2.9 bushels. This same cross gave similar results

FIG. 52.—TWO METHODS OF CORN BBEEDING

Above, corn from good open-pollinated seed; below, corn from the first-generation cross of two compatible and highly resistant inbred strains of the same variety as above (Table 36 and Fig. 53). Farm of Mr. E. D. Funk, near Bloomington, 1923.

the previous three years. Further data and discussion of disease resistance and its relation to corn improvement will be found in other sections of this bulletin.

FIG. 53.—EACH METHOD OF BREEDING HAS ITS PLACE IN A PROGRAM OF CORN IMPROVEMENT

Same plots as shown in Fig. 52, but with leaves stripped to show uniformity in good characteristics. Complete resistance or immunity to a majority of the corn rot diseases seems possible only by the recombination of two or more highly resistant and reasonably productive inbred strains which nick together in a compatible way.

PART III

ECONOMIC IMPORTANCE OF CORN ROT DISEASES

It is difficult to estimate accurately the losses to corn growers resulting from the use of infected seed and seed of corn especially susceptible to disease and to injuries under unfavorable soil and weather conditions. Severity of the losses depends on many factors, chief among which are soil management and soil fertility, crop sequences and crop rotation systems, climatic and seasonal conditions, time of planting, and quality of strain and of seed. The use of such seed undoubtedly is responsible for losses to the extent of 25 to 50 percent on many farms in the corn belt. Occasionally, especially with sweet corn, these diseases have resulted in the loss of almost an entire crop. Losses frequently vary from less than 5 percent to as much as 50 percent on adjoining farms, depending on the character and condition of seed used and the kind of farming practiced. Parts of fields have commonly been found in which the grain was damaged to the extent of 25 percent by ear rots alone, while in other parts of the same fields grain from good seed was damaged but little.

FIELD EXPERIMENTS WITH VARIOUS SEED SELECTIONS

Since 1917 experiments have been conducted to determine, as nearly as possible, the loss due to corn rot diseases thru the use of seed the progeny from which was susceptible to disease.

SCUTELLUM-ROTTED SEED

The data from the experiments with scutellum-rotted seed are summarized in Table 37. The scutellum-rotted seed used in these experiments was probably as good as most of the seed planted thruout the state during those years. All lots of nearly disease-free seed used were good in vitality and comparatively free from infection with organisms known to be parasitic to corn. The difference in the yields from the scutellum-rotted seed and from the good seed, ranging from less than 3 percent to approximately 50 percent (Table 37 and Chart 20), suggests that scutellum-rotted seed is a probable cause of reduction in yield. On the basis of sound corn, reductions in yield were much greater than the above.

Under the most favorable conditions scutellum-rotted seed usually produces a satisfactory field stand. However, if the weather and soil conditions are very unfavorable for germination of corn, the use of such seed may result in a failure. Different lots of scutellum-rotted seed vary greatly in their ability to germinate and yield well under adverse conditions. While occasionally certain lots are only slightly inferior to good seed, in general it may be said that they are distinctly inferior and in certain instances are no better than Diplodia-infected seed under the same adverse conditions.

DIPLODIA-INFECTED SEED

Of the parasitic organisms causing ear rots and seed infections, *Diplodia zeae* is one of the most important. Every year there is an appreciable amount of the corn crop damaged by ear rots for which Diplodia is chiefly responsible. However, damage from Diplodia is not confined to badly rotted ears. The organism may be present in many apparently good ears that are selected for seed purposes. In some lots of seed corn prepared by farmers, 50 percent of the kernels have been found to be infected chiefly with *Diplodia zeae,* while in other lots of seed, similarly prepared, only a few kernels were found to be infected with this organism. *Planting of Diplodia-infected seed always has resulted in a reduced stand, many blighted and weak plants, and a lowered vigor and vitality of those plants which survive.*

Table 38 and Chart 21 present yield data for four years from experiments the object of which was to compare the behavior of corn grown from Diplodia-infected seed with that grown from good seed. Reductions in yield following the planting of seed infected with this organism varied from less than 15 percent to more than 50 percent, depending on date of planting, soil temperature, and soil moisture, especially during the first two weeks following planting, previous cropping, and the fertility of the soil.

Durrell,[22] of the Iowa Agricultural Experiment Station, makes the following significant statements regarding the economic importance of this disease:

"The study of the dry rot disease of corn caused by *Diplodia zeae* shows it to be a prevalent disease in Iowa, resulting in losses, the past two seasons, ranging from 3 to 15 percent of the ears at harvest and a 11 percent damage to the seed corn. The loss in stand from diseased seed in many fields amounted to 15 percent. A still further loss results from nodal infection and weak plants grown from slightly infected seed."

FUSARIUM-INFECTED SEED

Seed infection with *Fusarium moniliforme* is of considerable economic importance. Altho extensive field inoculation studies have failed to yield definite data concerning the pathogenicity of this organism, the planting of seed primarily infected with *Fusarium moniliforme* has consistently resulted in a reduced yield of sound corn. Where conditions are favorable thruout the growing season, the reductions may be only very slight, but under certain soil condi-

TABLE 37.—YIELDS OF CORN FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED Grown at various points in Illinois, 1917 to 1923

Year	Location of experiment (Illinois)	Previous crop	Relative time of planting	Acre yield		Reduction following use of scutellum-rotted seed	
				Good seed	Scutel-lum-rot-ted seed		
				bu.	*bu.*	*bu.*	*perct.*
1917	Bloomington....	Sweet clover.......	Early.........	90.0	79.0	11.0	12.2
	Bloomington....	Corn.............	Early.........	102.5	67.5	35.0	34.1
1918	Bloomington....	Corn.............	Early.........	70.1	49.6	20.5	29.2
	Bloomington....	Winter wheat......	Early.........	67.0	54.0	13 0	19.4
	Sidell..........	Corn.............	Intermediate...	77.4	62.7	14.7	19.0
1919	Bloomington....	Clover...........	Early.........	71.2	55.2	16.0	22.5
	Bloomington....	Alfalfa...........	Early.........	82.0	69.5	12.5	15.2
	Bloomington....	Spring wheat......	Intermediate...	81.3	60.0	21.3	26.2
	Bloomington....	Clover...........	Intermediate...	90.9	80.7	10.2	11.2
	Yates City.....	Clover...........	Intermediate...	72.2	66.9	5.3	7.3
1920	Urbana........	Potatoes..........	Intermediate...	77.8	63.5	14.3	18.4
	Urbana........	Clover...........	Intermediate...	86.7	69.8	16.9	19.5
	Rock Island....	Clover...........	Intermediate...	89.0	86.7	2.3	2.6
	Media..........	Corn.............	Intermediate...	44.4	36.3	8.1	18.2
	Decatur........	Corn.............	Intermediate...	59.0	50.9	8.1	13.7
	Yates City......	Corn.............	Intermediate...	69.7	60.8	8.9	12.8
	Virginia........	Clover...........	Late..........	67.1	51.1	16.0	23.8
	Morris.........	Clover........ ...	Intermediate...	70.3	58.3	12.0	17.1
	Clinton.........	Corn.............	Intermediate...	57.3	48.6	8.7	15.2
1921	Peoria.........	Corn.............	Early.........	81.5	66.6	14.9	18.3
	Bloomington....	Virgin prairie......	Early.........	91.0	88.3	2.7	3.0
	Bloomington....	Corn.............	Early.........	86.6	75.8	10.8	12.5
	Bloomington....	Virgin prairie......	Late..........	93.8	84.5	9.3	9.9
	Urbana........	Potatoes..........	Early.........	103.5	94.0	9.5	9.2
	Urbana........	Potatoes..........	Intermediate...	101.9	88.0	13.9	13.6
	Urbana........	Potatoes..........	Intermediate...	94.3	84.9	9.4	10.0
	Urbana........	Potatoes..........	Late..........	92.3	80.5	11.8	12.8
	Amboy.........	....	Intermediate...	86.2	81.7	4.5	5.2
	Amboy.........	....	Intermediate...	96.8	82.8	14.0	14.5
	Ontario Parish..	Timothy..........	Early.........	74.9	70.9	4.0	5.3
	Ontario Parish..	Timothy..........	Intermediate...	74.7	68.3	6.4	8.6
	Ontario Parish..	Timothy..........	Late..........	70.3	68.7	1.6	2.3
	Cambridge.....	Oats.............	Intermediate...	68.7	63.0	5.7	8.3
	Cambridge.....	Corn............	Intermediate...	65.8	56.4	9.4	14.3
1922	Bloomington....	Corn, 2d year on virgin sod.......	Intermediate..	100.2	94.3	5.9	5.9
	Urbana.........	Clover...........	Intermediate...	59.9	51.2	8.7	14.5
	Urbana........	Corn.............	Intermediate...	33.3	28.2	5.1	15.3
	Urbana........	Potatoes..........	Early.........	59.2	57.5	1.7	2.9
	Urbana........	Potatoes..........	Intermediate...	58.3	54.6	3.7	6.3
	Urbana........	Potatoes..........	Intermediate...	56.1	44.7	11.4	20.3
	Urbana........	Potatoes..........	Late..........	53.0	41.0	12.0	22.6

TABLE 37.—*Concluded*

Year	Location of experiment (Illinois)	Previous crop	Relative time of planting	Acre yield		Reduction following use of scutellum-rotted seed	
				Good seed	Scutel-lum-rot-ted seed		
				bu.	*bu.*	*bu.*	*perct.*
1923	Bloomington....	Alfalfa............	Early.........	85.0	65.0	20.0	23.5
	Bloomington....	Alfalfa............	Late..........	90.4	70.9	19.5	21.6
	Cambridge.....	Prairie sod.........	Early.........	62.9	47.8	15.1	24.0
	Cambridge.....	Prairie sod.........	Late..........	61.7	48.3	13.4	21.7
	Cambridge.....	Prairie sod.........	Early.........	63.3	54.7	8.6	13.6
	Cambridge.....	Prairie sod.........	Late..........	62.9	56.4	6.5	10.3
	Cambridge.....	Corn..............	Early.........	63.1	41.7	21.4	33.9
	Cambridge.....	Corn..............	Late..........	55.1	38.4	16.7	30.3
	Hopedale........	Corn..............	Intermediate...	67.4	54.8	12.6	18.7
	Hopedale........	Corn..............	Late..........	78.7	47.1	31.6	40.2
	Urbana........	Clover	Early.........	65.7	33.0	32.7	49.8
	Urbana........	Clover............	Intermediate...	70.0	55.2	14.8	21.1
	Urbana........	Clover............	Late..........	59.2	36.8	22.4	37.8

Mean reduction in acre yield of sound corn in plots planted with scutellum-rotted seed, 12.4 ± 0.66 bushels.

$\frac{12.4}{0.66} = 18.8$. Odds greater than one million to one.

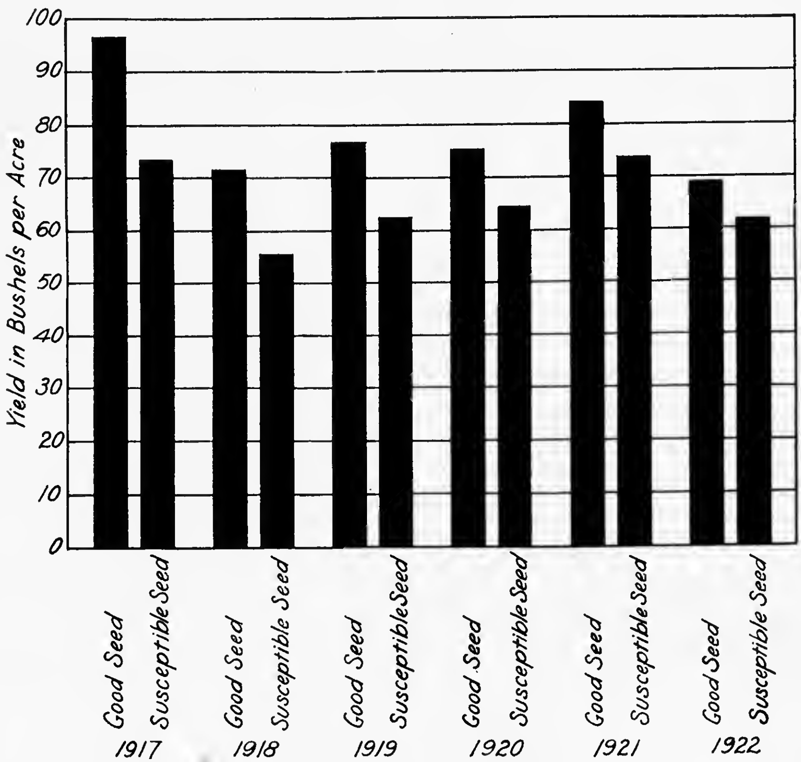


CHART 20.—COMPARATIVE YIELDS FROM GOOD SEED AND FROM SCUTELLUM-ROTTED SEED (Table 37)

tions Fusarium-infected seed has yielded little more than Diplodia-infected seed.

Data for three years from experiments comparing corn grown from good seed with corn grown from seed infected with *Fusarium* spp. are summarized in Table 39. The reductions in yield, ranging

TABLE 38.—YIELDS OF DENT CORN FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED

Year	Location of experiment (Illinois)	Previous crop	Relative time of planting	Acre yield				Reduction in sound corn following use of infected seed	
				Good seed		Seed infected with *Diplodia zeae*			
				Total	Sound	Total	Sound		
				bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
1920	Urbana.......	Alfalfa..........	Early.......	103.9		60.7			
	Bloomington..	Corn............	Early.......	73.6	52.3	42.8	32.5	19.8	37.9
	Bloomington..	Corn............	Intermediate	69.5	47.7	53.3	38.2	9.5	19.9
	Bloomington..	Corn............	Intermediate	71.2	47.5	58.2	40.8	6.7	14.1
	Bloomington..	Corn............	Late........	82.7	57.6	54.4	35.9	21.7	37.7
	Clinton.......	Corn............	Intermediate	59.8	52.1	49.0	39.9	12.2	23.4
	Decatur......	Clover..........	Intermediate	55.6	48.2	46.9	40.1	8.1	16.8
1921	Peoria........	Clover..........	Intermediate	75.8	59.4	58.6	46.5	12.9	21.7
	Virginia......	Clover..........	Late........	65.9	58.7	54.2	42.6	16.1	27.4
	Bloomington..	Corn, 2d year on virgin sod.....	Intermediate	100.0	93.7	78.9	72.1	21.6	23.1
	Girard.......	Sod.............	Intermediate	71.8	61.1	47.9	39.0	22.1	36.2
	Urbana.......	Clover..........	Intermediate	59.6	49.3	29.4	25.4	23.9	48.5
	Urbana.......	Corn............	Intermediate	35.0	27.6	19.3	12.8	14.8	53.6
	Urbana.......	Potatoes........	Early.......	59.2	45.0	41.0	31.8	13.2	29.3
	Urbana.......	Potatoes........	Intermediate	58.3	44.8	32.1	22.6	22.2	49.6
	Urbana.......	Potatoes........	Intermediate	56.1	46.6	33.6	27.6	19.0	40.8
	Urbana.......	Potatoes........	Late........	53.0	45.5	29.2	24.1	21.4	47.0
1922	Ontario Parish	Sod.............	Early.......	74.0	67.5	55.1	48.3	19.2	28.4
	Ontario Parish	Sod.............	Intermediate	77.0	71.3	59.0	53.9	17.4	24.4
	Ontario Parish	Sod.............	Late........	72.7	67.1	60.1	53.6	13.5	20.1
	Hopedale.....	Sod.............	Early.......	81.4	69.5	41.8	33.5	36.0	51.8
	Hopedale.....	Sod.............	Intermediate	93.4	87.2	55.5	50.2	37.0	42.4
	Hopedale.....	Sod.............	Late........	78.7	68.5	47.5	38.9	29.6	43.2
1923	Bloomington..	Alfalfa..........	Early.......	82.3	74.0	48.4	41.7	32.3	43.6
	Bloomington..	Alfalfa..........	Late........	94.6	83.3	80.1	69.9	13.4	16.1
	Bloomington..	Barley..........	Intermediate	71.9	62.1	61.5	53.7	8.4	13.5
	Hopedale.....	Corn............	Intermediate	67.4	53.9	40.2	25.6	28.3	52.5
	Hopedale.....	Corn............	Late........	78.7	61.0	47.2	33.8	27.2	44.6
	Ontario Parish	Corn............	Early.......	66.1	57.5	26.6	22.7	34.8	60.5
	Ontario Parish	Corn............	Intermediate	71.9	59.2	38.6	32.5	26.7	45.1
	Ontario Parish	Corn............	Late........	68.6	55.9	56.3	45.7	10.2	18 2
	Urbana.......	Clover..........	Early.......	65.7	55.9	20.3	15.8	40.1	71.7
	Urbana.......	Clover..........	Intermediate	70.0	60.3	36.1	27.8	32.5	53.9
	Urbana.......	Clover..........	Late........	59.2	49.1	39.4	28.8	20.3	41.3
	Urbana.......	3d year corn.....	Early.......	56.3	49.3	21.7	18.3	31.0	62.9
	Urbana.......	3d year corn.....	Intermediate	54.4	47.1	27.2	22.0	25.1	53.3
	Urbana.......	3d year corn.....	Late........	48.4	41.4	36.5	30.2	11.2	27.1

Mean reduction in acre yield of sound corn in plots planted with Diplodia-infected seed, 21.1 ± 1.009 bushels.

$\frac{21.1}{1.009} = 20.9$. Odds greater than one million to one.

from traces to as much as 43. percent, are very significant. *These data show that seed with heavy Fusarium infection, as revealed in a properly conducted germination test, is inferior for seed purposes. Corn grown from such seed usually is susceptible to injury under unfavorable weather and soil conditions.*

CEPHALOSPORIUM-INFECTED SEED

The economic importance of the black-bundle disease of corn has been discussed by Reddy and Holbert.[81] Undoubtedly the causal organism (*Cephalosporium acremonium*) is responsible for much loss to the corn crop, altho the extent of the damage is difficult to estimate accurately at the present time. Experimental data on the behavior of corn grown from good seed and from seed infected with *Cephalosporium acremonium* suggest that seed infection with this organism, under some conditions, may cause a very material loss in the corn crop (Table 40).

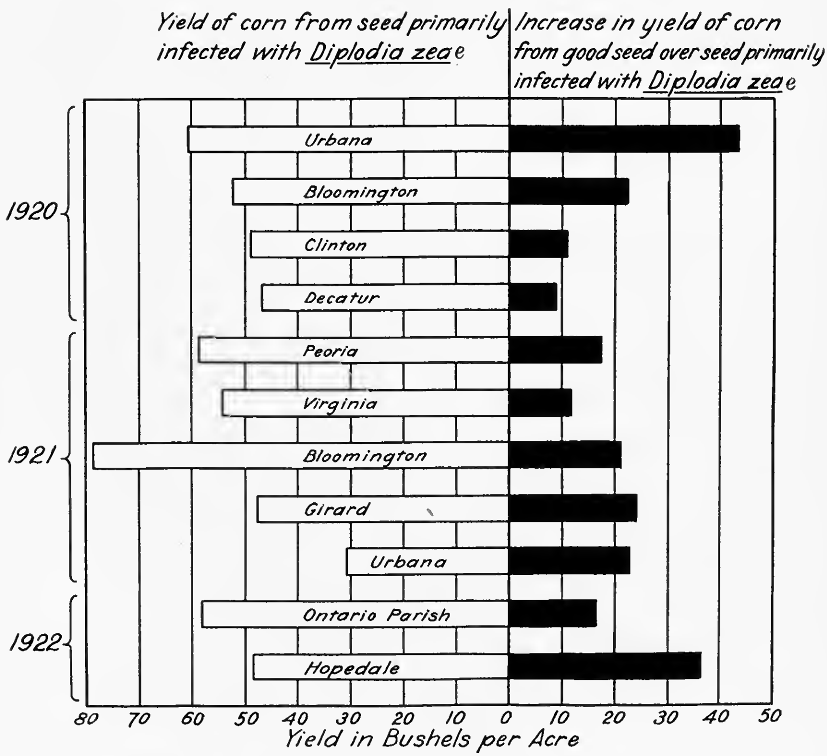


CHART 21.—YIELDS FROM GOOD SEED AND FROM DIPLODIA-INFECTED SEED (Table 38)

Under like conditions, yields of corn from good seed always are higher than those from Diplodia-infected seed.

TABLE 39.—YIELDS OF DENT CORN GROWN FROM GOOD SEED AND FROM FUSARIUM-INFECTED SEED

Year	Location of experiment (Illinois)	Previous crop	Relative time of planting	Acre yield: Good seed, Total	Good seed, Sound	Fusarium-infected seed, Total	Fusarium-infected seed, Sound	Reduction in sound corn following use of infected seed	
				bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
1921	Bloomington	Corn	Early	73.6	52.3	67.5	44.4	7.9	15.1
	Bloomington	Corn	Intermediate	69.5	47.7	62.8	42.6	5.1	10.7
	Bloomington	Corn	Intermediate	71.2	47.5	65.1	42.0	5.5	11.6
	Bloomington	Corn	Late	82.7	57.6	74.7	49.2	8.4	14.6
	Bloomington	Corn	Late	71.0	48.5	68.2	33.5	15.0	30.9
	Urbana	Corn	Intermediate	50.2	40.2	39.2	23.5	16.7	41.5
	Clinton	Corn	Intermediate	52.8	46.5	36.2	30.7	15.8	34.0
	Clinton	Corn	Intermediate	59.0	52.1	52.0	37.9	14.2	27.3
	Decatur	Clover	Intermediate	55.6	48.2	43.5	34.1	14.1	29.3
	Peoria	Clover	Intermediate	75.8	59.4	74.2	56.2	3.2	5.4
	Virginia	Clover	Late	61.8	54.6	53.1	40.6	14.0	25.6
	Bloomington	Corn, 2d year on virgin sod	Intermediate	100.0	93.7	98.2	91.0	2.7	2.9
1922	Girard	Sod	Intermediate	74.2	64.1	68.4	56.7	7.4	11.5
	Urbana	Clover	Intermediate	59.6	49.3	50.8	37.7	11.6	23.5
	Urbana	Corn	Intermediate	35.0	27.6	30.5	21.1	6.5	23.6
	Urbana	Potatoes	Early	59.2	45.0	53.9	40.3	4.7	10.4
	Urbana	Potatoes	Intermediate	58.3	44.8	51.5	36.8	8.0	17.9
	Urbana	Potatoes	Intermediate	56.1	46.6	51.2	41.4	5.2	11.2
	Urbana	Potatoes	Late	53.0	45.5	50.6	42.2	3.3	7.3
	Ontario Parish	Sod	Early	74.0	67.5	70.0	63.3	4.2	6.2
	Ontario Parish	Sod	Intermediate	77.0	71.3	73.2	63.1	8.2	11.5
	Ontario Parish	Sod	Late	72.7	67.1	63.6	60.2	6.9	10.3
	Hopedale	Sod	Early	81.4	69.5	71.5	61.3	8.2	11.8
	Hopedale	Sod	Intermediate	93.4	87.2	90.8	78.8	8.4	9.6
	Hopedale	Sod	Late	78.7	68.5	74 0	61.0	7.5	10.9
1923	Bloomington	Alfalfa	Intermediate	95.5	89.5	93.4	87.6	1.9	2.1
	Bloomington	Alfalfa	Late	97.8	88.4	97.6	79.6	8.8	10.0
	Bloomington	Barley	Intermediate	73.1	61.6	69.6	58.3	3.3	5.4
	Hopedale	Corn	Intermediate	67.4	53.9	48.9	30.7	23.2	43.0
	Hopedale	Corn	Late	78.7	61.0	60.3	43.8	17.2	28.2
	Urbana	Clover	Early	65.7	55.9	62.4	51.9	4.0	7.2
	Urbana	Clover	Intermediate	68.9	59.3	65.8	57.7	1.6	2.7
	Urbana	Clover	Intermediate	70.0	60.3	70.3	62.6	−2.3	−3.8
	Urbana	Clover	Late	59.2	49.1	56.9	46.1	3.0	6.1
	Urbana	Corn following clover	Early	60.7	52.6	54.7	47.2	5.4	10.3
	Urbana	Corn following clover	Intermediate	60.1	52.7	49.6	44.0	8.7	16.5
	Urbana	Corn following clover	Intermediate	57.9	50.4	54.0	47.2	3.2	6.3
	Urbana	Corn following clover	Late	51.4	43.3	50.3	43.0	0.3	0.7

Mean reduction in acre yield of sound corn in plots planted with Fusarium-infected seed, 7.7 ± 0.58 bushels.

$$\frac{7.7}{0.58} = 13.28.$$ Odds greater than one million to one.

TABLE 40.—YIELDS OF YELLOW DENT CORN FROM GOOD SEED AND FROM CEPHALOSPORIUM-INFECTED SEED

Grown at various points in central Illinois, 1922 and 1923

Year	Character of seed	Number of experiments	Mean acre yield		Reduction following use of infected seed		
			Total	Sound			
			bu.	*bu.*	*bu.*	*perct.*	*odds*
1922	Good..........	13	59.8	51.5			
	Cephalosporium-infected......	13	55.2	45.9	5.6	10.9	1110:1
1923	Good..........	28	61.3	52.3			
	Cephalosporium-infected......	28	57.6	48.7	3.6	6.9	908:1

EXTENT OF SEED INFECTION ON ILLINOIS FARMS

The extent of disease infection in the seed corn of Illinois again is difficult to estimate accurately. However, judging from the many hundred samples that have been sent in for germination tests, both at Urbana and Bloomington, as well as from samples secured at many corn shows during the past two years, it is safe to say that the larger part of the seed corn being used thruout the state is more or less diseased. Much of it is badly diseased and produces corn very susceptible to disease infection and easily injured by any unfavorable soil or seasonal condition. A comparatively small portion of it is excellent as regards viability, vigor in germination, and freedom from disease, and produces corn highly resistant to disease. The percentage of good seed in the lots examined by the authors during the past six years has ranged from zero to as much as 90 percent, varying with the year, locality, variety, previous selection and breeding, and other factors.

ESTIMATE OF LOSSES DUE TO CORN DISEASES

From the foregoing data and discussion it must be realized that it is exceedingly hazardous to attempt to make any estimate of the combined total losses due to all the diseases under discussion in this bulletin. Holbert[44] has made the following statement: "Those in close touch with the situation feel that these rots are cutting the yields of corn in the state fully 15 percent."

The Office of Plant Disease Survey[78] placed the loss from all corn diseases in Illinois at 13.5 percent for the year 1921. *On the basis of all data reported in this bulletin, as well as on the basis of observations made thruout Illinois for a period of years, the authors feel that where inferior and infected seed is used, losses to the corn crop from disease, including smut and rust, can very conservatively be placed at 20 percent.*

PART IV

EXPERIMENTAL CONDITIONS AND METHODS

EXPERIMENTAL PLOTS

The comprehensive field experiments herein reported were conducted principally on the University South Farm at Urbana, and on the Funk Farms at Bloomington, Illinois. In addition to the many projects conducted at these two places, numerous experiments have been located and supervised in various localities thruout the state (Fig. 54) where effective cooperation could be established with corn breeders, farm bureau organizations, and other agricultural agencies. More recently a number of the University of Illinois soil fields have been used for the cooperative investigations of corn diseases, soil treatment, and soil management problems.

UNIVERSITY SOUTH FARM

On the University South Farm at Urbana, several series of plots devoted primarily to special crop production experiments are laid out to show the effects of certain soil treatments, such as the application of limestone and rock phosphate. Various systems of crop rotations are employed and the crops are so handled as to exemplify the two general systems of farming, grain and live-stock.

Four different rotations are being studied on these fields. The first, designated as the Northwest rotation, is a system of cropping in which the alfalfa remains down for six years and the primary part of the rotation, comprizing corn, soybeans, and potatoes, completes two cycles before the alfalfa is moved to another field. The second, or North-Central rotation, consists of corn, corn, spring grains, and clover. This represents a very common rotation. The third, or South-Central rotation, consists of corn, corn, corn, and soybeans, and should be regarded as an undesirable rotation because of the three years of corn. The fourth is known as the Southwest rotation and is considered one of the most desirable types. It is a four-crop system consisting of wheat, corn, oats, and clover.

The general soil treatment in all these rotations consists of rock phosphate, crop residues, and manures, with a light initial application of limestone.

BLOOMINGTON FIELDS

Opportunity was afforded on the Funk Farms for selecting field plots from a very wide range of choice sites. The areas occupied by these various field experiments ranged in size from a small plot to as much as 30 acres, depending on the objects of the particular series of experiments. Previous cropping varied from native grasses on virgin prairie sod to ground on which there had been continuous corn for seven years. Inasmuch as all standard rotations of the corn belt are represented on these farms, it has been possible, in practically every instance, to outline the experiments and then to choose suitable uniform land on which to conduct the field work. The soil used on the Funk Farms was of the brown silt loam type. All cultural operations on the experimental plots were under the direct supervision of the investigators.

OUTLYING FIELDS

In the early experiments the outlying fields (Fig. 54) were all located on uniform soil mostly of the brown silt loam type. In the more recent experiments, however, additional representative soil types have been included. Altho the outlying fields did not receive the constant attention that was given the experimental plots at Urbana and at Bloomington, they were well supervised and it is believed that the data from these fields are reliable. Where there was any question about the field technic at any time during the season, the data were discarded.

SOIL CONDITIONS

The term "clean" soil, as used in this bulletin in contrast to infested soil, refers to such ground as has been cropped neither with small grains that were scabby (Fusarium head blight) nor with corn for at least five years. In some cases the land was virgin prairie soil; in other cases it had been in pasture for a period of years or had been cropped with clover and other miscellaneous crops. Such soil is reasonably free from corn disease pathogenes. Whenever the terms "clean" and "infested" soil are used

FIG. 54.—LOCATION OF EXPERIMENTS

in connection with experiments discussed in this bulletin, the specific previous cropping is mentioned in that connection.

STRAINS OF CORN USED

Varietal names of the different strains of yellow dent corn used in the experiments herein reported have been avoided purposely. All the strains originally came from Reid's Yellow Dent. It is well known that a strain of corn can be considered to be the same strain only so long as it is selected with the original ideal in view. Very generally a strain loses its identity soon after it leaves the original producer. Mr. Reid himself changed the standard of his yellow dent several times

FIG. 55.—MULTIPLE TRAY GERMINATOR IN OPERATION

The primary purposes of the germinator are to show the presence or absence of disease and the vigor or lack of vigor of the seedlings.

during his lifetime. During the first thirty years of his work he selected for a rather smooth, horny type,[28,31] possessing a number of those ear character that later have been found to be associated with disease resistance. Later he was overruled by other members of the Illinois Corn Breeders' Association, who were confident that the rough ear was a better and more profitable ear to grow. Mr. Reid reluctantly selected toward a rougher type until 1909, when at the Illinois Corn Breeders' Association Mr. E. D. Funk[28] presented seven years' experimental data giving concrete proof that the smoother type, under his selection, had superior yielding ability. It is said that Mr. Reid danced like a school boy, saying, "I told you so." Mr. Reid immediately and enthusiastically went back to growing his smoother type, but, unfortunately, it was the last year of his life.

The nearly disease-free seed used for the control plots in these experiments was from a strain of corn which had been carefully selected over a period for those plant and ear characters that have been found to be associated with productivity, freedom from disease, and disease resistance. These characters are described in detail elsewhere in this bulletin under "Value of Physical Appearance as a Basis for Selection," page 431. Other strains used had been selected toward somewhat different standards, while still others had not been selected toward any definite type. Thus it has been deemed advisable not to use varietal names, which in most cases would mean nothing and might be misleading. However, each type or strain used in the experimental work is described as to ear characters and in most cases is illustrated by a typical ear.

GERMINATION AND SELECTION OF SEED

Description of Germinator

Seed corn for all the experiments reported in this bulletin was tested for viability and disease symptoms on a limestone-sawdust germinator, a development of the table germinator described by Holbert and Hoffer,[47] which was used in the tests previous to 1921. The improvements greatly increased the capacity of the germinator but its fundamental principle remained the same. A series of trays made to slide into an upright framework takes the place of the tables (Fig. 55). These trays are spaced seven inches apart, ten trays in an upright tier. The dimensions of each tray are 3 by 4½ feet by 2 inches deep. The bottoms of the trays are made of four slats, on which strong hardware cloth is first laid, and over this a layer of wire mosquito netting. Well leached sawdust, one inch deep, is then put in the trays, and over this is spread just enough limestone to cover the sawdust.

A sheet of heavy unbleached muslin is placed on each of the trays of the germinator just before putting on the seed. The seed is covered with a lighter piece of unbleached muslin. Before the muslins are used for the first time and each time thereafter, they are boiled in water for an hour and put thru a clothes wringer just before using.

With such a large extent of wet surface in the germinating room, the relative humidity is very high, and for this reason the burlap covering which on the old table germinator was used in addition to the muslin is dispensed with. The trays are watered three times daily at eight-hour intervals. A fine spray nozzle such as is used with power-spraying machinery is connected directly with a city water hydrant and gives excellent results. The water passes thru a large pressure tank located in the germinator room, by which arrangement lukewarm water is available at all times for watering the trays. Each test is continued for a period of seven days, at a temperature of 85° F. An automatic thermostat control keeps the temperature practically constant.

TESTING THE EARS

Ten kernels are removed in a spiral from butt to tip of each ear to be tested. These kernels are laid out in a straight row on a germinator tray with about an inch space between kernels. The distance between rows, however, is at least three inches. Each test is later repeated by taking another ten kernels from a different spiral on the same ear. In some of the experiments herein reported each ear was tested four times, making a total of forty kernels per ear. A slightly different technic is used in preparing the Diplodia composites.

In making the germination readings the factors considered are: viability; size and diameter of plumule; number, length, and branching of roots; presence of parasitic fungi; and extent of rotting caused by these fungi.

The term viability, as used in this bulletin, refers to the ability to germinate and grow regardless of the kind of growth.

SELECTION OF SEED

Each year germination tests were made of many hundred ears, and on the basis of these tests a large number of ears were selected to represent the various kinds of infected ears and the nearly disease-free ears. These groups of ears were known as composites, and from them seed packets were made according to the outline of the experiments of that season. These packets were made up so that each contained the same number of kernels from each ear in its respective composite. Following is a discussion of these various composites.

GOOD-SEED COMPOSITES

Ears of which the germinated kernels produced strong plumules of good diameter and an abundant, vigorous root system, and which showed a bright external appearance of the kernels with no sign of discoloration when the kernels were cut lengthwise thru the middle, were classed as nearly disease-free ears. The viability on the germinator was always 100 percent (Fig. 1 and Plate I). The term "nearly" is used because some types of infection perhaps may escape detection on the germinator, and furthermore, infection in slight forms may sometimes be local on an ear, and the infected section may not be represented by any of the kernels tested. Unless otherwise specified, the nearly disease-free seed was selected from apparently disease-free plants and possessed those physical characteristics, later herein described, that were found to be associated with freedom from disease and disease resistance. In this bulletin the term "good seed" is used synonymously with the term "nearly disease-free seed."

SCUTELLUM ROT COMPOSITES

The scutellum rot composites were made up of ears that had 57 to 70 percent of the kernels scutellum-rotted on the germinator (Fig. 2 and Plate I), and only traces of *Fusarium moniliforme* and *Diplodia zeae* infection. The viability on the germinator was from 95.5 to 100 percent.

FUSARIUM-INFECTED COMPOSITES

The Fusarium-infected composites were made up of ears ranging from 57 to 92 percent in Fusarium infection (Fig. 22 and Plate I), but showing no Diplodia infection and only traces of scutellum rot. The viability was from 97 to 98 percent.

CEPHALOSPORIUM-INFECTED COMPOSITES

The Cephalosporium-infected composites ranged from 65 to 95 percent in infection and from 99 to 100 percent in viability. The seedlings had a good appearance on the germinator and might have been passed as nearly disease-free seed by an inexperienced person. It is true that when this fungus grows on kernels in conjunction with other organisms such as *Fusarium moniliforme, Diplodia zeae,* or *Rhizopus* spp., it easily escapes detection by the usual macroscopic examination. However, the Cephalosporium composites used in these experiments were made up of ears selected by microscopically examining germinating kernels and choosing ears that were infected with this organism only.

DIPLODIA-INFECTED COMPOSITES

A slightly different technic was used in preparing the Diplodia-infected composites. In the previously described composites the ear was considered the unit, and the whole ear was either used or rejected. Ears severely infected with Diplodia cannot be used for field experiments because the kernels are dead. Slightly infected ears generally show three successive zones when tested on the germinator: first, there may be a portion in which infection has progressed to such an extent that the kernels are dead; next, there is a zone that is infected but still viable; and, third, there may be an uninfected zone (Fig. 56). Ears which showed the presence of *Diplodia zeae* when given a germination test in the usual manner were retested by taking ten kernels in a straight row from opposite sides of each ear (Fig. 56) and placing these kernels in two parallel rows on the germinator. By this method it was determined whether infection and zonation were uniform around the circumference of the ears. The kernels from the zones that were dead and also those from the zones that were not infected were then removed and the remainder were used in preparing the Diplodia-infected composites.

The Diplodia-infected composites ranged from 64 to 86 percent in infection with *Diplodia zeae* and from 87 to 92 percent in viability.

MODERATELY DISEASED COMPOSITES

In data obtained from the experiments up to and including 1920, the term "moderately diseased" is used. The diseases concerned were principally of the scutellum-rot type but there was some Fusarium, Diplodia, Cephalosposium, and perhaps other infections. In none of the seed lots, however, was the proportion of infected kernels greater than 50 percent, and in every case the viability was 99 percent or over.

HORNY AND STARCHY COMPOSITES

The horny composites were made up of corn that showed three-fourths or more of each kernel, as viewed on the side opposite the germ, to be of horny composition (Plate IV). The starchy composites were made up of corn that showed half or more of each kernel, when examined in a similar way, to be starchy.

The term "horny," as used in this bulletin, refers to the corneous starchy portion of the endosperm. The term "starchy" refers to the soft, white starchy portion found mostly in the crown portion of the endosperm. The horny part is more translucent than the starchy portion and in yellow corn is of a much deeper shade. It is well known, of course, that neither portion is purely starch. Hopkins, Smith, and East[50] have reported in detail on the structure and composition of the corn kernel, and their data show that the horny portion is richer in protein than the soft, starchy portion, while the latter has a higher percentage of ash.

PLANTING AND CULTURAL METHODS

All plots except those at Urbana were planted in hills 42 inches apart each way, and except in a few cases, at the rate of three kernels per hill. At Urbana they were planted in hills 40 inches apart each way and at the rate of two kernels per hill. To insure an accurate drop, all plantings were made by means of specially designed hand planters, having a funnel at the top and a tube leading to the outlet.

The usual size of these plots was 4 rows wide by 10 hills long. Alternate with every plot planted with infected or inoculated seed was a plot of the same size planted with nearly disease-free check seed, or uninoculated seed. These were replicated a number of times, in most cases a large number of times, so that some experiments numbered 420 individual plots.

The stand was not thinned or tampered with in any way. No seed was used that did not have a very high percentage of germination.

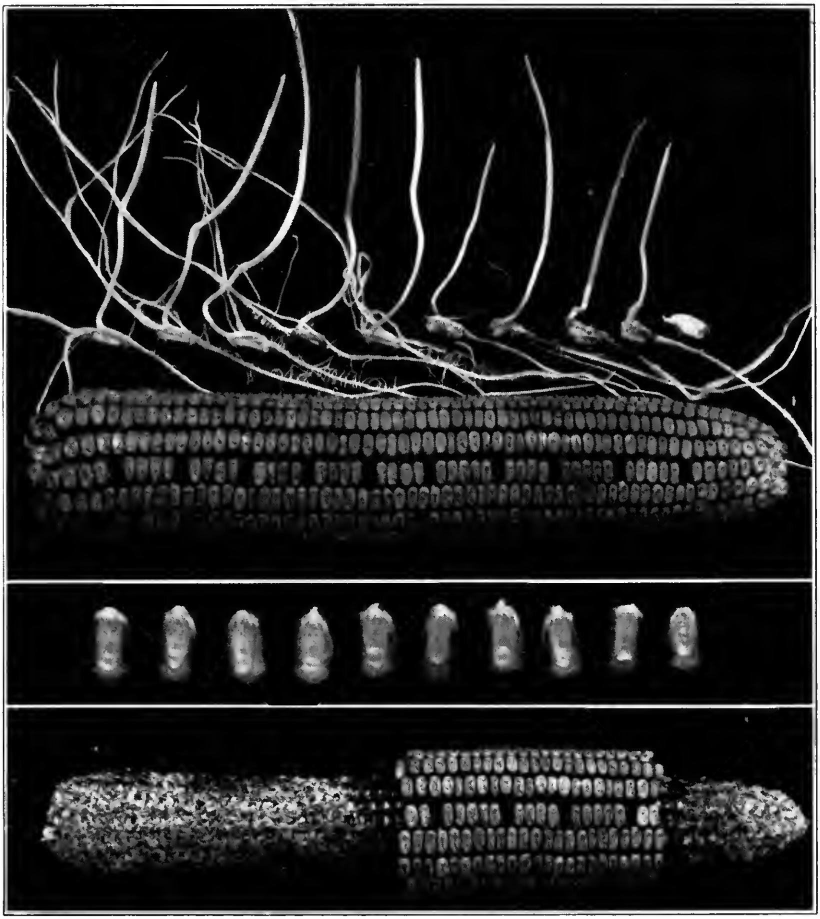


FIG. 56.—PREPARATION OF DIPLODIA-INFECTED SEED COMPOSITE

(Above) Diplodia-infected ear, showing manner in which kernels are taken out. A similar row is taken out on the opposite side of the ear, and both sets of kernels are germinated at the same time. The row of germinated kernels shows that the tip half of the ear is infected. (Center) An enlarged view of ten of the kernels from this ear. (Below) The part of this ear that is used in the Diplodia-infected composite. The butt half was taken off because it showed no infection, and the tip was removed because infection had progressed to the point where the kernels would not germinate.

One of the effects of corn disease is an increased percentage of weak and blighted plants. By planting thick and later thinning out the weak plants a disproportional part of the diseased plants is eliminated, thereby partly controlling the disease. As such a method of control is worthless to the corn grower in the corn belt because it could not be put into practical operation, it was avoided in all experiments where yield data were to be obtained.

Great care was exercised thruout the season to avoid mechanical injury to the plants during cultivation, and to guard against insect pests and rodents. Whenever there was any appreciable amount of damage due to any of these causes, that part of the experiment or the whole experiment, as the case happened to be, was discarded.

HARVESTING METHODS

In all the experiments the entire population from each plot was harvested. In several experiments the outer two rows of each plot were harvested separately in an attempt to determine the border effect. As the stand was fairly even in all the plots, the border effect was either lacking or very small and was insignificant in view of the probable errors involved (Table 42). Therefore it was deemed advisable to use the entire yield rather than the yield of the central rows only, as the advantages gained in accuracy by working with a larger population more than offset any border effect that may have occurred.

When the corn was harvested it was put into open-meshed onion bags and the bags were sewed up. These were then taken into a warm building and placed on a frame of slats at some distance from the floor to allow free circulation of air. Later in the season the corn was separated into marketable and unmarketable grades, and shelled.

TABLE 41.—BORDER EFFECT IN CORN PLOTS, BLOOMINGTON, 1921

Four rows were planted in each plot and every alternate plot was planted with nearly disease-free seed. The yields from the outer and the inner rows were weighed separately.

Experiment	Condition of seed	Number of replications	Acre yield: Outer two rows	Acre yield: Inner two rows	Difference	Difference / Probable error
			bu.	*bu.*	*bu.*	
A	Nearly disease-free.........	10	99.9 ± 1.5	97.1 ± 1.0	2.8 ± 1.8	1.6
	Moderately diseased.......	10	82.7 ± 1.0	83.0 ± 1.6	0.3 ± 1.9	0.2
B	Nearly disease-free.........	9	100.3 ± 1.3	98.0 ± 1.6	2.3 ± 2.1	1.1
	Moderately diseased.......	9	80.3 ± 1.8	78.8 ± 1.0	1.5 ± 2.0	0.7

Its moisture percentages were then determined, and the yields calculated on the basis of shelled corn reduced to a uniform moisture content. Exceptions were made in the case of some of the outlying experiments in other parts of the state where this procedure could not be followed. In these cases the experiments were harvested rather late in the season when the ears had dried considerably, and yields were based on the air-dry weight of ear corn.

Beginning with 1920, all yields were separated into marketable (sound) and unmarketable grades. This technic is illustrated and described in detail by Holbert et al.[18] The unmarketable grade included sound nubbins less than half the length of a normal-sized ear for the variety, or larger ones that were poorly filled, ears or nubbins with an appreciable amount of ear rot, and chaffy ears or nubbins. There is usually a higher percentage of unmarketable corn in the yields from diseased seed than from disease-free seed. Unless this separation is made, therefore, the differences in the economic values of the yields often are not shown by the data.

STATISTICAL ANALYSIS

Hall and Russell[34] state that "an experiment may be defined as a question put to Nature; but tho we may say that Nature never lies, that is only true in so far as we have put the right question and interpreted the answer correctly." If it is assumed that in the experiments reported in this bulletin the right question has been put, then the correctness of the answer sought from nature will hinge on the *interpretation* of the results obtained.

In field trials it is common experience to find considerable variation in yields of plots given the same treatment or planted to the same variety, due mainly to variation in soil. For this reason, more accurate comparisons are made if the test with the variety or treatment is replicated, for of course an average of several results is much nearer the truth than any single result. The more numerous the replications, the more justification for applying the statistical method to their yields.

The interpretation of experimental results is concerned with the significance or non-significance of differences in the results obtained from the treatments or varieties under comparison. In dealing with variables, we must necessarily deal with a large number of causes that bring about variation. If, in a field experiment, all causes of variation could be removed so that any differences obtained would be due wholly to the factor being tested, interpretation of the results would of course be clear and unmistakable. So many external causes, however, are constantly at work to bring about variation that uncertainty always exists regarding the correct interpretation of the results. The determination of the probable error is believed to remove this uncertainty to a large extent.

The probable error is an expression of the reliance that can be placed in the results of an experiment. In the words of Babcock and Clausen[3] the probable error "is an arbitrary term used to denote the amount that must be added to or subtracted from the observed value to obtain two limiting figures of which it may be said that there is an even chance that the true value lies within or without these limits." Such limiting figures include approximately one-half of the distribution. If twice the probable error be added to or subtracted from the observed value, the chances that the true value lies *within* rather than outside these limits increases to 4:1; and with three times the probable error, to 21:1. In this bulletin a result which differs from the observed value by 3.2 (or more) times the probable error is regarded as significant.

The probable errors given in this bulletin were calculated by the following formula, except where otherwise indicated:

$$E = \pm 0.8453 \frac{\Sigma V}{N\sqrt{N-1}},$$

where ΣV is the sum of the variations from the mean, and N the number of variates. This is commonly known as Peter's formula. It is preferred to Bessel's formula,

$$E = \pm 0.6745 \sqrt{\frac{\Sigma V^2}{N(N-1)}},$$

because there is a considerable saving of time in making the calculations. Furthermore, the values of E obtained by the two formulas are practically the same.

When it is desired to compare two values (as means or standard deviations), each with its own probable error, the difference between them is first determined and the probable error of this difference calculated by the formula—

$$E \text{ of difference} = \pm \sqrt{E_a^2 + E_b^2},$$

where E_a is the probable error of one of the values under comparison, and E_b is the probable error of the other. The difference is then divided by the probable error of the difference to determine how many times greater the former is than the latter. If this quotient is as much as 3.2 or greater, the difference between the values under comparison is considered great enough to be significant. The odds of probability corresponding to the quotients $\frac{\text{Difference}}{\text{E of Difference}}$ are given in Table 41.

An example will make the application clear. In Table 6 in the planting of May 14, two yields are given—66.3 ± 1.2 and 52.9 ± 3.0 bushels. The difference between these two yields is 13.4 bushels and the probable error of this difference is 3.2 bushels. The difference, 13.4, is four times the probable error of the difference, 3.2, and hence is sufficiently great in comparison with the probable error of this experiment to justify the conclusion that this increase in yield is due to real superiority in yielding ability and not to favorable location in the field, so far as such factors as soil fertility or soil moisture are concerned.

A number of experiments reported in this bulletin are concerned with the comparison of good seed with seed infected with any one of the several organisms causing corn root, stalk, and ear rots. These experiments have been conducted at different locations during the same year and in different years. Obviously the variations in yield of good seed or diseased seed under these conditions are not such as can be treated by the method just described. There are two ways of treating such data, as Love[64] has pointed out. In one, the differences can be calculated for paired plots, and the probable error of these differences determined by Bessel's formula in the usual way. The

TABLE 42.—PROBABILITY OF OCCURRENCE OF STATISTICAL DEVIATIONS OF DIFFERENT MAGNITUDES RELATIVE TO THE PROBABLE ERROR

Deviation divided by probable error	Probable occurrence of a deviation as great as or greater than the designated one in 100 trials	Odds against the occurrence of a deviation as great as or greater than the designated one	Deviation divided by probable error	Probable occurrence of a deviation as great as or greater than the designated one in 100 trials	Odds against the occurrence of a deviation as great as or greater than the designated one
1.0	50.00	1.00 to 1	3.5	1.82	53.95 to 1
1.1	45.81	1.18 to 1	3.6	1.52	64.79 to 1
1.2	41.83	1.39 to 1	3.7	1.26	78.37 to 1
1.3	38.06	1.63 to 1	3.8	1.04	95.15 to 1
1.4	34.50	1.90 to 1	3.9	0.853	116.23 to 1
1.5	31.17	2.21 to 1	4.0	0.698	142.26 to 1
1.6	28.05	2.57 to 1	4.1	0.569	174.75 to 1
1.7	25.15	2.98 to 1	4.2	0.461	215.92 to 1
1.8	22.47	3.45 to 1	4.3	0.373	267.10 to 1
1.9	20.00	4.00 to 1	4.4	0.300	332.33 to 1
2.0	17.73	4.64 to 1	4.5	0.240	415.67 to 1
2.1	15.67	5.38 to 1	4.6	0.192	519.83 to 1
2.2	13.78	6.26 to 1	4.7	0.152	656.89 to 1
2.3	12.08	7.28 to 1	4.8	0.121	825.45 to 1
2.4	10.55	8.48 to 1	4.9	0.095	1 051.63 to 1
2.5	9.18	9.89 to 1	5.0	0.074	1 350.35 to 1
2.6	7.95	11.58 to 1	6.0	0.005 2	19 230.00 to 1
2.7	6.86	13.58 to 1	7.0	0.000 23	434 782.00 to 1
2.8	5.90	15.95 to 1	8.0	0.000 000 068	1 470 588 234.00 to 1
2.9	5.05	18.80 to 1			
3.0	4.30	22.26 to 1			
3.1	3.65	26.40 to 1			
3.2	3.09	31.36 to 1			
3.3	2.60	37.46 to 1			
3.4	2.18	44.87 to 1			

mean difference divided by the probable error of this difference gives a quotient, from which the odds can be readily interpolated from Table 42 (Pearl and Miner).[77] In the other way of treating such data, a method known as Student's[100] can be used. In this method the individual differences between the paired items are determined as above, and squared; the sum of the squares is then divided by the number of differences, and from the quotient the square of the mean difference is subtracted. The square root of the remainder is the standard deviation (Grindley and Mitchell).[32] The next step is to find the value *Z,* which is the ratio between the mean deviation and the standard deviation. Student[101] has computed a table of probabilities for values of *Z* for any number of differences from 2 to 30, and from this table the odds that the difference between the plots compared is large enough to be significant can be readily interpolated. Odds of 30 to 1 or better are accepted in this bulletin as indicating significant gain or reduction.

PART V

PHYSICAL CHARACTERS OF SEED EARS ASSOCIATED WITH SEED INFECTION AND NONINFECTION

EARLY WORK ON THE GERMINATOR TO DETECT NONINFECTION AND SUPERIOR VIGOR

During the earlier years of the investigations reported in this bulletin, it was the privilege of the senior author to supervise the selection and germination of many thousands of bushels of seed corn for Mr. Eugene D. Funk. At that time the principal objective was to find any relation that might exist between the appearance of corn on the germinator and its performance in the field. Many experiments were conducted that gave nothing of value. Others, however, suggested lines of attack that have since proved very productive.

Performance of Germinator-Selected Ears

During the winter of 1915-1916, fifty ears were selected irrespective of physical appearance but the kernels from which were the most vigorous and most nearly disease-free on the germinator. These fifty ears probably represented the best germinating ears out of more than one hundred thousand ears tested at that time. The fifty ears were then retested and only the superior half of them were saved. The following spring these twenty-five carefully selected seed ears were included in experiments along with more than a thousand ears of fancy appearance which were prized highly on account of their size, symmetry, and uniformity of type. The thousand ears had been germinated to determine viability only. No attempt had been made to eliminate those ears which showed a moldy condition on the germinator, since at that time this condition was not known to be particularly significant.

Much to the surprise of the investigators, the corn grown from the twenty-five ears selected on the basis of vigor of germination and freedom from infection, as well as viability, proved to be superior in both yield and quality to the corn grown from the seed ears selected on the basis of appearance.

These experiments were repeated the following year with a much larger number of ears from different sources representing several standard varieties of field corn. Results again were decidedly in favor of corn selected from the germinator on the basis of vigor and freedom from disease, as well as viability. A few of these original germinator-selected ears are shown in Fig. 57.

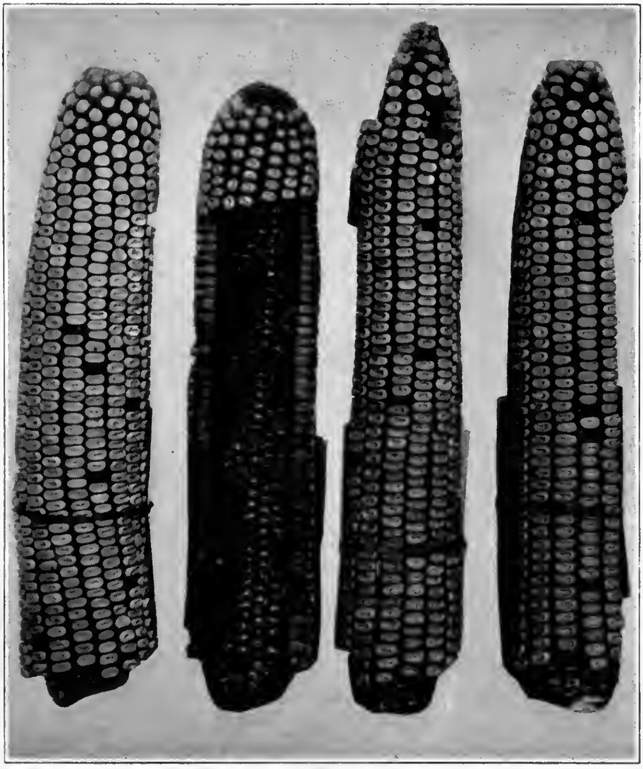


FIG. 57.—EARS SELECTED ON THE BASIS OF PERFORMANCE ON THE GERMINATOR

The corn grown from ears selected on the basis of germination and freedom from infection, as well as viability, on the germinator, proved to be superior in both yield and quality to the corn grown from the seed ears selected on the basis of appearance.

Physical Appearance of Germinator-Selected Ears

Much to the disappointment of the investigators, at that time, the seed ears selected on the basis of their germination record were anything but ideal from the standpoint of conformity to commonly recognized standards. The ears were of mid-smooth to smooth indentation and possessed bright kernels of horny composition. They also were decidedly smaller in circumference in proportion to length than the ears that had been selected up to that time for breeding purposes.

RELATION OF GENERAL APPEARANCE OF SEED EARS TO SEED CONDITION

As a result of the various experiments with healthy and diseased corn, both in the field and in the laboratory, it was noted that certain physical characters of seed ears were correlated with certain performances on the germinator and in the field. In 1919-1920 an experiment was conducted to determine more definitely the relation between the physical appearance of seed ears and their infection or freedom from infection. Approximately 600 ears of yellow dent corn which had been carefully selected in the field from good stalks and stored on racks, were classified on the basis of their physical appearance as apparently good or apparently diseased. These ears then were germinated under uniform conditions. At the end of the germination test they were reclassified on the basis of their record on the germinator (Table 43). Of the ears that had been classed as apparently good, 86.9 percent proved to be relatively disease-free on the germinator, while of the ears that had been classed as apparently diseased, only 37.9 percent proved to be relatively disease-free on germination.

The above results led to a more critical study of the physical characteristics of a large group of ears classified on the basis of the germinator test, as diseased, moderately diseased, and disease-free.

Table 43.—Effectiveness of Selecting Seed Corn on the Basis of Physical Appearance as Determined by Later Tests on the Germinator

All ears were selected from good mother plants and properly stored in the fall of 1919. Germination tests were made in the spring of 1920.

Ear classification on basis of physical appearance	Ear classification on the basis of germination record	
	Relatively disease-free	Diseased
	perct.	*perct.*
Apparently good	86.9	13.1
Apparently diseased	37.9	62.1

These studies are reported in Tables 44 to 50. No ears were included in the diseased groups that did not have high viability. The 80 ears reported in Table 44 were selected from 2,500 ears that were tested regardless of physical appearance. The 95 ears reported in Table 45 were selected from approximately 1,000 ears. Ears reported in Table 47 and 48 were those from which nearly disease-free seed composites and the composites primarily affected with scutellum rot were made for 1920, 1921, and 1922. Of the diseased ears the percentages of kernels affected with scutellum rot on the germinator in the three respective years were 26.4, 50.6, and 57. Of the nearly disease-free composites, the percentages of affected kernels were 1.3, 3.5, and 4.6 percent, respectively. The viability in the case of the nearly disease-free ears was 100 percent thruout the three years. These ears showed no evidence of either Fusarium or Diplodia infection.

Ears whose physical characteristics and laboratory germination records are given in Tables 49 and 50, comprized the Fusarium-infected, Diplodia-infected, and good-seed composites used in the many experiments thruout the state under the supervision of the authors in 1921 and 1922. They were all from the same strain of corn. For the most part, the ears had been selected in the field from desirable plants. Fig. 67 illustrates the appearance of a few representative ears from which the good-seed composites planted in 1921 were made.

Of the many characters recorded and studied, those in which the disease-free ears differed most consistently from ears known to be infected were: (1) luster of ear, (2) shank attachment, or nature of butt of cob, (3) characteristics of tip of ear, (4) type of kernel indentation, (5) nature of endosperm, and (6) luster of kernel.

LUSTER OF EAR

Disease-free ears of good viability and vigor that have matured normally on healthy plants have a bright, rich luster. On the other hand, ears that have come from root-rotted and stalk-rotted plants usually present a dry, dull appearance after curing. This difference in luster is particularly apparent when disease-free and diseased ears are compared side by side. Considerable experience in comparing ears known to be infected and ears known to be free from infection is necessary to fix the proper standard of luster in the mind of the worker, but when once established, this difference in physical appearance may be used to great advantage as one determining factor in the selection of seed corn.

SHANK ATTACHMENT

The shank is a very important organ of the corn plant. It not only supports the ear but is the structure thru which food materials are conducted to the ear. Surrounded by both leaf sheath and husks, it

FIG. 58.—BROKEN AND ROTTED SHANKS

When weakened by local rotting, the shank often breaks or crumples under the weight of the ear and no longer is able to function normally.

usually is encased in a film of moisture. Both dew and rain, as well as pollen and dust, are retained in the cavities surrounding the shank. Thus fungus spores lodging near the base or middle of the shank have an environment very favorable for germination and growth. This fungus growth not infrequently may start on the outside of the shank, invade its tissues, and cause local infections. The extent of infection depends on several factors, chief of which are the nature of the fungi and the resistance of the plants attached.

If the shank is weakened in any way, either by mechanical injuries or by physiologic disturbances in the plant, it usually is more readily invaded by fungi. When weakened by local rotting, the shank often breaks or crumples under the weight of the ear (Fig. 58) and

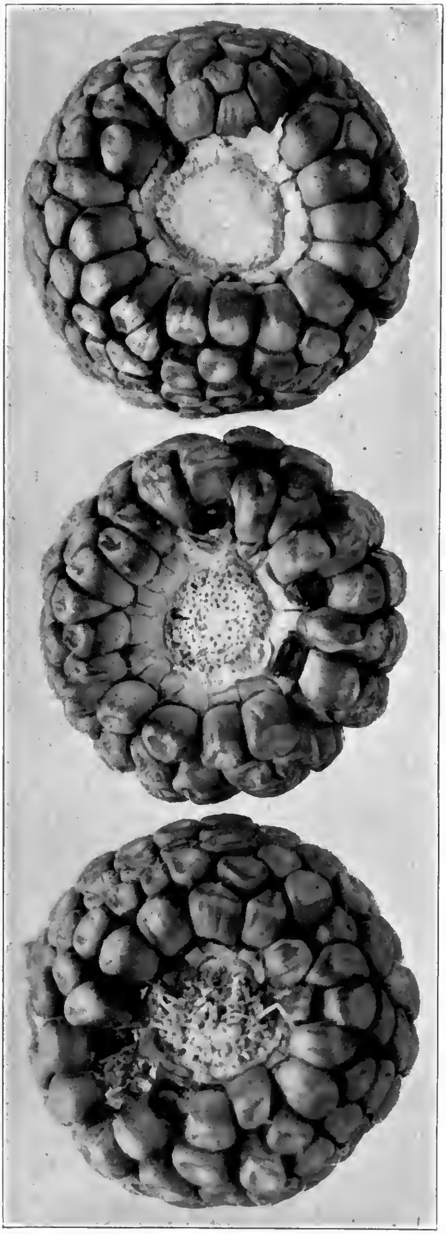


FIG. 59.—THREE SHANK ATTACHMENTS
Above, bright healthy condition; center, dark vascular bundles associated with Cephalosporium; below, a shredded condition indicating that the ear came from a rotted and prematurely dead shank.

no longer is able to function normally. Such injuries frequently are the cause of light, chaffy ears that would not be considered for seed. But where the injuries occur late in the development of the ear, the reduction in quality of grain may not be so apparent. If the infecting organism is *Diplodia zeae*, the shank and the butt of the ear may be badly rotted.

Ears selected from plants with rotted or partially rotted shanks have a more or less discolored or shredded shank attachment (Fig. 59 and Plate IV). The kernels on ears with such shank attachments may or may not actually be infected. Judged on the basis of viability, vigor, and freedom from infection, as shown in this study, the percentage of desirable seed ears with badly discolored or shredded shank is comparatively low (Tables 46 and 51). Altho some badly diseased ears were found with bright shank attachments, the percentage of such ears also was low (Tables 44, 45, 46, 47, and 49, and Chart 22). *The data from these experiments indicate that good seed ears have bright, clean shanks or shanks with only slight discolorations* (Plate IV).

EAR-TIP COVERING

Ears whose tips are exposed to the weather before maturity (Fig. 60) often are

PLATE IV

A   A clean, sound shank is an important consideration in the selection of good seed corn.

B   Slightly pink shank.

C   Pink shank

D   Brown shank

E   Shredded shank

F   Moldy shank

Good seed ears have bright clean shanks or shanks with only slight discoloration.

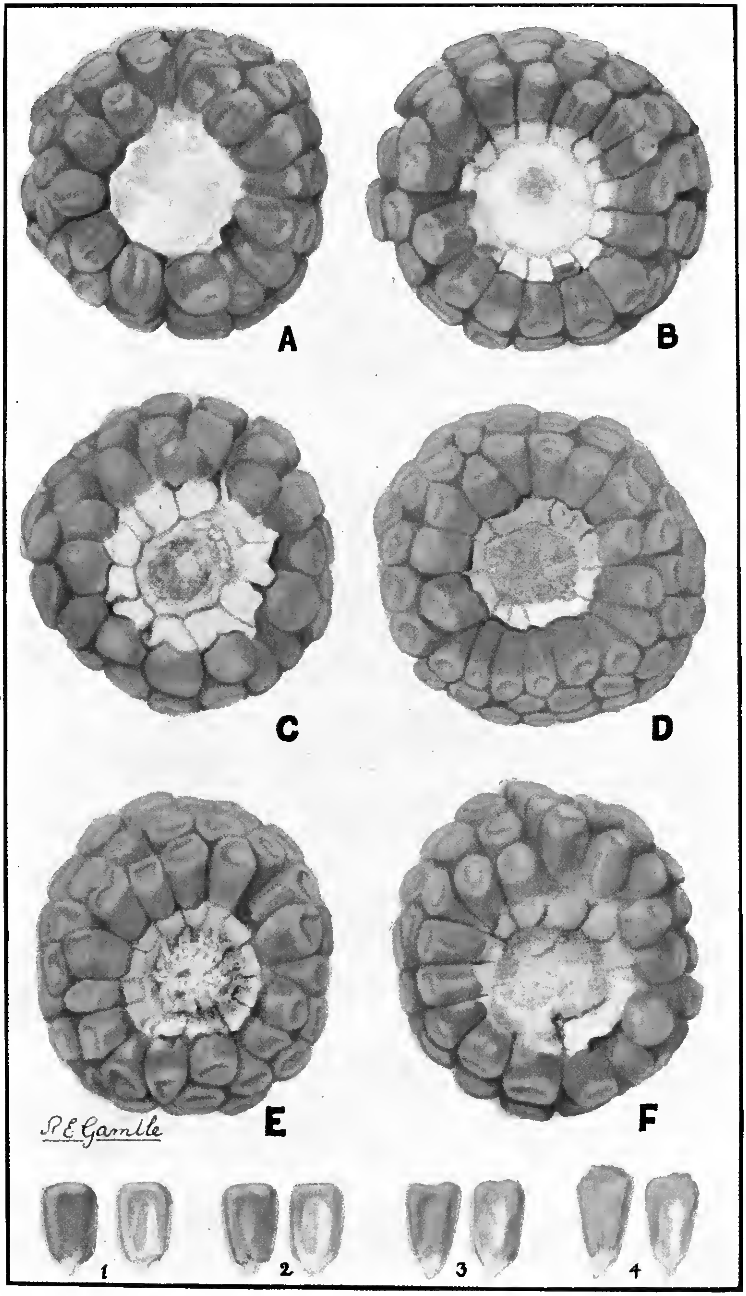
1   Horny seed

2   Moderately horny seed

3   Moderately starchy seed

4   Starchy seed

Disease resistance has been found to be rather generally associated with seed from apparently healthy plants that is nearly disease-free, horny, and shows vigorous germination.


A
B
C
D
E
F
P E Gamble
1
2
3
4

infected with *Fusarium* spp. and *Diplodia zeae*. Such local infections vary in extent from a few kernels to the whole ear. Classifications made in these studies showed that the tips of a large proportion of the infected and diseased ears had been exposed (Tables 44, 45, 46, 47, and 49, and Chart 22). Both data from experiments on the physical characters of seed ears and general experience of corn breeders indicate that it is highly desirable, from the standpoint of freedom from infection, that the tips of ears should be well covered by the husks as a protection from the weather and fungus infection.

KERNEL INDENTATION

For many years the indentation of the corn kernel has been the subject of much discussion, controversy, and experimentation. Experiments relating to this specific character are reviewed elsewhere in this bulletin. From the standpoint of best yields and quality, the evidence of much experimentation favors long, smoothly dented ears, with large well-developed kernels of medium depth. It has been found in these investigations, covering a period of years, that careful testing for viability, vigor, and freedom from disease has almost invariably resulted in the selection of corn of medium smooth to smooth indentation, regardless of source and previous breeding. Such a statement does not imply that ears of smooth indentation have always been free from infection or even relatively disease-free. Some smooth corn is badly diseased and decidedly inferior in quality.

Comparatively few ears of rough indentation have been found to pass repeated germination tests that considered vigor and freedom from disease. Rough ears that have passed such tests at this Station have proved to be rather susceptible to ear rots in the field. They also have shown no superiority in yielding ability to the ears more smoothly dented. Data presented in Tables 44, 45, 46, 47, and 49, and Chart 22 show that 95 to 100 percent of the disease-free seed ears were mid-smooth to smooth in indentation. These data are supported also by many data and much experience of the authors not herein reported, and by the experience of many other workers thruout Illinois.

NATURE OF ENDOSPERM

Kernel structure and composition, as determined physically by the quantity of vitreous, or horny, endosperm (Plate IV), is closely correlated with kernel indentation in most commercial varieties of dent corn in the corn belt. Altho there are smooth ears that are starchy, and rough ears that are horny, this seems to be the exception rather than the rule. In general, roughly dented kernels are decidedly more starchy and lighter in specific gravity than those more smoothly dented.

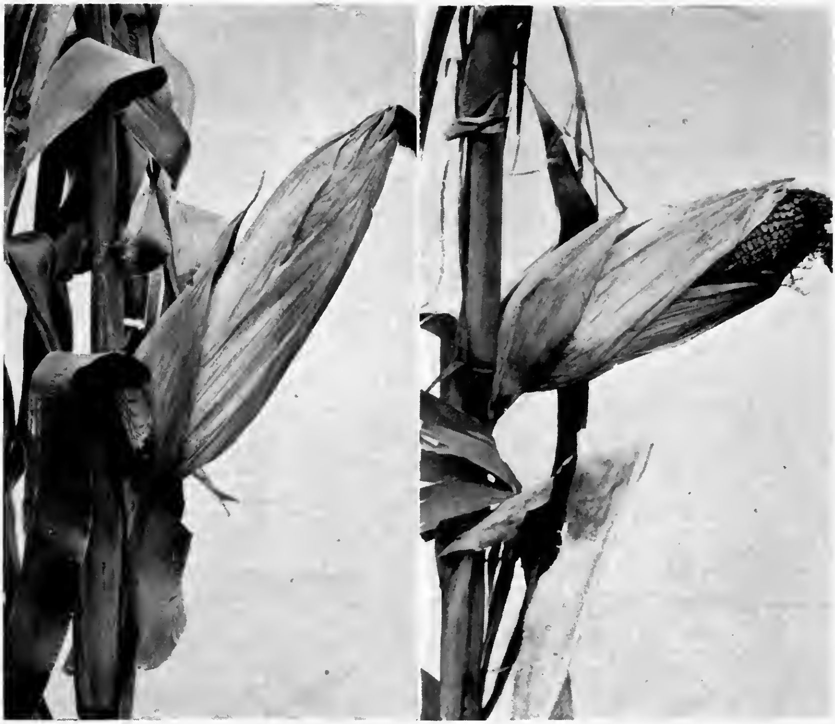


FIG. 60.—COVERED AND EXPOSED EAR-TIPS

Ears whose tips are exposed to the weather before maturity often are infected with *Fusarium* spp. and *Diplodia zeae.*

Very early in the investigations reported in this bulletin differences in kernel structure of diseased and of relatively disease-free ears were observed and recorded. In this particular study ears showing infection with *Fusarium moniliforme* and *Diplodia zeae* and those affected with scutellum rot were found to be much more starchy than those free from infection (Tables 47 and 49). Seed which tested nearly disease-free was found repeatedly to contain only a very low percentage of ears with decidedly starchy kernels (Tables 47 and 49). Trost and Hoffer[106] and Trost[107] also have reported this condition.

TABLE 44.—CERTAIN PHYSICAL CHARACTERISTICS OF EARS WHICH CLASSIFIED ON THE GERMINATOR AS MODERATELY DISEASED AND NEARLY DISEASE-FREE

Yellow dent ears from different sources, 1920. Classification based on three and sometimes four germination tests of ten kernels each

Characters observed	Macon county		Macon county		Rock Island county		McLean county	
	Diseased (10 ears)	Nearly disease-free (10 ears)	Diseased (10 ears)	Nearly disease-free (10 ears)	Diseased (10 ears)	Nearly disease-free (10 ears)	Diseased (10 ears)	Nearly disease-free (10 ears)
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Luster of ear								
Bright	0	80	0	100	0	80	20	90
Intermediate	0	20	20	0	20	20	30	10
Dull	100	0	80	0	80	0	50	0
Shank attachment								
Bright	0	0	0	80	0	70	40	90
Slightly pink or slightly brown	60	100	20	20	30	30	20	0
Pink or brown	40	0	80	0	70	0	40	10
Tip of ear								
Covered by husk	20	60	20	40	20	70	100	90
Slightly exposed	60	20	60	40	20	20	0	10
Exposed	20	20	20	20	60	10	0	0
Indentation								
Smooth	0	50	0	80	10	60	10	10
Intermediate	40	50	20	20	70	40	30	60
Rough	60	0	80	0	20	0	60	30
Luster of kernel								
Bright	20	100	60	100	60	90	30	100
Intermediate	60	0	20	0	10	10	20	0
Dull	20	0	20	0	30	0	50	0
Kernel composition								
Horny	0	0	0	0	10	90	60	70
Intermediate	0	100	0	100	80	10	0	20
Starchy	100	0	100	0	10	0	40	10

LUSTER OF KERNEL

Brightness, or luster, of the germ side of shelled corn is a physical character that has long been used by veteran corn growers in selecting seed. These studies showed that altho some badly infected ears may have bright kernels, nearly disease-free seed very seldom contains dull kernels (Tables 44, 45, 46, 47, and 49).

TABLE 45.—CERTAIN PHYSICAL CHARACTERISTICS OF EARS WHICH CLASSIFIED ON THE GERMINATOR AS DISEASED AND NEARLY DISEASE-FREE

Yellow dent ears from different sources, 1922. Classification based on three and sometimes four germination tests of ten kernels each

Characters observed	De Witt county		Knox county		Tazewell county	
	Diseased (37 ears)	Nearly disease-free (17 ears)	Diseased (7 ears)	Nearly disease-free (9 ears)	Diseased (15 ears)	Nearly disease-free (10 ears)
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Luster of ear						
Bright	0.0	11.8	0.0	22.2	0.0	0.0
Intermediate	51.4	82.4	28.6	66.7	73.4	100.0
Dull	48.6	5.8	71.4	11.1	26.6	0.0
Shank attachment						
Bright	2.7	5.8	0.0	0.0	0.0	0.0
Slightly pink or slightly brown	24.3	64.8	85.7	88.9	20.0	70.0
Pink or brown	73.0	29.4	14.3	11.1	80.0	30.0
Tip of ear						
Covered by husk	18.9	64.8	0.0	22.2	0.0	30.0
Slightly exposed	56.8	35.2	85.7	66.7	60.0	50.0
Exposed	24.3	0.0	14.3	11.1	40.0	20.0
Indentation						
Smooth	35.1	100.0	71.4	66.7	13.3	100.0
Intermediate	27.1	0.0	0.0	33.3	40.0	0.0
Rough	37.8	0.0	28.6	0.0	46.7	0.0
Luster of kernel						
Bright	0.0	100.0	100.0	100.0	93.3	100.0
Intermediate	67.6	0.0	0.0	0.0	6.7	0.0
Dull	32.4	0.0	0.0	0.0	0.0	0.0
Kernel composition						
Horny	35.1	88.2	0.0	88.9	13.3	90.0
Intermediate	40.6	11.8	100.0	11.1	60.0	10.0
Starchy	24.3	0.0	0.0	0.0	26.7	0.0

GENERAL DISCUSSION

Perhaps the most consistent differences in physical characteristics between the Fusarium-infected composites and the good-seed composites were in brightness of luster, character of shank attachment, and evidence of ear-tip exposure. Among the Fusarium-infected composites used in 1921 and 1922 (Table 49), only a small percentage of ears could be classed as bright in luster—9.7 and 12.4 percent, respectively, in the two years, as compared with 53.4 and 62.0 percent in the good seed. The percentages of ears with bright, sound shank attachments were very low—3.2 and 1.0 percent, as compared with 87.2 and 30.7 percent in the good seed. Also, the high proportion of ears with pink or brown shanks—67.8 and 71.1 percent in the Fusarium-infected composites as compared with 2.3 and 28.2 in the good-seed composites—is significant. The difference in percentage of ears with covered tips in 1922, 12.3 percent in the Fusarium-infected com-

TABLE 46.—CERTAIN PHYSICAL CHARACTERISTICS OF COMPOSITES OF MODERATELY DISEASED AND NEARLY DISEASE-FREE YELLOW DENT SEED EARS, BLOOMINGTON, 1922

Characters observed	Moderately diseased (1346 ears)	Nearly disease-free (1103 ears)
	perct.	*perct.*
Luster		
Bright	9.5	53.4
Intermediate	51.3	44.2
Dull	39.2	2.4
Shank attachment		
Bright	6.1	53.9
Slightly pink or slightly brown	32.5	38.9
Pink or brown	61.4	7.2
Tip of ear		
Covered with husk	20.3	57.2
Slightly exposed	35.2	32.2
Exposed	44.5	10.6
Indentation		
Smooth	29.8	70.9
Intermediate	33.5	24.1
Rough	36.7	5.0
Brightness of kernel		
Bright	55.7	89.9
Intermediate	26.1	3.7
Dull	18.2	6.4
Kernel composition		
Horny	26.9	66.5
Intermediate	43.0	32.6
Starchy	30.1	0.9

posite as compared with 71.8 percent in the good-seed composite, suggests that in many cases the initial infections of *Fusarium moniliforme* may have been in the exposed tips of the ears, from which point of attack the fungus spread thruout the ear.

Differences between the Fusarium-infected composites and good-seed composites in indentation, nature of endosperm, and kernel luster are not so consistent as differences in luster of ear, character of shank attachment, and evidence of ear-tip exposure. This may be accounted for in part by the fact that the Fusarium-infected ears that also were infected with *Diplodia zeae* and those affected with scutellum rot were not included in the seed lots infected primarily with *Fusarium moniliforme*. In general it has been found that Fusarium-infected ears are usually rougher in indentation and more starchy in composi-

PLATE V

A, B, C Cob interiors of good seed ears.

In the coloring of the interior cob, considerable natural variation occurs. In some ears the coloration extends to the point of attachment between cob and shank, and thus gives the shank attachment a pink or brown appearance. In such cases pink or brown shanks are normal.

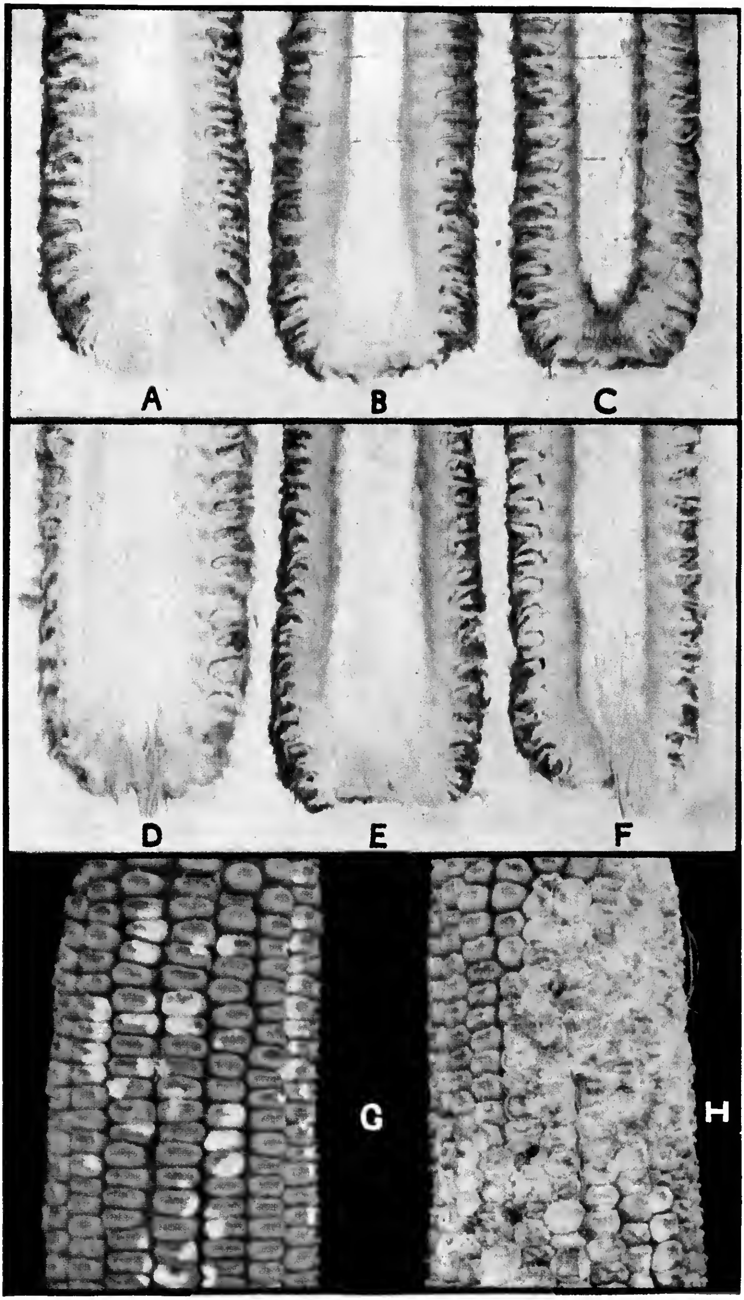
D, E, F Cob interiors of undesirable seed ears.

Note that discolorations at the butts of cobs are due to rotting of the tissues.

Where shank discolorations and shreddings are plainly the result of decayed tissue, the seed value of such ears is very questionable, especially when considered from the standpoint of disease resistance.

G Ear of corn from highly resistant strain that had been injured by earworms.

H Ear of corn from susceptible strain that had been injured by earworms. *There are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection.*


A
B
C
D
E
F
G
H

tion. Kernel brightness does not seem to be any evidence of noninfection with *Fusarium* spp.

Diplodia-infected ears (Table 49) usually lack the bright, rich luster and clean shank attachments characteristic of disease-free ears,

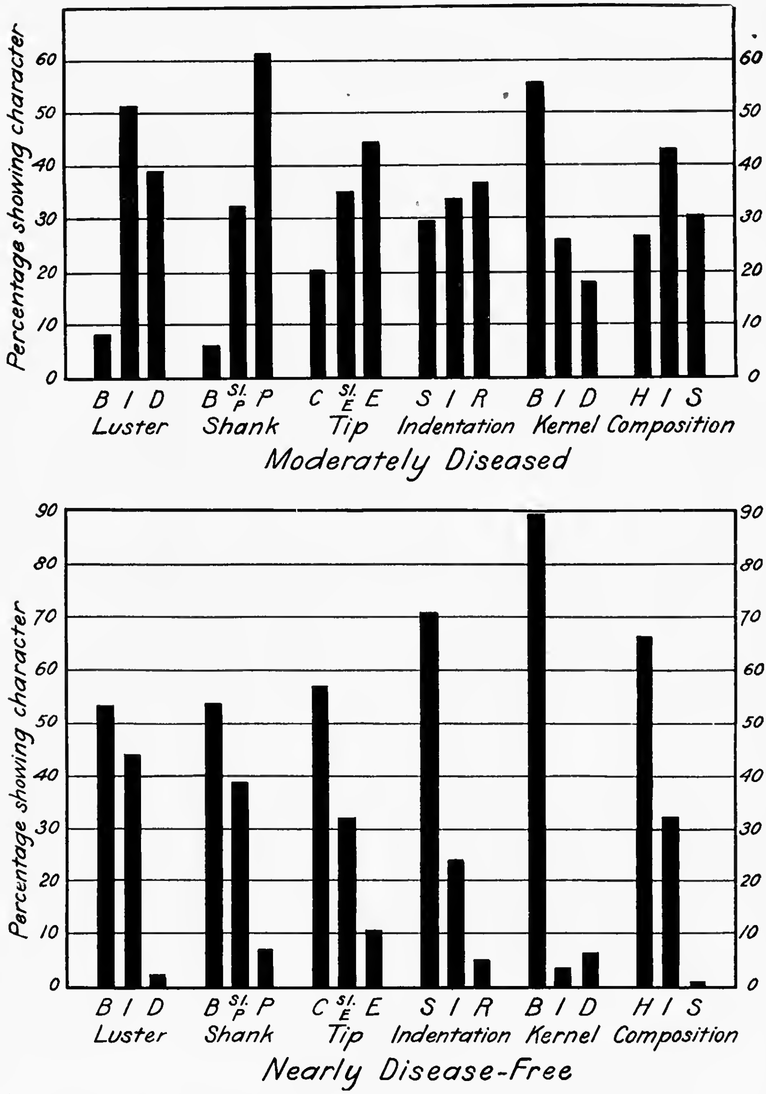


CHART 22.—PHYSICAL CHARACTERISTICS OF MODERATELY DISEASED AND NEARLY DISEASE-FREE SEED (For meaning of letters, see Table 46)

Good seed composites, as compared with diseased seed composites, have been found to contain a much higher percentage of ears with bright luster, clean shank attachments, covered tips, smooth indentation, bright kernels, and ears horny in kernel composition.

TABLE 47.—CERTAIN PHYSICAL CHARACTERISTICS OF THE SEED EARS ENTERING INTO THE NEARLY DISEASE-FREE COMPOSITES AND THE COMPOSITES AFFECTED PRIMARILY WITH SCUTELLUM ROT IN 1920, 1921, AND 1922

Characters observed	1920		1921		1922	
	Diseased (99 ears)	Nearly disease-free (62 ears)	Diseased (238 ears)	Nearly disease-free (120 ears)	Diseased (64 ears)	Nearly disease-free (202 ears)
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Luster						
Bright	8.0	75.8	10.9	53.4	4.7	62.0
Intermediate	30.3	24.2	67.2	45.1	40.7	34.6
Dull	61.7	0.0	21.9	1.5	54.6	3.4
Shank attachment						
Bright	10.1	87.0	2.5	87.2	23.4	30.7
Slightly pink or slightly brown	40.4	11.4	49.2	10.5	23.4	41.1
Pink or brown	49.5	1.6	48.3	2.3	53.2	28.2
Tip of ear						
Covered by husk	40.4	72.6	24.8	71.4	29.7	71.8
Slightly exposed	28.3	21.0	35.7	26.3	34.4	18.3
Exposed	31.3	6.4	39.5	2.3	35.9	9.9
Indentation						
Smooth	17.1	71.0	14.3	75.9	18.8	68.9
Intermediate	46.5	29.0	33.6	21.8	40.6	26.7
Rough	36.4	0.0	52.1	2.3	40.6	4.4
Brightness of kernel						
Bright	59.5	100.0	42.4	98.5	70.3	97.0
Intermediate	18.2	0.0	35.3	1.5	15.6	2.5
Dull	22.3	0.0	22.3	0.0	14.1	0.5
Kernel composition						
Horny	1.0	17.8	15.5	74.4	18.7	87.7
Intermediate	35.4	80.6	59.3	24.8	46.9	12.3
Starchy	63.6	1.6	25.2	0.8	34.4	0.0

TABLE 48.—GERMINATION RECORDS OF SEED EARS ENTERING INTO THE SCUTELLUM ROT AND THE NEARLY DISEASE-FREE COMPOSITES IN 1920, 1921, AND 1922

Percentages are based on 3 ten-kernel tests from each ear. Ears are described in Table 47

Characters observed	1920		1921		1922	
	Diseased (99 ears)	Nearly disease-free (62 ears)	Diseased (238 ears)	Nearly disease-free (120 ears)	Diseased (64 ears)	Nearly disease-free (202 ears)
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Viability	99.9	100.0	99.7	100.0	99.5	100.0
Seedlings showing scutellum rot when sectioned	26.4	1.3	50.6	3.5	57.0	4.6
Seedlings showing visible infection with *Fusarium moniliforme*	trace	0.0	3.5	0.0	2.2	0.0
Seedlings showing visible infection with *Diplodia zeae*	trace	0.0	0.0	0.0	0.0	0.0

TABLE 49.—CERTAIN PHYSICAL CHARACTERISTICS OF SEED EARS ENTERING INTO COMPOSITES INFECTED PRIMARILY WITH FUSARIUM AND DIPLODIA, AND THE NEARLY DISEASE-FREE SEED COMPOSITES OF YELLOW DENT CORN IN 1921 AND 1922

Characters observed	1921			1922		
	Fusarium (31 ears)	Diplodia (51 ears)	Nearly disease-free (120 ears)	Fusarium (97 ears)	Diplodia (191 ears)	Nearly disease-free (202 ears)
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Luster						
Bright	9.7	19.6	53.4	12.4	31.9	62.0
Intermediate	74.2	62.7	45.1	75.2	48.7	34.6
Dull	16.1	17.7	1.5	12.4	19.4	3.4
Shank attachment						
Bright	3.2	2.0	87.2	1.0	4.1	30.7
Slightly pink or slightly brown	29.0	11.8	10.5	27.9	18.9	41.1
Pink or brown	67.8	86.2	2.3	71.1	77.0	28.2
Tip of ear						
Covered by husk	....	....	71.4	12.3	....	71.8
Slightly exposed	....	....	26.3	77.4	....	18.3
Exposed	....	....	2.3	10.3	....	9.9
Indentation						
Smooth	45.2	72.5	75.9	75.2	71.8	68.9
Intermediate	48.3	19.6	21.8	21.7	22.5	26.7
Rough	6.5	7.9	2.3	3.1	5.7	4.4
Kernel brightness						
Bright	58.1	74.5	98.5	90.7	51.8	97.0
Intermediate	29.0	15.7	1.5	7.2	26.7	2.5
Dull	12.9	9.8	0.0	2.1	21.5	0.5
Kernel composition						
Horny	32.2	66.6	74.4	76.3	60.8	87.7
Intermediate	25.8	27.5	24.8	23.7	39.2	12.3
Starchy	42.0	5.9	0.8	0.0	0.0	0.0

TABLE 50.—GERMINATION RECORDS OF SEED EARS ENTERING INTO THE COMPOSITES INFECTED PRIMARILY WITH FUSARIUM AND DIPLODIA, AND THE NEARLY DISEASE-FREE COMPOSITES OF YELLOW DENT CORN, IN 1921 AND 1922

Percentages are based on 3 ten-kernel tests from each ear. Ears are described in Table 49

Characters observed	1921			1922		
	Fusarium	Diplodia	Nearly disease-free	Fusarium	Diplodia	Nearly disease-free
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Viability	97.2	91.5	100.0	97.5	87.0	100.0
Seedlings showing scutellum rot when sectioned	0.0	0.0	3.5	4.0	3.0	4.6
Seedlings showing visible infection with *Fusarium moniliforme*	57.0	0.0	0.0	92.6	0.5	0.0
Seedlings showing visible infection with *Diplodia zeae*	0.0	64.0	0.0	0.0	92.6	0.0

but often they are just as horny in kernel composition as is good seed. When infection has entered the ear thru the shank, the kernels are somewhat more starchy than are kernels on uninfected ears. In general, however, the selection of horny seed is no assurance against ears infected with *Diplodia zeae.* Frequently, infected ears that might be selected for seed contain a few kernels that have been completely overrun by the fungus and present a brown appearance on the germ side of the kernel. Ears containing such discolored kernels should not be considered for seed as they very likely contain many kernels of good appearance that are slightly infected with *Diplodia zeae.*

VALUE OF SINGLE EAR CHARACTERS IN SEED SELECTION

From the previous data it is evident that there are distinct differences in the general appearance of nearly disease-free seed ears and diseased seed ears. These differences in physical characteristics may not always be confined to a single ear character, such as luster of ear, nature of shank attachment, character of endosperm, or kernel indentation. On this account there is much advantage in considering a number of characters in the physical selection of seed ears. However, certain single ear characters, perhaps on account of their conspicuousness, have received undue emphasis as criterions of field performance. Data on the value of considering single ear characters in seed selection are given in Tables 51 to 60.

SHANK ATTACHMENT

Badly discolored and shredded shank attachments very frequently are associated with poor seed condition. The data thus far collected, however, do not show that variations in discolorations or shredding are significant. Practically the same high percentages of ears with brown shank attachments were found in both Fusarium and Diplodia composites (Table 51). Also, ears with shredded attachments were observed in both Fusarium and scutellum rot composites.

Data bearing on the relation of character of shank attachments to yield are presented in Tables 52 and 53. Mr. R. I. McKeighan's strain of yellow dent corn was used in the experiment reported in Table 52. The corn had not been selected from special plants in the field, nor had a germination test been made of the ears prior to the selection and grouping for planting. Results reported in Table 52 are decidedly in favor of ears with sound, bright shanks.

The reduction in acre yield (Table 52) of 8.8 bushels, or 12.9 percent, in plots planted with seed from ears with shanks showing black bundles is of special interest. In this case, they were ears with shank attachments having many black or brown vascular bundles set in clear white pith (Fig. 59). Reddy and Holbert[81] have shown that this

TABLE 51.—DETAILED DESCRIPTION OF SHANK ATTACHMENTS OF THE SEED EARS ENTERING INTO THE STANDARD COMPOSITES PLANTED IN 1922

Character of shank attachment	Fusarium-infected composite (97 ears)	Diplodia-infected composite (191 ears)	Scutellum rotted composite (64 ears)	Nearly disease-free composite (202 ears)
	perct.	*perct.*	*perct.*	*perct.*
Bright	1.0	3.1	23.4	30.7
Bright but slightly shredded	0.0	1.0	0.0	0.0
Total bright	1.0	4.1	23.4	30.7
Medium	0.0	0.0	3.1	6.4
Slightly brown	21.7	15.2	11.0	25.7
Slightly pink	1.0	1.6	9.4	5.0
Slightly brown and slightly shredded	5.2	2.1	0.0	4.0
Total medium	27.9	18.9	23.5	41.1
Dull	0.0	0.0	3.1	6.9
Brown	46.4	45.6	23.4	11.4
Pink	3.1	1.6	17.2	1.0
Red	9.3	6.8	0.0	3.0
Brown and shredded	11.3	22.0	9.4	5.9
Red and shredded	1.0	1.0	0.0	0.0
Total dull	71.1	77.0	53.1	28.2

blackening of the vascular bundles very frequently is caused by infection with *Cephalosporium acremonium.* No doubt a high percentage of the kernels, as well as of the shanks of these ears, were infected with this organism, which probably was responsible for the reduction in yield in this particular case. Cephalosporium infection of kernels thru the shank, however, does not always discolor the vascular system enough to make such discolorations plainly visible. Neither does the presence of black bundles in the shank attachment necessarily indicate kernel infection with this organism. Under certain

TABLE 52.—RELATION OF CONDITION OF SHANK ATTACHMENT TO YIELD

Yellow dent corn grown on brown silt loam of good fertility, on which corn had been grown the previous season, near Yates City, 1921

Condition of shank attachment	Total acre yield	Reduction in yield	
	bu.	*bu.*	*perct.*
Bright (check)	68.4		
Shredded	61.2	7.2	10.5
Bright (check)	72.2		
Pink	60.9	11.3	15.7
Bright (check)	72.2		
Brown	61.7	10.5	14.5
Bright (check)	68.2		
Black-bundle	59.4	8.8	12.9

conditions corn grown from seed infected with Cephalosporium may yield just as much as corn grown from uninfected seed; under other conditions the same seed may produce a crop very inferior in both quantity and quality (Table 40).

In the experiment reported in Table 53 the reduction in the plots planted with corn from ears showing the presence of black bundles in the shank was only 2.5 bushels per acre, or 3.9 percent. The factors determining reductions in yield due to seed infection with Cephalosporium are not yet clearly understood. This phase of the corn disease situation is being investigated further. More data and further discussion are presented by Reddy and Holbert.[81]

Ears included in the experiment reported in Table 53 had been selected in the field from good standing plants, and were classed as nearly disease-free in the first germination test. A second and third germination test indicated that the ears with shredded shank attachments were slightly infected with *Diplodia zeae.* Plots planted with these ears were the only series in this experiment to show an appreciable reduction in yield.

There is much variation in color and in intensity of color of cob interiors either when viewed in cross-section after the cobs have been broken or when viewed in longitudinal section after they have been sawed longitudinally (Plate V). Interior cob coloring variations prevail in most open-pollinated strains of corn, even in those that have been selected rather closely for several years. It seems probable in many cases that red, pink, and brown colorings in the shank are due simply to lodgment in the shank attachment of the same pigment found in the vascular cylinder of the cob and do not indicate infection. Hence, in observing the nature of the shank attachment for the selec-

TABLE 53.—RELATION OF CONDITION OF SHANK ATTACHMENT TO YIELD
Yellow dent corn grown on University South Farm, Urbana, 1921

Condition of shank attachment	Total acre yield	Reduction in yield	
	bu.	*bu.*	*perct.*
Bright (check)	67.8		
Shredded	53.6	14.2	20.9
Bright (check)	65.0		
Pink	62.5	2.5	3.8
Bright (check)	63.8		
Brown	65.2	−1.4	−2.2
Bright (check)	64.0		
Red	66.9	−2.9	−4.5
Bright (check)	63.6		
Black-bundle	61.1	2.5	3.9

TABLE 54.—PERCENTAGE OF DIFFERENTLY COLORED VASCULAR CYLINDERS OF COBS FROM THE GOOD-SEED, FUSARIUM-INFECTED, AND DIPLODIA-INFECTED COMPOSITES SELECTED FOR PLANTING IN 1923

Condition of shank attachment	Relative amount of pigmentation and coloration in the vascular cylinder in the interior of cob	Seed composites		
		Nearly disease-free (324 ears)	Fusarium-infected (145 ears)	Diplodia-infected (280 ears)
		perct.	*perct.*	*perct.*
Bright	None	34.6	6.9	2.9
	Slight to moderate	36.7	6.9	7.8
	Considerable	24.4	11.0	2.9
Slightly pink or slightly brown	None	0.9	4.8	2.9
	Slight to moderate	1.9	15.9	12.9
	Considerable	1.2	22.1	16.0
Pink or brown	None	0.0	3.5	0.7
	Slight to moderate	0.0	8.2	15.0
	Considerable	0.3	13.8	14.6
Shredded	None	0.0	0.7	1.8
	Slight to moderate	0.0	2.1	14.6
	Considerable	0.0	4.1	7.9

tion of seed, it is very important to distinguish between normal colorations and discolorations resulting from decayed tissues.

During the spring of 1923 a study was made of the color of the vascular cylinder of cobs taken from the standard composites. Some of these data are reported in Tables 54, 55, and 56. In the nearly disease-free composite (Tables 54 and 55) the different degrees of coloration in the vascular cylinder of the cobs (Plate V) were fairly evenly divided, there being 35.5 percent with no coloration, 38.6 percent with a slight to moderate amount, and 25.9 percent with a considerable amount. However, in both the Fusarium-infected and Diplodia-infected composites much larger proportions of the cobs had colored vascular cylinders. Only 8.3 percent of the Diplodia-infected ears, as compared with 35.5 percent in the nearly disease-free ears, had cobs showing no coloration of the vascular cylinders.

The proportion of ears having broken at the final shank node, or the node nearest the ear, was very much less in the nearly disease-free

TABLE 55.—SUMMARY OF DATA PRESENTED IN TABLE 54

Relative amount of pigmentation and coloration in the vascular cylinder in the interior of the cob	Seed composites		
	Nearly disease-free (324 ears)	Fusarium-infected (145 ears)	Diplodia-infected (280 ears)
	perct.	*perct.*	*perct.*
None	35.5	15.9	8.3
Slight to moderate	38.6	33.1	50.3
Considerable	25.9	51.0	41.4

TABLE 56.—DATA ON PLACE OF BREAKING FROM SHANK OF EARS COMPRIZING THE STANDARD COMPOSITES FOR PLANTING IN 1923

Place at which ear was broken from shank	Seed composites		
	Nearly disease-free (324 ears)	Fusarium-infected (145 ears)	Diplodia infected (280 ears)
	perct.	*perct.*	*perct.*
At final shank node	29.6	71.7	70.7
Below final shank node	70.4	28.3	29.3

composite than in either of the other composites (Table 56), 29.6 percent in the good-seed composite as compared with 71.7 and 70.7 percent in the Fusarium-infected and the Diplodia-infected composites, respectively. This difference in the place at which the ear breaks from the shank would appear to be significant. Unfortunately there are only one year's data on this point.

Where shank discolorations and shreddings are plainly the result of decayed tissue, the seed value of such ears is very questionable, especially when considered from the standpoint of disease resistance. Data presented later show that ears with rotted, shredded, and badly discolored shank attachments can have no part in the development of strains of corn more nearly resistant to the rot diseases.

NATURE OF ENDOSPERM

Differences in the nature of endosperm in nearly disease-free and diseased ears of seed corn were observed very early in the investigations reported in this bulletin. Since 1917, ears with horny kernels and ears with starchy kernels (Plate IV) have been compared in experiments to study the behavior under different conditions of corn grown from seed differing in endosperm character. Yields from these experiments are presented in Table 57 and Chart 23. The differences in grain yields from corn grown from starchy seed and that grown from horny seed varied from slight increases to reductions of 35 bushels per acre, or 28 percent, depending on the previous cropping, fertility of soil, time of planting, and other factors.

In 1919, at Bloomington, the plots were planted with horny and starchy kernels selected from the same ears. The same number of both horny and starchy kernels was used from each of the ears entering into the experiment. The selection of the kernels was based solely on the physical appearance of the endosperm. The difference in the resulting yields, in favor of the horny kernels, is very significant.

The starchy seed used in 1920 and in 1921 was nearly disease-free. The same composites of horny and starchy seed were used in all the experiments in 1921. At Urbana where corn followed clover the difference in yield in favor of the horny seed was only 2.2 bushels per acre, or 3.1 percent, but where corn followed corn in the same rotation series the difference was 8.2 bushels, or 12.7 percent, in favor of the horny seed. Plantings of starchy and horny seed were made on the same day. Both were nearly disease-free. Such results suggest that previous cropping may be a very important factor in determining the comparative yields of corn grown from horny and from starchy seed where both kinds of seed are nearly disease-free.

In 1922 the same nearly disease-free horny and starchy composites and also diseased starchy composites were used in all experiments. Where the previous crop had been corn, the reductions in yield, where starchy seed was used, usually were sufficiently large to be significant even tho the starchy seed was nearly disease-free.

Further data on the relative seed value of infected and nearly disease-free starchy seed are given in Table 58 and Chart 24. The same seed composites were used in these experiments as in those reported for 1922 in Table 57. None of these experiments was located on ground that had produced corn the previous year. In the experiment near Girard, Macoupin county, the difference in acre yield of sound corn between the nearly disease-free starchy and the nearly

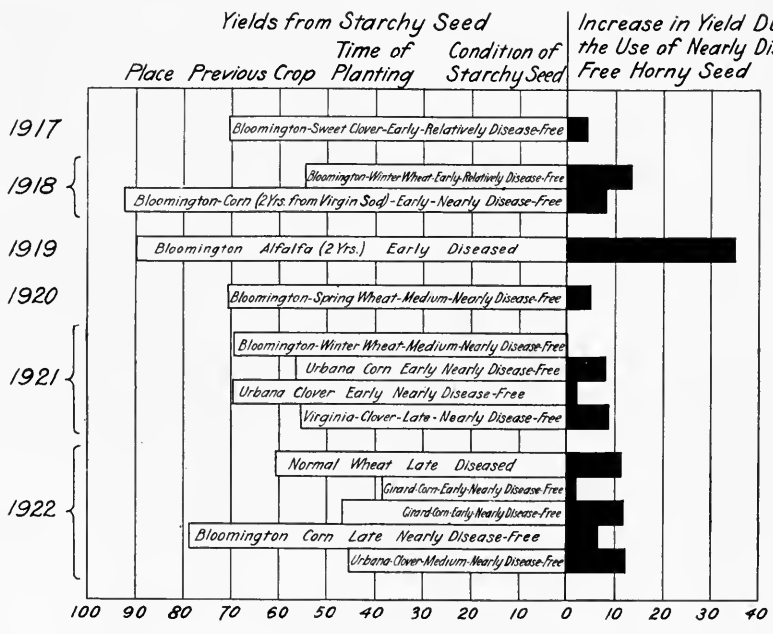


CHART 23.—SUPERIORITY OF HORNY SEED (Table 57)

Under the many conditions encountered in six years' experimentation, corn grown from nearly disease-free horny seed consistently yielded more than corn grown from starchy seed.

disease-free horny seed lots, 3.3 bushels, was not significant. At Yates City, Knox county, the difference was 5.9 bushels, which is over five times the probable error, thus being significant. At Stanford, McLean county, the yields were practically the same, 33.5 and

TABLE 57.—YIELDS FROM HORNY AND FROM STARCHY SEED

Yellow dent corn grown on brown silt loam at various points in Illinois, 1917 to 1923

Year	Location of experiment	Previous crop	Relative time of planting	Condition of starchy seed	Acre yield from— Horny (disease-free)	Acre yield from— Starchy	Reduction in yield from starchy seed	
					bu.	*bu.*	*bu.*	*perct.*
1917	Bloomington..	Sweet clover.	Early.......	Relatively disease-free	74.4	70.3	4.1	5.5
1918	Bloomington..	Winter wheat	Early.......	Relatively disease-free	68.2	54.7	13.5	19.8
	Bloomington..	Corn (2d yr. from virgin sod)......	Early.......	Nearly disease-free ..	100.6	92.4	8.2	8.2
1919	Bloomington..	Alfalfa (12 yrs.) ..	Early.......	Diseased....	125.0	90.0	35.0	28.0
1920	Bloomington..	Spring wheat	Intermediate	Nearly disease-free	75.3	70.5	4.8	6.4
	Bloomington..	Winter wheat	Intermediate	Nearly disease-free	69.5	69.4	0.1	0.1
1921	Urbana.......	Corn........	Early.......	Nearly disease-free	64.7	56.5	8.2	12.7
	Urbana.......	Clover......	Early.......	Nearly disease-free	72.1	69.9	2.2	3.1
	Virginia......	Clover......	Late........	Nearly disease-free	64.2	55.6	8.6	13.4
	Normal......	Wheat......	Late........	Diseased....	72.8	62.7	10.1	13.9
	Normal......	Wheat......	Late........	Diseased....	70.2	58.2	12.0	17.1
1922	Girard.......	Corn........	Early.......	Nearly disease-free	40.7	38.5	2.2	5.4
	Girard.......	Corn........	Early.......	Diseased....	46.2	34.4	11.8	25.5
	Bloomington.	Corn........	Late........	Nearly disease-free	75.3	67.8	7.5	10.0
	Bloomington..	Corn........	Late........	Nearly disease-free	96.3	91.2	5.1	5.3
	Urbana.......	Clover......	Intermediate	Nearly disease-free	57.5	45.5	12.0	20.9
1923	Bloomington..	Alfalfa......	Early.......	Nearly disease-free	84.0	86.0	−2.0	−2.4
	Bloomington .	Alfalfa......	Late........	Nearly disease-free	96.4	85.6	10.8	11.2
	Bloomington..	Corn........	Early.......	Nearly disease-free	47.2	40.5	6.7	14.2
	Bloomington..	Corn........	Late........	Nearly disease-free	46.7	41.9	4.8	10.3
	Bloomington..	Corn........	Early.......	Nearly disease-free	66.3	63.1	3.2	4.8
	Bloomington..	Corn........	Late........	Nearly disease-free	79.7	74.4	5.3	6.6
	Hopedale.....	Corn........	Intermediate	Nearly disease-free	67.4	62.7	4.7	7.0
	Hopedale.....	Corn........	Late........	Nearly disease-free	78.7	68.1	10.6	3.5

Mean reduction in acre yield of corn in plots planted to starchy seed, 7.9 ± .95 bushels.

$$\frac{7.9}{.95} = 8.32.$$ Odds greater than one million to one.

34.0 bushels. However, the corn grown from the infected starchy seed was decidedly inferior in yielding ability to that grown from the good horny seed in every instance, the differences in yield in favor of the horny seed ranging from 4 to 11.6 times the probable error.

Additional data on the behavior of the nearly disease-free horny and starchy composites in experiments made at Urbana are presented in Table 59. In spite of the fact that the starchy seed was nearly disease-free, the differences in yield of sound corn between corn grown from such seed and from nearly disease-free horny seed ranged, in the experiments where corn followed corn, from 2.4 bushels per acre, or 9.1 percent, to 8.7 bushels, or 36.7 percent, differences sufficiently large to be significant. In the plantings following clover such differences ranged from 3.7 bushels per acre, or 6.9 percent, to 14.7 bushels, or 26.3 percent.

The data from experiments extending over a period of seven years (Tables 57, 58, and 59), *together with the fact that the large majority of starchy seed in seed stocks in the corn belt are likely to be more or less diseased, justify the discarding of starchy ears for seed purposes.*

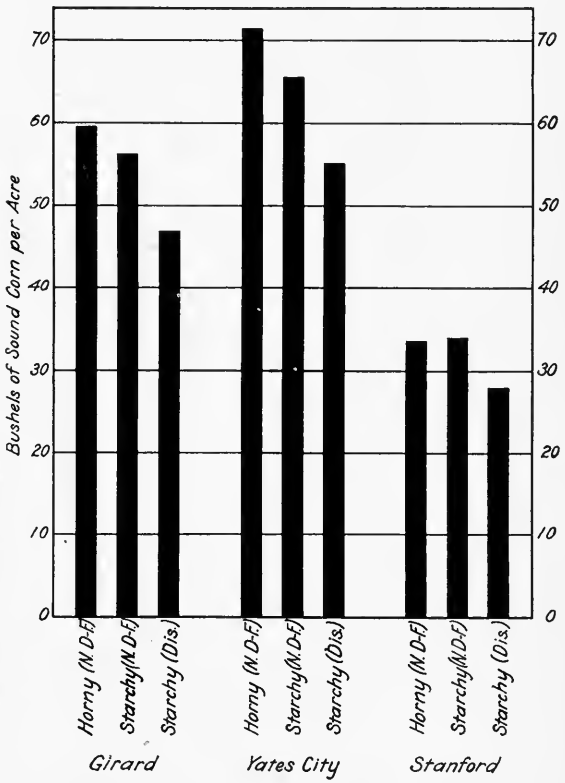


CHART 24.—YIELD OF SOUND CORN AS AFFECTED BY CHARACTER OF ENDOSPERM AND SEED INFECTION (Table 58)

The corn grown from the infected starchy seed was decidedly inferior in yielding ability to that grown from the good horny seed in every instance.

LUSTER OF KERNEL

Altho most ears with discolored or brown kernel tips are likely to be infected, there are ears of horny composition with kernels decidedly brown on the germ side that show no evidence of being infected when tested

TABLE 58.—INFLUENCE OF CHARACTER OF ENDOSPERM AND SEED INFECTION ON YIELD

Yellow dent corn grown on brown silt loam at various points in Illinois, 1922

Location of experiment	Previous crop	Relative time of planting	Character of endosperm	Seed infection	Number of replica-tions	Acre yield		Reduction in sound corn based on yield of nearly disease-free horny seed	
						Total	Sound		
						bu.	bu.	bu.	perct.
Girard......	Sod, 10 years	Early.......	Horny....	Nearly disease-free .	10	69.9 ± 0.8	59.5 ± 1.0		
Girard......	Sod, 10 years	Early.......	Starchy...	Nearly disease-free .	5	66.9 ± 1.5	56.2 ± 1.7	3.3 ± 2.0	5.5
Girard......	Sod, 10 years	Early.......	Starchy...	Diseased..........	10	58.1 ± 1.1	46.8 ± 0.9	12.7 ± 1.3	21.3
Yates City..	Clover......	Intermediate	Horny....	Nearly disease-free .	18	78.8 ± 0.5	71.3 ± 0.8		
Yates City..	Clover......	Intermediate	Starchy...	Nearly disease-free .	18	74.6 ± 0.7	65.4 ± 0.8	5.9 ± 1.1	8.3
Yates City..	Clover......	Intermediate	Starchy...	Diseased..........	11	68.0 ± 1.3	55.0 ± 1.2	16.3 ± 1.4	22.9
Stanford....	Clover......	Late........	Horny....	Nearly disease-free .	2	41.2 ± 0.3	33.5 ± 0.3		
Stanford....	Clover......	Late........	Starchy...	Nearly disease-free .	2	43.4 ± 0.9	34.0 ± 1.3	−.5 ± 1.3	−1.5
Stanford....	Clover......	Late........	Starchy...	Diseased..........	2	35.8 ± 1.5	28.2 ± 1.3	5.3 ± 1.3	15.8

on the germinator in the usual way. The seed value of such ears was the subject of a series of experiments reported in Table 60 and Chart 25.

At Urbana there was practically no difference in yields in the plantings following clover, but in the plantings following corn in the same rotation series, planted on the same day, there was a reduction of 6.8 bushels per acre, or 10.1 percent. In each of the experiments at Bloomington seed from different sources was used. In four out of the five experiments, corn grown from brown-tipped horny seed yielded less than corn grown from bright-tipped horny seed.

There was evidence that the brown-tipped kernels on some of the ears used in the above-described experiments may have been infected with an organism, and that the infection could not be detected readily either on or in the germinating seedling. There also was evidence that brown-tipped kernels, at least in some ears of corn, are normal, and that this characteristic is inherited. *However, experimental data are decidedly in favor of the selection of ears whose kernels are bright in every respect.*

An analysis of all the data presented in Tables 43 to 60, inclusive, indicates that ears infected with Fusarium, Diplodia, or Cephalosporium and ears affected with scutellum rot very frequently have marked physical characteristics by which they can be detected and

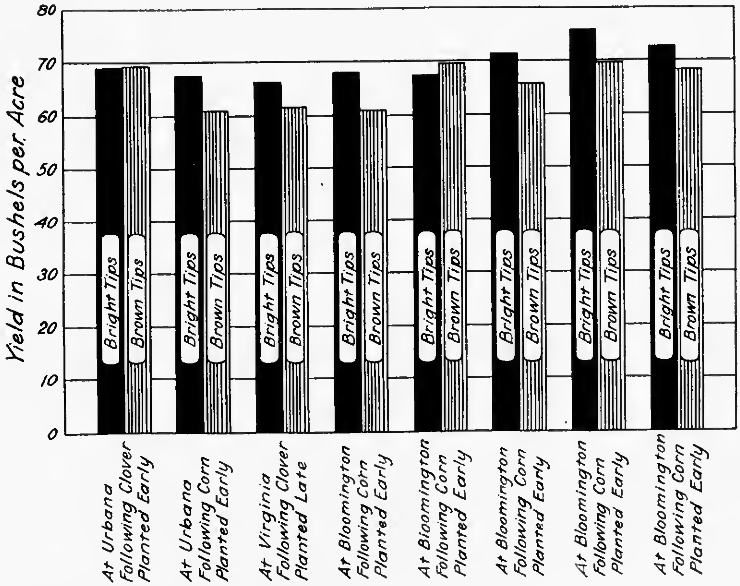


CHART 25.—SUPERIORITY OF BRIGHT-TIPPED KERNELS OVER BROWN-TIPPED FOR SEED (Table 60)

Experimental data are decidedly in favor of the selection of ears having kernels with bright tips.

TABLE 59.—YIELDS FROM NEARLY DISEASE-FREE HORNY SEED AND FROM NEARLY DISEASE-FREE STARCHY SEED

Yellow dent corn grown on brown silt loam, University South Farm, Urbana, 1922

Rotation	Previous crop	Character of Seed	Acre yield		Reduction in sound corn from starchy seed	
			Total	Sound		
			bu.	*bu.*	*bu.*	*perct.*
North-Central (corn, corn, spring grains, clover)	Clover....	Horny....	67.8	56.9		
		Starchy...	55.8	46.3	10.6	18.6
	Clover....	Horny....	59.6	51.2		
		Starchy...	56.5	46.5	4.7	9.2
	Clover....	Horny....	66.8	55.9		
		Starchy...	52.0	41.2	14.7	26.3
	Clover....	Horny....	61.7	53.3		
		Starchy...	59.6	49.6	3.7	6.9
South-Central (corn, corn, corn, soybeans)	2d yr. corn	Horny....	34.0	23.7		
		Starchy...	23.4	15.0	8.7	36.7
	2d yr. corn	Horny....	34.9	26.4		
		Starchy...	32.5	24.0	2.4	9.1
	2d yr. corn	Horny....	38.1	30.4		
		Starchy...	32.2	22.4	8.0	26.3
	2d yr. corn	Horny....	41.9	35.7		
		Starchy...	38.5	30.5	5.2	14.6

eliminated. Further data on the value of physical selection in maintaining and increasing yields will be given following the presentation of the data bearing on resistance and susceptibility of different strains and selections of corn to these diseases.

TABLE 60.—YIELDS OF CORN GROWN FROM BRIGHT-TIPPED AND FROM BROWN-TIPPED HORNY SEED, ALL OF WHICH HAD BEEN CLASSED AS NEARLY DISEASE-FREE ON THE BASIS OF ONE GERMINATION TEST, 1921

Location of experiment	Previous crop	Relative time of planting	Acre yield		Reduction from brown-tipped kernels	
			Bright-tipped kernels	Brown-tipped kernels		
			bu.	*bu.*	*bu.*	*perct.*
Urbana.........	Clover......	Early.......	69.1	69.3	−0.2	−0.3
Urbana.........	Corn........	Early.......	67.6	60.8	6.8	10.1
Virginia........	Clover......	Late........	66.3	61.5	4.8	7.2
Bloomington....	Corn........	Early.......	68.2	60.9	7.3	10.7
Bloomington....	Corn........	Early.......	67.5	69.7	−2.2	−3.3
Bloomington....	Corn........	Early.......	71.3	65.8	5.5	7.7
Bloomington....	Corn........	Early.......	75.9	69.8	6.1	8.0
Bloomington....	Corn........	Early.......	72.7	68.4	4.3	5.9

Mean reduction in acre yield of corn in plots planted to brown-tipped horny seed, 4.05 ± .787 bushels.

$\frac{4.05}{.787}$ = 5.15, odds greater than one thousand to one.

PART VI

SUSCEPTIBILITY AND RESISTANCE TO THE ROOT, STALK, AND EAR ROT DISEASES

EVIDENCES OF SUSCEPTIBILITY AND RESISTANCE

The common occurrence thruout the corn belt of many hills of corn similar to the one illustrated in Plate VI suggests at once the idea of varying degrees of susceptibility of corn plants to the rot diseases. In most commercial fields, at least where corn follows corn in the rotation, it is not difficult to find hills in which the roots, crown, and stalk of one plant are badly affected, while another plant in the same hill apparently is not affected. At first it was thought that such conditions might possibly be the result of insect or mechanical injuries, but repeated examinations have shown that in practically all cases the trouble is caused by certain of the root, stalk, and ear rot diseases. This occurrence of apparently healthy and badly diseased plants in the same hill is evidence that some plants must possess considerable resistance.

Abundant evidence of variation in susceptibility and resistance to certain of these diseases has also been found in the germination laboratory. Germinating kernels from some ears within a given lot may be entirely overrun with *Rhizopus* spp. and other fungi, while adjacent kernels from other ears of the same seed lot may remain free from the attack of these organisms (Fig. 61). Again, some lots of corn on the germinator may be covered with fungus growth, while other lots of corn on the same tray and germinated under the same conditions may be entirely free from such growth, even when spores of *Rhizopus* spp. are sprayed on the kernels.

INFLUENCE OF HEALTHY AND OF DISEASED PARENT PLANTS

During the summer of 1918 many controlled pollinations were made in ear-rows of Bloody Butcher corn planted on heavily infested soil of good fertility. The corn was all of the same strain grown from open-pollinated seed. At harvest time careful descriptions were made of the plants on which the ears had been artificially pollinated. Several ears bearing first-generation hybrid seed were obtained, of which both staminate and pistillate parents were either badly diseased or apparently healthy.

In 1919 these selected ears were included in an experimental series planted on infested soil of medium fertility. As the kernels were being dropped at planting time, half of the hills were inoculated with a pure culture of *Gibberella saubinetii*. The inoculation was made by placing next to the corn kernels a few wheat kernels overgrown with a pure culture of this organism. The resulting yield data are presented in Table 61. The corn grown from seed both of whose par-

PLATE VI

A Plant prematurely dead on account of disease.

B Plant maturing normally.

In the diseased plant (A) the leaves are dying or are already dead, and the ear is hanging as the result of a crumpled and rotted shank. Corn produced on such plants is light or chaffy and undesirable for seed purposes.

In the healthy plant (B) the ear is maturing normally while the leaves and stalk are still green. Corn from such plants makes excellent material from which to select good seed.


A
B

ents were apparently disease-free was highly resistant to injury from inoculation with this organism. On the other hand, the corn grown from seed both of whose parents were badly root- and stalk-rotted,

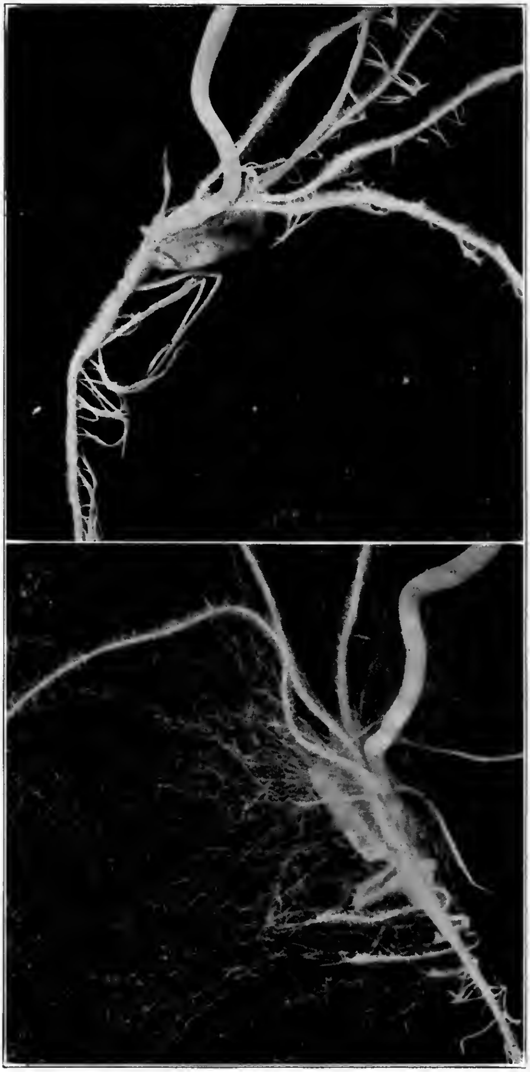


Fig. 61.—Resistance and Susceptibility to *Rhizopus* spp. on the germinator

Germinating kernels from some ears will be entirely overrun with *Rhizopus* spp. and other fungi, while adjacent kernels from other ears from the same seed lot will remain free from the attack of these organisms.

was seriously affected by the same inoculation, the reduction in acre yield amounting to 19.3 bushels, or 43.2 percent.

In the light of data presented later in this bulletin the comparative acre yields of 44.7 and 56.9 bushels from the two uninoculated seed lots grown under the same conditions on infested soil, may be interpreted as further evidence of a variation among plants in their resistance and susceptibility to the corn diseases.

During the same season (1919) five other inoculation experiments were conducted. In one of these experiments all the ear-rows were planted with seed selected from apparently healthy open-pollinated plants. Seedlings from half these seed ears had been nearly disease-free on the germinator and those from the other half had been vigorous but badly affected with scutellum rot. Part of the seed was inoculated with *Gibberella saubinetii* at planting time. Considerable variation in effect was noted. Some of the inoculated rows grown from nearly disease-free seed were highly resistant under the conditions encountered, while others proved susceptible. Rows grown from seed of strong vigor but badly affected with scutellum rot on the germinator were very susceptible in the majority of cases to injury from inoculation. Typical ears testing nearly disease-free and representing selections from rows apparently resistant and from those apparently susceptible, are shown in Figs. 62 and 63. These ears together with nearly disease-free seed and moderately diseased seed selected from apparently good plants in the field were used in experiments in 1920 at DeKalb and Martinsville. The moderately diseased seed was affected on the germinator with scutellum rot, but showed no evidence of infection with either *Diplodia zeae* or *Fusarium moniliforme*. The results of these experiments are reported in Table 62 and shown in graph form in Chart 26.

At both DeKalb and Martinsville the corn grown from the nearly disease-free seed selected from susceptible ear-rows in the inoculation

TABLE 61.—INFLUENCE OF COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF PARENT PLANTS ON THE RESISTANCE AND SUSCEPTIBILITY OF PROGENY TO INJURY BY SEED INOCULATION WITH *Gibberella saubinetii*

Bloody Butcher corn grown from artificially pollinated seed inoculated at planting time with pure cultures of *Gibberella saubinetii*. Infested soil of medium fertility, near Bloomington, 1919

Condition of parent plants from which seed was selected	Acre yields		Reduction in yield following inoculation	
	Uninoculated	Inoculated		
	bu.	*bu.*	*bu.*	*perct.*
Both parents apparently disease-free	56.9	56.5	0.4	0.7
Both parents affected badly with root and stalk rot diseases	44.7	25.4	19.3	43.2

experiment the previous year was decidedly inferior in both total yield and yield of sound corn to that grown from nearly disease-free seed selected from resistant ear-rows. At DeKalb the corn grown from the good seed selected from the resistant ear-rows produced only 6.5 bushels of rotted and chaffy ears and nubbins per acre, or 9.9 percent, while the corn grown from seed selected from the susceptible ear-rows produced 16.6 bushels, or 31.6 percent, of unsound corn. The results at Martinsville were similar in this respect.

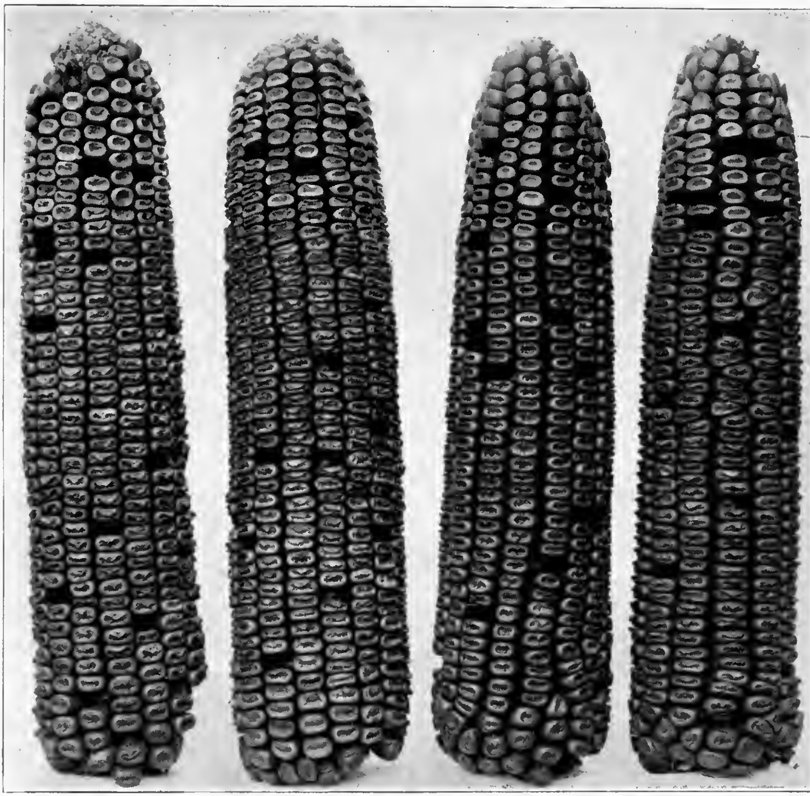


FIG. 62.—TYPICAL EARS FROM HIGHLY RESISTANT EAR-ROWS

Ears of ninety-day corn testing nearly disease-free obtained from selections that were quite resistant to injury by seed inoculation with *G. saubinetii.* (Table 62.)

In the experiment located at DeKalb, where the previous crop had been clover, the difference between the good and the moderately diseased field-selected seed was only 3.6 bushels per acre, or 6.2 percent, in favor of the good seed. At Martinsville, however, where corn followed corn in the rotation, the difference in yield of sound corn in

TABLE 62.—YIELDS OF CORN FROM NEARLY DISEASE-FREE SEED SELECTED FROM APPARENTLY RESISTANT AND APPARENTLY SUSCEPTIBLE EAR-ROWS

Ninety-day corn grown at two widely separated points in Illinois, 1920

Location	Previous crop	Soil type	Character of seed	Acre yield		Reduction in sound corn	
				Total	Sound		
				bu.	*bu.*	*bu.*	*perct.*
De Kalb (De Kalb county)	Clover	Brown silt loam	Nearly disease-free seed from apparently good plants (field selection)	65.4	58.0		
De Kalb	Clover	Brown silt loam	Moderately diseased seed from apparently good plants (field selection)	62.5	54.4	3.6	6.2
De Kalb	Clover	Brown silt loam	Nearly disease-free seed from resistant ear-rows (selected from inoculation experiment)	65.5	59.0		
De Kalb	Clover	Brown silt loam	Nearly disease-free seed from susceptible ear-rows (selected from inoculation experiment)	52.5	35.9	23.1	39.2
Martinsville (Clark county)	Corn	Yellow-gray silt loam	Nearly disease-free seed from apparently good plants (field selection)	35.8	26.4		
Martinsville	Corn	Yellow-gray silt loam	Moderately diseased seed from apparently good plants (field selection)	31.6	20.1	6.3	23.9
Martinsville	Corn	Yellow-gray silt loam	Nearly disease-free seed from resistant ear-rows (selected from inoculation experiment)	40.1	28.6		
Martinsville	Corn	Yellow-gray silt loam	Nearly disease-free seed from susceptible ear-rows (selected from inoculation experiment)	30.2	15.9	12.7	44.4

plots grown from the same seed lots was 6.3 bushels per acre, or 23.9 percent.

These data, as well as those presented in Table 55, *indicate that nearly disease-free seed of a susceptible strain or selection may yield even less than moderately diseased seed selected from apparently good plants of a resistant strain, thus suggesting the advantage of careful plant selection and the value of the germination test in securing seed which will produce plants more highly resistant. The importance of comparative resistance in open-pollinated seed of the same strain and in open-pollinated strains as a whole is clearly emphasized.*

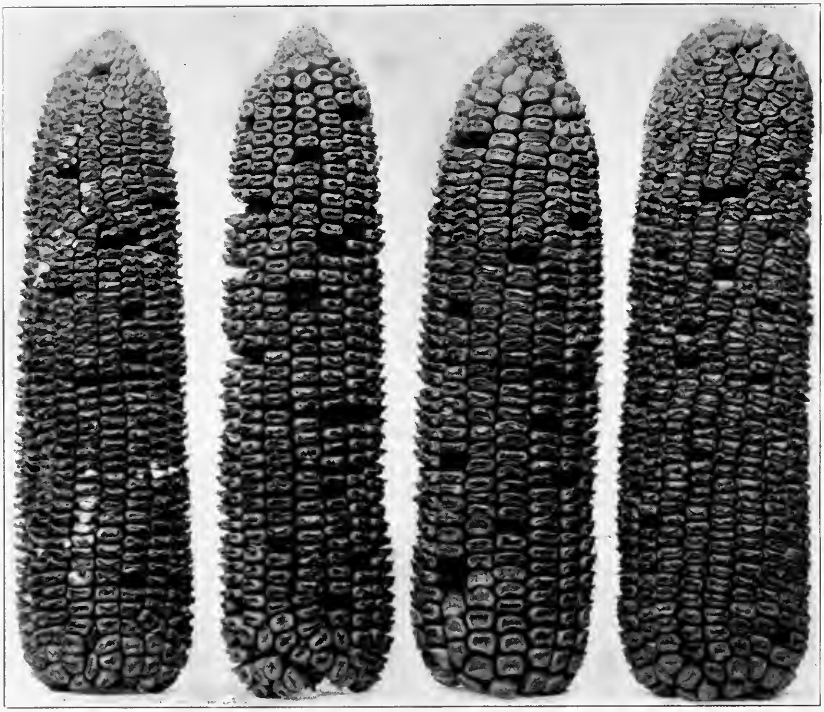


FIG. 63.—TYPICAL EARS FROM SUSCEPTIBLE EAR-ROWS

Ears of ninety-day corn testing nearly disease-free but obtained from selections that were very susceptible to injury by seed inoculation with *G. saubinetii* (Table 62). Nearly disease-free seed of a susceptible strain or selection may yield even less than moderately diseased seed selected from apparently good plants of a resistant strain.

During the fall of 1919 several hundred ears were selected from plants the condition of whose roots and stalks was carefully noted and recorded. All the selections were made from corn growing in the sec-

FIG. 64.—SUSCEPTIBILITY AND RESISTANCE TO THE CORN ROT DISEASES

At the left, yellow dent corn from seed that tested nearly disease-free on the germinator but which was selected from root- and stalk-rotted plants. At the right, the same strain of corn grown from seed that tested nearly disease-free on the germinator and which was selected from apparently disease-free plants. Disease-free seed selected from diseased plants is very likely to produce plants more or less susceptible to the corn rot diseases.

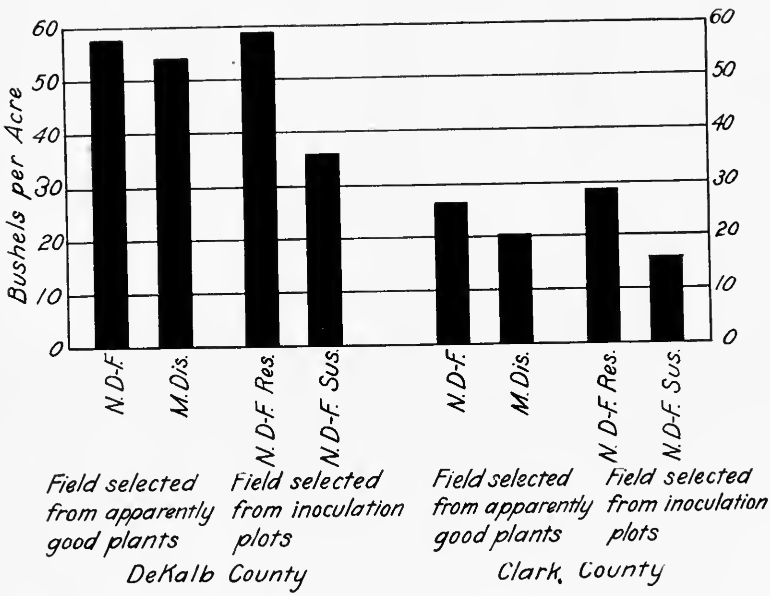


CHART 26.—RELATIVE IMPORTANCE OF RESISTANT STRAINS AND NEARLY DISEASE-FREE SEED (Table 62)

Yields of corn from nearly disease-free resistant seed were larger in each of the experiments than yields from either the moderately diseased resistant seed or the nearly disease-free susceptible seed. However, under the same conditions the moderately diseased resistant seed outyielded the nearly disease-free susceptible seed.

ond- and third-year corn following clover or other sod. The following winter ten kernels were tested from each ear at three successive times. On the basis of the germination record thus obtained, the ears that might have been selected for seed by most farmers or seedsmen, were classified as follows: (1) nearly disease-free seed from apparently disease-free plants, (2) nearly disease-free seed from root- and stalk-rotted plants, and (3) seed from apparently healthy plants which was 100 percent viable and vigorous in germination, but with 20 percent or more of the seedlings showing scutellum rot on the germinator. Ears that were obviously undesirable for seed were not included. From approximately 300 ears of good appearance that had been selected from badly root- and stalk-rotted plants, only ten were found to be vigorous in germination and at the same time free from Diplodia and Fusarium infection and not affected by scutellum rot. The physical characteristics of these ten ears, and also those of the nearly disease-

TABLE 63.—CERTAIN PHYSICAL CHARACTERISTICS OF NEARLY DISEASE-FREE SEED EARS SELECTED FROM DISEASED AND FROM APPARENTLY DISEASE-FREE MOTHER PLANTS

Ears selected in October, 1919, and planted in experiment reported in Table 64

Characters observed	Nearly disease-free ears from diseased mother plants (10 ears)	Nearly disease-free ears from apparently disease-free plants (62 ears)
	perct.	*perct.*
Luster		
Bright	10.0	75.8
Intermediate	60.0	24.2
Dull	30.0	0.0
Shank attachment		
Bright	20.0	87.0
Slightly pink or slightly brown	40.0	11.4
Pink or brown	40.0	1.6
Tip of ear		
Covered by husk	50.0	72.6
Slightly exposed	20.0	21.0
Exposed	30.0	6.4
Indentation		
Smooth	10.0	71.0
Intermediate	70.0	29.0
Rough	20.0	0.0
Brightness of kernel		
Bright	70.0	100.0
Intermediate	0.0	0.0
Dull	30.0	0.0
Kernel composition		
Horny	0.0	17.8
Intermediate	100.0	80.6
Starchy	0.0	1.6

free ears from apparently healthy plants, are given in Table 63. Of the ten ears mentioned, only two had bright shank attachments. The disease-free ears from the badly diseased plants were duller in luster, rougher in indentation, and with less horny endosperm than the disease-free ears from healthy plants.

Seed from these different groups of ears was planted across a series of twenty-one soil experimental plots designated as the Limestone Series on the farm of Mr. Eugene D. Funk. Twelve of these soil plots had been in clover sod for two years, none of the crop being removed the second year. The remaining nine plots were on ground that had produced a crop of spring wheat following corn. The corn crop had been badly diseased and the wheat crop had been so heavily scabbed that it was not harvested. This soil is classified as brown silt loam. It is of medium fertility with good natural drainage. The entire field was fall plowed. The resulting yields are presented in Table 64.

On the comparatively clean soil the difference in total acre yield between the disease-free corn from healthy plants and the disease-free corn from badly diseased plants was only 4.0 bushels, or 85.6 bushels as compared with 81.6 bushels. However, on heavily infested soil, the difference in total acre yield from these two seed lots was 12.6 bushels, or 79.4 bushels as compared with 66.8 bushels. Differences in acre yield of sound corn were greater; namely, 4.8 bushels on the comparatively clean soil and 19.4 bushels on the infested soil.

The corn from nearly disease-free seed selected from apparently healthy plants yielded 6.7 bushels, or 8.2 percent, less sound corn per acre on the heavily infested soil than on the comparatively clean soil (Table 64). No doubt a part of this reduction must have been due to the lower supply of nitrogen in the plots in this part of the experiment. However, the corn grown from the nearly disease-free seed selected from badly root- and stalk-rotted plants proved to be very susceptible to injury on the heavily infested soil, yielding 21.3 bushels, or 27.7 percent, less sound corn on the infested soil than on the comparatively clean soil (Fig. 64). Moreover, it yielded no better than corn grown from seed lots affected with scutellum rot, which also were very susceptible to injury.

These data, together with those presented in Tables 61 and 62, show that disease-free seed selected from diseased plants is very likely to produce plants more or less susceptible to the corn rot diseases. Data in Table 64 indicate that corn grown from seed affected with scutellum rot may be susceptible to disease and to injury from unfavorable soil conditions. This suggestion is borne out by data presented in Tables 74 and 77. Furthermore, since the nearly disease-free seed from the badly diseased plants had more starchy endosperm

TABLE 64.—SUSCEPTIBILITY OF DIFFERENT SEED SELECTIONS AS DETERMINED BY GROWING ON COMPARATIVELY CLEAN AND ON HEAVILY INFESTED SOIL

Yellow dent corn planted May 17 on brown silt loam, near Bloomington, 1920

Character of seed	Acre yields				Reduction in marketable corn on heavily infested soil	
	Comparatively clean soil		Heavily infested soil			
	Total	Sound	Total	Sound		
	bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
Nearly disease-free seed from apparently disease-free plants	85.6	81.7	79.4	75.0	6.7	8.2
Nearly disease-free seed from root- and stalk-rotted plants	81.6	76.9	66.8	55.6	21.3	27.7
Standard diseased composite used in 1920 (mostly scutellum rot)	74.8	69.7	61.8	53.2	16.5	23.7
Seed selected from standing apparently disease-free plants; 100 percent in viability, but 20 percent of germinated seedlings showed scutellum rot	79.6	75.2	62.7	55.2	20.0	26.6

than the nearly disease-free seed from apparently healthy plants, these data (Table 64) suggest that nearly disease-free starchy seed may be more susceptible to the root, stalk, and ear rot diseases than disease-free horny seed.

INFLUENCE OF CHARACTER OF ENDOSPERM

During the winter of 1920-1921 two nearly disease-free composites differing widely in character of endosperm were prepared, the one horny and the other starchy. Each composite included kernels from approximately 75 ears. Ears with starchy kernels that were 100 percent viable, vigorous in germination, and at the same time uninfected, are not easily found, as most starchy ears are more or less diseased. The 75 ears from which this nearly disease-free starchy composite was made were gradually accumulated during the germination tests of over 2,000 bushels of seed corn.

These seed lots were planted on duplicate plots following clover and following corn in a rotation of corn, corn, spring grains, and clover. The yield data are given in Table 65. Altho the corn grown from nearly disease-free starchy seed was practically equal in yield to that from the nearly disease-free horny seed on the plot following clover, the corn grown from the same lot of starchy seed was decidedly inferior in yielding ability on the infested soil following corn, where soil conditions were less favorable.

Similar nearly disease-free horny and starchy composites representing a large number of ears were prepared for planting in 1922. Nearly disease-free starchy ears were even more difficult to obtain than they had been the previous year. They represented a very choice selection from approximately 3,000 bushels of seed. These two composites were used in an inoculation experiment conducted on very fertile soil on which a crop of corn had been grown in 1921. Previous to that time the land had been virgin prairie sod. Seed for part of the experiment was inoculated by soaking it for about thirty minutes, immediately before planting, in a water suspension of young conidia of *Gibberella saubinetii.* The yield data are given in Table 66.

In the uninoculated part of the experiment there was little difference in the total yields of corn grown from nearly disease-free horny and starchy seed, the results being 107.6 ± 1.3 bushels as compared with 109.6 ± 1.3 bushels, respectively. However, the corn grown from the same two seed lots was affected very differently by the inoculation of the seed. The total yield of corn from the nearly disease-free horny seed was reduced 5.0 ± 1.7 bushels, or 4.6 percent, while the yield from the nearly disease-free starchy seed was reduced 24.4 ± 3.6 bushels, or 22.3 percent. Comparisons made with yields of sound corn in this experiment are practically in accord with those of total yields.

These differences in resistance and susceptibility to injury from seed inoculation with *Gibberella saubinetii,* one of the organisms associated with the corn rot diseases, are presented graphically in Chart 27. These data, together with those presented in Table 59, indicate that corn grown from nearly disease-free starchy seed is less resistant than corn from nearly disease-free horny seed not only to pure-culture in-

TABLE 65.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF NEARLY DISEASE-FREE STARCHY AND HORNY SEED AS DETERMINED BY GROWING ON CLEAN AND ON INFESTED SOIL

Yellow dent corn grown in duplicate plots on soil of medium fertility, University South Farm, Urbana, 1921

Character of seed	Acre yield		Reduction following planting on infested soil	
	Comparatively clean soil (following clover)	Infested soil (following corn)		
	bu.	*bu.*	*bu.*	*perct.*
Horny	73.5	63.4	10.1	13.7
Starchy	71.1	56.8	14.3	20.1
Horny	70.7	66.0	4.7	6.6
Starchy	68.6	56.1	12.5	18.2

TABLE 66.—COMPARATIVE SUSCEPTIBILITY OF CORN GROWN FROM NEARLY DISEASE-FREE STARCHY AND HORNY SEED, TO INOCULATION AT PLANTING TIME WITH A PURE CULTURE OF *Gibberella saubinetii*

Yellow dent corn planted May 26 and 27 on brown silt loam of high fertility, near Bloomington, 1922

Character of seed	Number of replications	Mean acre yield				Reduction in inoculated plots			
		Uninoculated		Inoculated		Total		Sound	
		Total	Sound	Total	Sound				
		bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Horny...	12	107.6 ± 1.3	100.9 ± 1.4	102.6 ± 1.1	97.8 ± 1.3	5.0 ± 1.7	4.6	3.1 ± 1.9	3.1
Starchy..	6	109.6 ± 1.3	98.5 ± 0.9	85.2 ± 3.4	80.0 ± 2.9	24.4 ± 3.6	22.3	18.5 ± 3.0	18.8

oculations, but also to injury under unfavorable soil conditions that exist where corn follows corn in the rotation. In many instances corn from such starchy seed has proved to be inferior in yielding ability even on soil of high fertility where an approved rotation and system of farming has been practiced for several years (Tables 57, 58, and 59). *Thus it is evident that starchy seed, regardless of its germination record, is very likely to produce corn more or less susceptible to the attack of certain parasitic fungi and to injury from unfavorable weather or soil conditions.*

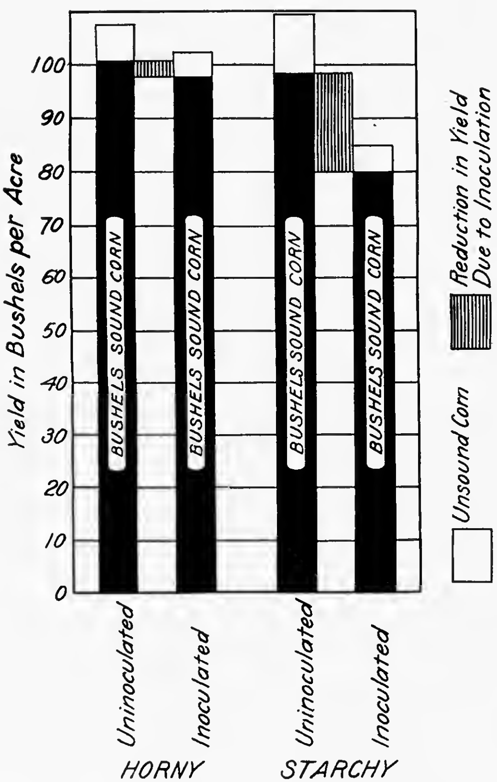


CHART 27.—CORN FROM STARCHY SEED IS MORE SUSCEPTIBLE TO INJURY BY INOCULATIONS WITH *G. saubinetii* THAN CORN FROM HORNY SEED (Table 66)

The above statement does not imply that horny seed always is likely to produce corn resistant to these diseases. Neither does it imply that all ears with horny kernels are desirable for seed purposes. Horny seed may carry considerable infection with *Diplodia zeae*, *Fusarium* spp., and *Cephalosporium acremonium.* Seed that is infected with disease-producing organisms, regardless of kernel composition, may produce corn very susceptible to injury under some conditions. *The important consideration is disease resistance, a condition which up to the present time the authors have not found associated with starchy seed or infected horny seed, but rather generally associated with seed from apparently healthy plants that shows vigor and freedom from disease on the germinator and that is horny in composition.*

DIFFERENCES IN COMMERCIAL STRAINS

During these investigations it became evident that the many strains of yellow dent corn, as they are selected and maintained on various farms thruout the corn belt, must differ widely in their yielding ability and resistance and susceptibility to disease. Data on which the above statement is based are presented in Table 67 and Chart 28. The differences in the proportion of unmarketable corn (rotted and chaffy ears and small nubbins) where the different strains were grown under the same soil and climatic conditions are very significant. In 1921, the year in which there was much damage from ear rots, Strains No. 9 and No. 10 produced total acre yields of 79.4 and 78.3 bushels, respectively. Yet the difference in yield of sound corn was 20.7 bushels, or 40.8 bushels as compared with 61.5 bushels. Strain No. 9 produced 38.6 bushels of damaged corn, while Strain No. 10 produced only 16.8 bushels. Since these strains were grown on adjoining plots receiving the same soil treatment, these large differences cannot be explained on the basis of differences in climatic or soil conditions. Obviously they were due to different degrees of disease resistance and susceptibility possessed by the several strains of corn in question.

Such a wide variation in resistance and susceptibility no doubt is one very important factor in determining the comparative yields of different strains from year to year. When all the conditions are favorable thruout the growing season, a strain of corn that is normally low in yielding ability may produce a very satisfactory yield; but the same strain under slightly adverse conditions may produce a very low yield.

In this connection the yield data from three strains of corn entered in the corn contest in Woodford County,[73] Illinois, have considerable significance. The samples were supplied thru the courtesy of Mr. M. L. Mosher and members of the Woodford County Farm Bureau. Sample No. 62 was furnished by Mr. George Krug. This strain of corn had been a consistently good yielder in that county for four consecutive years. The ears submitted were rather smooth in indentation, horny in composition, and bright in luster. Sample No. 77 had been

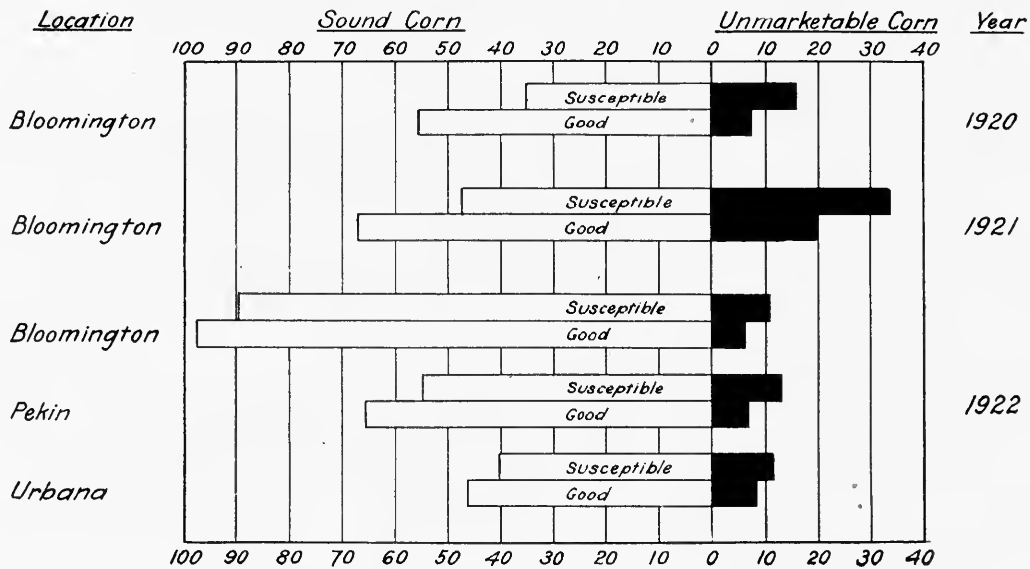


CHART 28.—VARIATION IN STRAINS IN SUSCEPTIBILITY TO EAR ROTS (Table 67)

Corn from susceptible seed produces a larger proportion of unmarketable corn than corn from good seed.

developed by another farmer in the same county. It had been selected for a specific kernel shape and indentation, and with special emphasis on a minimum of space between the rows. The ears submitted were mid-rough in denting, dull in luster, and with rather starchy endosperm. Sample No. 120 had been developed by still another farmer in Woodford county. This strain was the lowest yielder both years in which it was entered in the contest.

In order to compare the yielding ability of these three strains of yellow dent corn under more than one set of conditions, plantings were made in 1922 at Bloomington and at Peoria. The results are given in Tables 68 and 69. At Bloomington the soil and climatic conditions were very favorable thruout the season. The field in which

TABLE 67.—YIELDS FROM VARIOUS STRAINS OF YELLOW DENT CORN SHOWING VARIATIONS IN PROPORTION OF UNMARKETABLE EARS

Experiments conducted on brown silt loam at various points in Illinois, 1920-1922

Year	Location	Number of strain	Character of strain	Acre yield Total	Sound	Unmarketable	
				bu.	*bu.*	*bu.*	*perct.*
1920	Bloomington...	1	Susceptible.......	45.4	30.4	15.0	33.0
	Bloomington...	2	Good............	64.4	56.1	8.3	12.9
	Bloomington...	3	Susceptible.......	56.3	40.0	16.3	29.0
	Bloomington...	4	Good............	60.2	54.0	6.2	10.3
1921	Bloomington...	5	Susceptible.......	104.5	67.7	36.8	35.2
	Bloomington...	6	Good............	107.8	84.2	23.6	21.9
	Bloomington...	7	Susceptible.......	78.3	51.5	26.8	34.2
	Bloomington...	8	Good............	90.6	72.0	18.6	20.5
	Bloomington...	9	Susceptible.......	79.4	40.8	38.6	48.6
	Bloomington...	10	Good............	78.3	61.5	16.8	21.5
	Bloomington...	11	Susceptible.......	71.4	32.5	38.9	54.5
	Bloomington...	12	Good............	76.4	53.0	23.4	30.6
	Bloomington...	13	Susceptible.......	70.7	43.9	26.8	37.9
	Bloomington...	14	Good............	82.5	65.5	17.0	20.6
1922	Bloomington...	15	Susceptible.......	102.8	93.6	9.2	8.9
	Bloomington...	16	Good............	105.9	101.2	4.7	4.4
	Bloomington...	17	Susceptible.......	98.4	85.9	12.5	12.7
	Bloomington...	18	Good............	101.6	94.2	7.4	7.3
1922	Pekin.........	19	Susceptible.......	67.5	54.7	12.8	19.0
	Pekin.........	20	Good............	72.2	65.6	6.6	9.1
1922	Urbana.......	21	Susceptible.......	48.9	37.3	11.6	23.7
	Urbana.......	22	Good............	54.5	46.6	7.9	14.5
	Urbana.......	23	Susceptible.......	53.4	42.9	10.5	19.7
	Urbana.......	24	Good............	54.1	46.0	8.1	15.0

TABLE 68.—YIELDS FROM THREE STRAINS OF YELLOW DENT CORN

Planted May 27 on brown silt loam of high fertility, near Bloomington, 1922

Character of seed	Number of replications	Mean acre yield			
		Total	Sound	Unmarketable	
		bu.	*bu.*	*bu.*	*perct.*
Woodford county high-yielding No. 62......	18	96.6 ± 1.1	88.5 ± 1.2	8.1 ± 0.4	8.4
Woodford county low-yielding No. 77......	18	92.0 ± 1.3	78.8 ± 1.7	13.2 ± 0.6	14.3
Woodford county low-yielding No. 120.....	18	91.3 ± 1.4	79.2 ± 1.3	12.1 ± 0.6	13.3

the experiment was conducted had produced only one crop of corn, having been in virgin prairie sod previous to that time. Altho Sample No. 62 was in the lead, the difference in total yield between this corn and the lowest-yielding sample was only 5.3 ± 1.8 bushels, a figure which is not very significant in terms of the probable error involved. The difference in yield of sound corn, 9.3 ± 1.8 bushels, however, is significant. Corn from both low-yielding samples, No. 77 and No. 120, was decidedly more susceptible to ear rots than corn from the high-yielding sample No. 62, as shown by the quantities of unmarketable corn from each, that is, 13.2 ± 0.6 and 12.1 ± 0.6 bushels, respectively, as compared with 8.1 ± 0.4 bushels. The yield of sound corn from

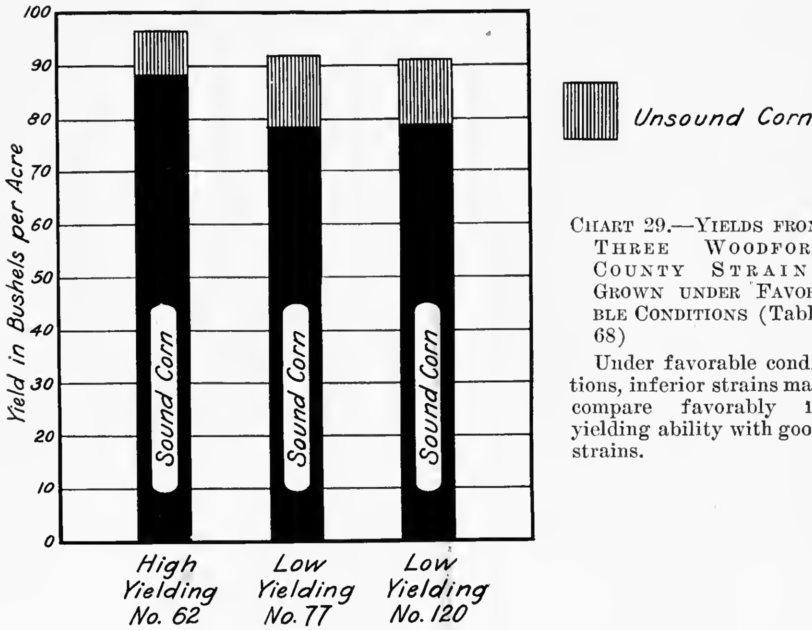


CHART 29.—YIELDS FROM THREE WOODFORD COUNTY STRAINS GROWN UNDER FAVORABLE CONDITIONS (Table 68)

Under favorable conditions, inferior strains may compare favorably in yielding ability with good strains.

TABLE 69.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF THE SAME THREE STRAINS OF YELLOW DENT CORN AS THOSE REPORTED IN TABLE 68, AS DETERMINED BY YIELDS

Planted May 29 in clean soil of high fertility and infested soil of medium fertility, near Peoria, 1922

Seed	Soil	Acre yield				Reduction in sound corn on infested soil	
		Total	Sound	Unmarketable			
		bu.	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Woodford county high-yielding, No. 62	Clean.....	96.0	81.7	14.3	14.9		
	Infested...	77.8	69.9	7.9	10.2	11.8	14.4
Woodford county low-yielding, No. 77	Clean.....	91.0	74.5	16.5	18.1		
	Infested...	69.1	57.3	11.8	17.1	17.2	23.1
Woodford county low-yielding, No. 120	Clean.....	90.9	70.5	20.4	22.4		
	Infested...	61.5	48.9	12.6	20.5	21.6	30.6

Sample No. 120 was slightly higher than that from Sample No. 77 in this experiment, or 79.2 ± 1.3 bushels as compared with 78.8 ± 1.7 bushels. These data are presented graphically in Chart 29.

At Peoria the same seed lots were planted at the same time on both

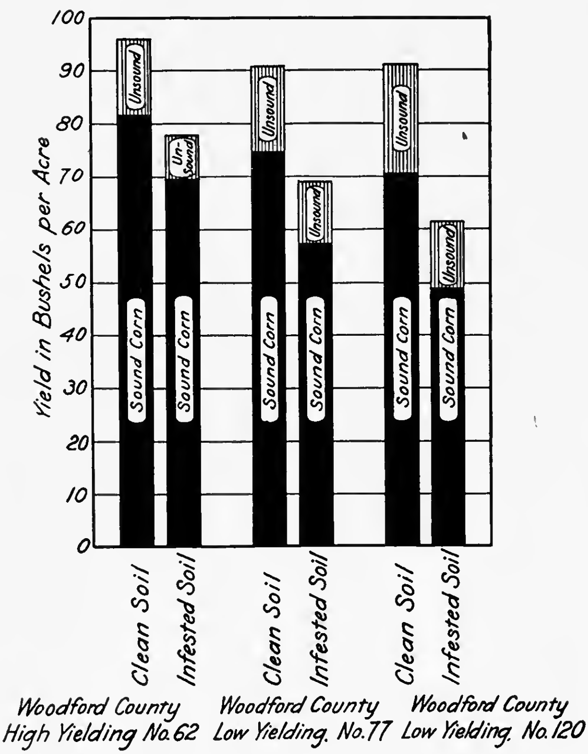


CHART 30.—YIELDS FROM THREE WOODFORD COUNTY STRAINS ON BOTH CLEAN AND INFESTED SOIL (Table 69)

Reductions in yield from the use of low-yielding strains, as compared with a high-yielding strain, were greater in infested soil than in clean soil. Also, reductions in yield following plantings on infested soil, as compared with plantings on clean soil, were greater in the low-yielding strains than in the high-yielding strain.

clean and infested soil in adjoining fields. Clean soil on the farm of Mr. Charles Gordon previously had been in virgin prairie sod. The infested soil had produced a crop of corn in 1921, and had been farmed for approximately forty years. Both soils have been classified as brown silt loam. On the clean soil the difference in acre yield between Samples No. 62 and No. 120 was 5.1 bushels in total yield and 11.2 bushels in sound corn (Table 69 and Chart 30). The difference between the same strains was much greater on infested soil, being 16.3 bushels in total yield and 21.0 bushels in sound corn. The reductions in yield of sound corn due to planting on infested soil as compared with planting on clean soil are very different for the two samples, being only 11.8 bushels for No. 62 and 21.6 bushels for No. 120, or 14.4 percent as compared with 30.6 percent. Sample No. 120, which produced at about the same rate as No. 77 on the Bloomington field, where conditions were more favorable, was 7.6 bushels below No. 77 on infested soil at Peoria. Thus it seems that resistance and susceptibility are very important factors in determining the relative merits of various strains of corn.

The data that have been presented on disease resistance and susceptibility furnish strong arguments for the adoption of resistant strains of corn and of approved rotations in which there is a more liberal use of legumes.

PHYSICAL CHARACTERS OF SEED CORN ASSOCIATED WITH SUSCEPTIBILITY AND RESISTANCE

From the foregoing data it is evident that there are many differences in the physical appearance of nearly disease-free seed ears of good viability and vigor in germination as compared with infected ears and ears the progeny of which is susceptible to the corn rot diseases. Outstanding examples of these differences in physical appearance are illustrated in Figs. 65 and 66. Infected and nearly disease-free ears often may be so much alike in some particular characters, such as luster, nature of shank attachment, exposure of tip of ear, character of endosperm, or kernel indentation, that no distinction based on that character can be made between them, but they seldom are alike in all of the above-mentioned characters.

SCOPE OF EXPERIMENTS

In view of the fact that such differences in physical appearance do exist and that ears from diseased plants frequently produce plants more or less susceptible to disease and injury under unfavorable soil and weather conditions, a series of experiments was planned during the winter of 1920-1921, to determine the need for considering all the physical characters under discussion in detecting seed ears which produce plants that are comparatively resistant, and those which produce plants that are susceptible (1) to inoculations with pure cultures of certain of the organisms associated with the root, stalk, and ear rot diseases, and (2) to injury from the unfavorable conditions encountered when planted in heavily infested soil. The experiments

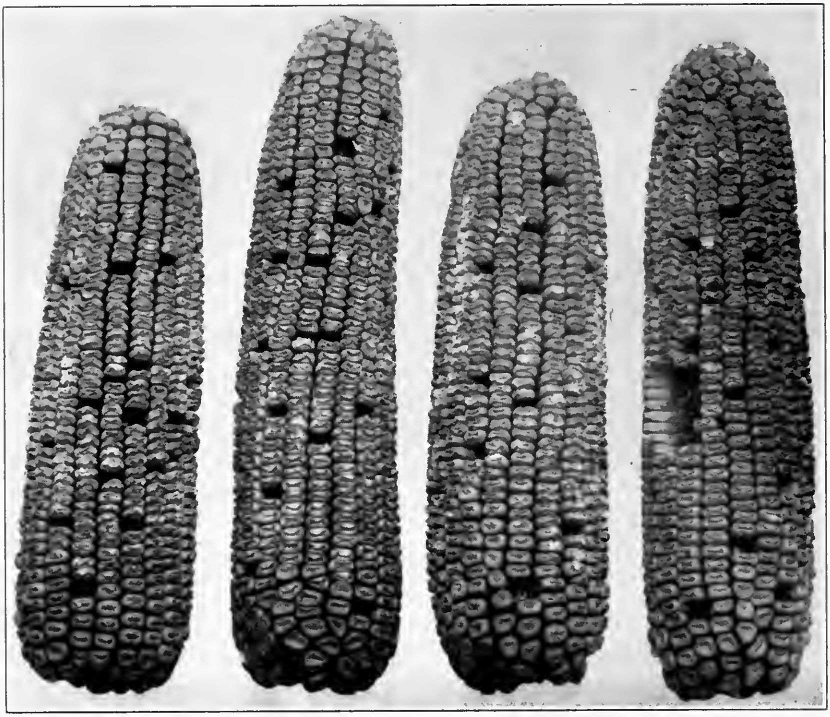


FIG. 65.—POOR SEED

Representative moderately diseased ears selected for experimental purposes from ears supplied by J. R. McKeighan and Son, Yates City. (Compare with Fig. 66.)

embraced an area of approximately 15 acres of virgin prairie sod and 10 acres of infested soil of high fertility, located on the farms of Mr. Eugene D. Funk and Mr. De Loss Funk, Bloomington, Illinois.

DESCRIPTION OF SEED

Four widely different strains of yellow dent corn that had been grown in central Illinois for several years were selected as a basis for these experiments. These were designated as Lots A, B, and C, and the nearly disease-free check. The first three lots of seed (A, B, and C) were furnished by three representative farmers from as many nearby counties. Each lot of seed was typical of the seed these farmers expected to plant.

Altho Lots A and B had not been given much attention from the standpoint of selection, Lot A for several years had been selected early in the field without particular attention to type of plant and had been germinated for viability. Also, in this strain of corn fairly large ears of rough indentation had been given preference. Lot C had been se-

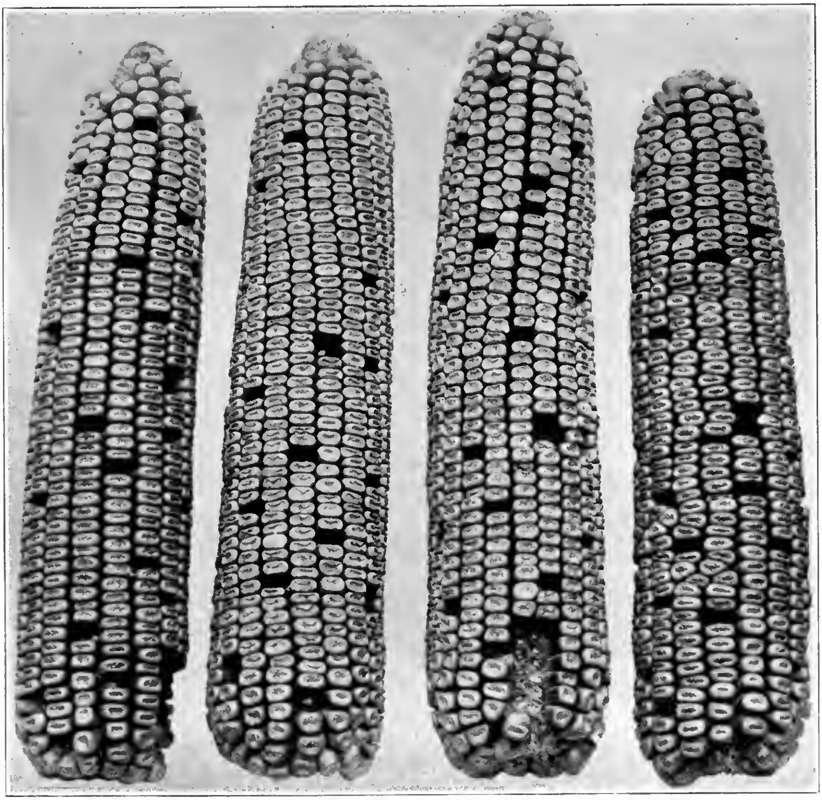


FIG. 66.—GOOD SEED

Nearly disease-free ears selected for experimental purposes from ears supplied by J. R. McKeighan and Son, Yates City. (Compare with Fig. 65.) It is evident that there are many differences in the physical appearance of nearly disease-free seed ears of good viability and vigor in germination as compared with infected ears and ears the progeny of which is susceptible to the corn rot diseases.

lected over a period of fifteen years for smooth, horny, rather heavy ears. The lot of nearly disease-free check seed was from a strain which had received six years' continuous selection for grain production and apparent freedom from disease in the field, and vigor and freedom from infection on the germinator. During this period the strain out of which the nearly disease-free check corn was chosen had become horny in composition and medium to smooth in indentation. More complete descriptions of these lots of corn are given in Tables 70 and 71.

In this series of inoculation experiments it was fundamentally important that corn used for checks be as nearly disease-free as possible. The particular 120 ears included in this composite behaved satisfactorily during four germination tests of ten kernels each. This group of ears represented a most careful selection from 1,500 bushels

TABLE 70.—CERTAIN PHYSICAL CHARACTERISTICS AND GERMINATION RECORDS OF APPARENTLY SUSCEPTIBLE AND APPARENTLY GOOD SEED SELECTIONS FROM LOTS A AND B, 1921

Characters observed	Lot A		Lot B	
	Apparently diseased (238 ears)	Apparently disease-free (88 ears)	Apparently diseased (100 ears)	Apparently disease-free (55 ears)
	perct.	*perct.*	*perct.*	*perct.*
Luster				
Bright	10.9	28.4	25.0	35.1
Intermediate	67.2	64.8	65.0	61.4
Dull	21.9	6.8	10.0	3.5
Shank attachment				
Bright	2.5	22.7	8.0	82.5
Slightly pink or slightly brown	49.2	69.3	30.0	17.5
Pink or brown	48.3	8.0	62.0	0.0
Tip of ear				
Covered by husk	24.8	27.3	30.0	31.6
Slightly exposed	35.7	62.5	28.0	42.1
Exposed	39.5	10.2	42.0	26.3
Indentation				
Smooth	14.3	62.5	16.0	68.4
Intermediate	33.6	36.4	50.0	31.6
Rough	52.1	1.1	34.0	0.0
Brightness of kernel				
Bright	42.4	82.9	61.0	84.2
Intermediate	35.3	14.8	28.0	15.8
Dull	22.3	2.3	11.0	0.0
Kernel composition				
Horny	15.5	70.4	23.0	70.2
Intermediate	59.3	28.4	55.0	29.8
Starchy	25.2	1.2	22.0	0.0
Germination record				
Viability	99.48	99.34	99.6	100.0
Strong vigor	75.38	84.80	61.1	88.0
Disease				
Scutellum rot	47.1	30.0	39.1	30.91
Visible Fusarium infection	3.45	0.9	7.4	2.54
Visible Diplodia infection	0.0	0.0	0.1	0.0

of corn that had been plant-selected in the field for good seed. Their viability was 99.94 percent, 97.22 percent of the seedlings being strong in vigor on the germinator with good root development (Table 71). Only 3.5 percent of the 4,800 kernels tested developed the scutellum rot. There was 0.05 percent Fusarium infection, but not a trace of Diplodia infection. Fig. 67 shows representative ears of this same strain of corn.

In the light of the data presented up to this point selections of *apparently good* seed and *apparently susceptible* seed from each of

TABLE 71.—CERTAIN PHYSICAL CHARACTERISTICS OF APPARENTLY SUSCEPTIBLE AND APPARENTLY GOOD SEED SELECTIONS FROM LOT C AND FROM THE EARS COMPRIZING THE NEARLY DISEASE-FREE CHECK, 1921; ALSO GERMINATION RECORDS

Characters observed	Lot C		Disease-free check (120 ears)
	Apparently diseased (41 ears)	Apparently disease-free (58 ears)	
	perct.	*perct.*	*perct.*
Luster			
Bright	12.2	46.6	53.4
Intermediate	82.9	53.4	45.1
Dull	4.9	0.0	1.5
Shank attachment			
Bright	2.4	56.9	87.2
Slightly pink or slightly brown	2.4	36.2	10.5
Pink or brown	95.2	6.9	2.3
Tip of ear			
Covered by husk	7.3	48.3	71.4
Slightly exposed	34.2	32.8	26.3
Exposed	58.5	18.9	2.3
Indentation			
Smooth	48.8	100.0	75.9
Intermediate	34.1	0.0	21.8
Rough	17.1	0.0	2.3
Brightness of kernel			
Bright	46.3	89.7	98.5
Intermediate	36.6	8.6	1.5
Dull	17.1	1.7	0.0
Kernel composition			
Horny	48.8	79.3	74.4
Intermediate	41.5	20.7	24.8
Starchy	9.7	0.0	0.8
Germination record			
Viability	93.41	96.21	99.94
Strong vigor	65.85	80.18	97.22
Disease			
Scutellum rot	12.47	8.66	3.5
Visible Fusarium	11.22	3.45	0.05
Visible Diplodia	0.97	0.34	0.0

the first three lots (A, B, and C) were made on the basis of physical characters only, prior to the germination test. No ear was included in the apparently good seed that did not appear to have matured normally and fully on a comparatively healthy plant. Kernels from both ends and from the middle of every ear were examined and those

FIG. 67.—TYPICAL GOOD SEED EARS USED IN THE 1921 EXPERIMENTS

The factors considered in the selection of these ears were: character of mother plants, protection by husks, condition of shank attachments, luster of ears, brightness of kernels, composition of kernels, and vigor and freedom from disease on the germinator.

ears showing any evidence of poor seed condition or infection were not included.

The selections of apparently susceptible seed were made up of ears that obviously had been produced on plants more or less affected

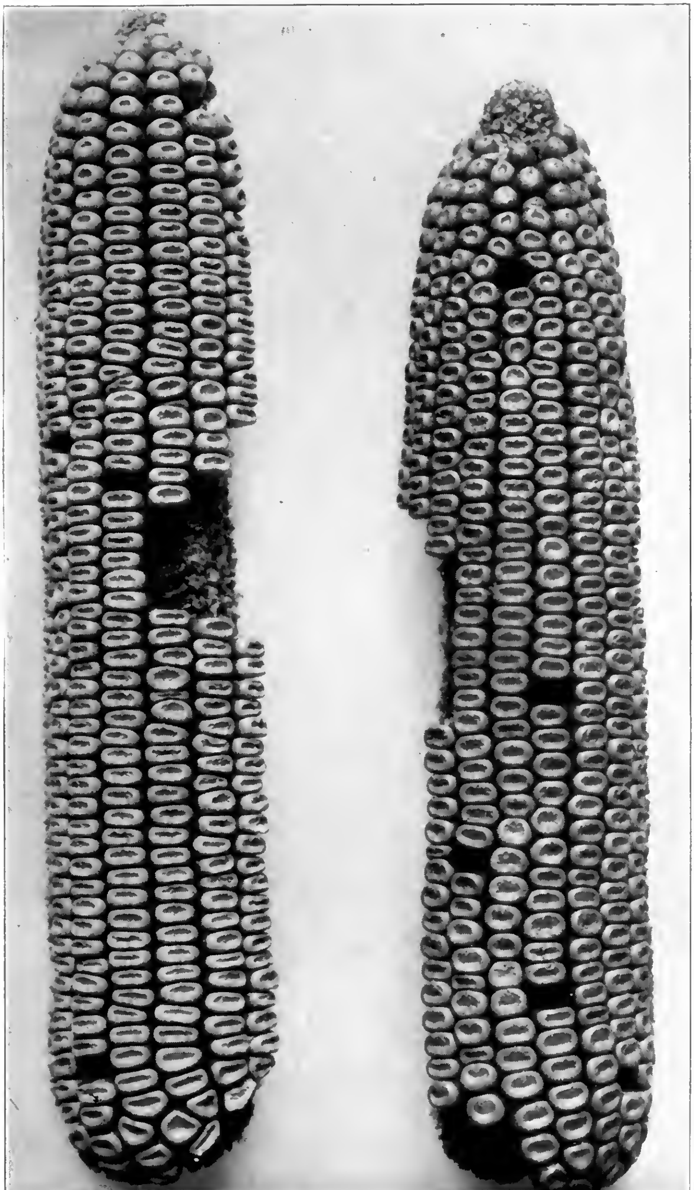


FIG. 68.—REPRESENTATIVE EARS FROM THE GOOD-SEED SELECTION—LOT A (Table 70)

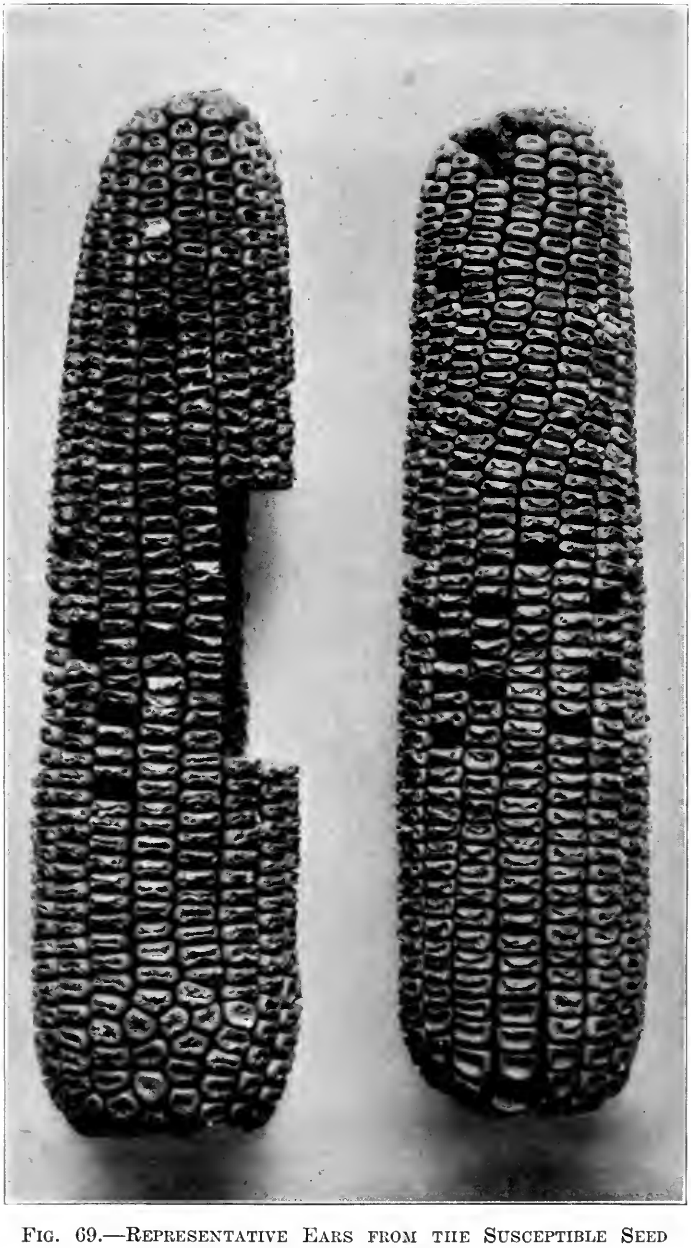


FIG. 69.—REPRESENTATIVE EARS FROM THE SUSCEPTIBLE SEED SELECTION—LOT A (Table 70)

with the root, stalk, and ear rot diseases. No ears with apparently poor seed condition or heavy infection were included. In Lots A and B the apparently susceptible selection was representative of about 90 percent of the entire sample of over 1,000 ears in each case.

Following the selections on the basis of physical appearances a germination test was made of 30 kernels from each ear. The results indicated that all the selections were reasonably good in viability with the exception of three ears from the apparently susceptible seed from Lot C. These were found to be dead and accordingly were discarded.

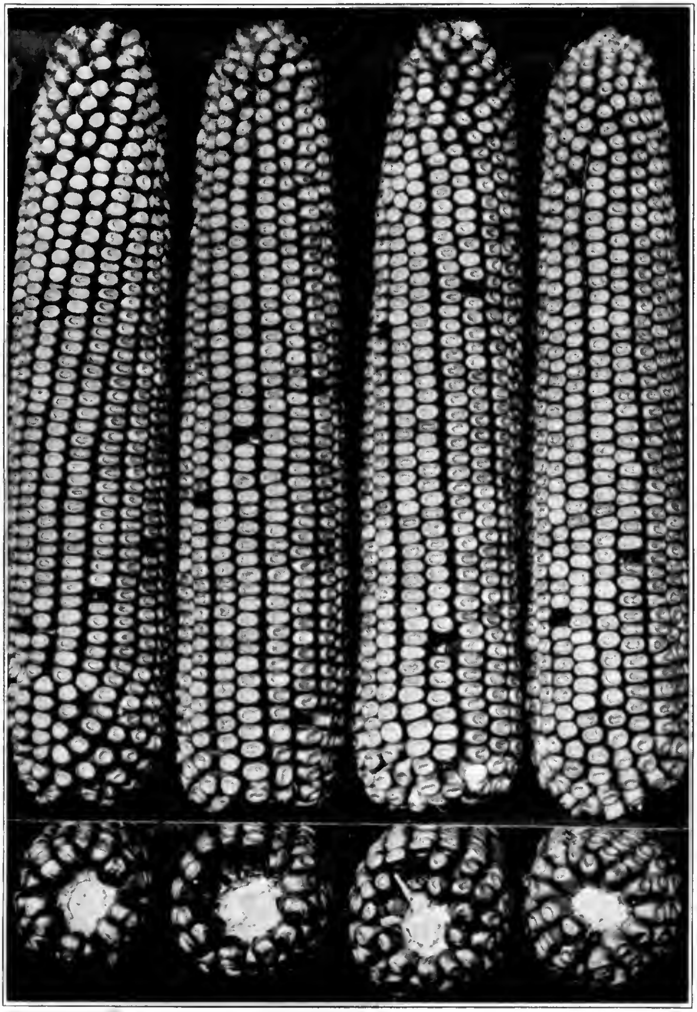


FIG. 70.—REPRESENTATIVE EARS FROM THE GOOD SEED SELECTION LOT C (Table 71)

FIG. 71.—EXPERIMENTAL PLOTS ON CLEAN AND ON INFESTED SOIL
At the right, the first crop grown on virgin prairie sod. At the left, the ninth cultivated crop since virgin prairie sod on a field that had produced six crops of corn, one crop of oats, and one crop of wheat. The soil type and topography of the two experimental fields were very similar. (Tables 74, 77, 79, 81) U. S. Department of Agriculture experimental plots on farm of Mr. E. D. Funk, Bloomington.

Germination records for the various lots, together with a description of the physical characters of the ears, are summarized in Tables 70 and 71. Representative ears from some of the selections are shown in Figs. 68, 69, and 70. The increases in percentages of strong, vigorous seedlings on the germinator, as well as the decreases in percentages of diseased seedlings, in the selections of apparently good seed, are very significant. They clearly indicate the value of such physical selection in increasing vigor of germination and reducing the percentage of infected ears and ears affected with scutellum rot.

DESCRIPTION OF EXPERIMENTAL FIELDS

The two fields chosen as the site for these studies were adjoining and were similar in soil type, topography, and fertility (Fig. 71). One field was virgin prairie sod. The adjoining field had produced corn six years, oats one year, and wheat one year since the virgin prairie sod had been broken in 1913. Both fields were fall plowed. As evidence of the good fertility of the soil in the cultivated field it may be stated that the wheat crop the preceding year yielded approximately 45 bushels per acre. Inasmuch as platings made from the virgin soil did not show the presence of any of the organisms known to be parasitic on corn, this soil has been designated as clean, and the soil in the adjoining field as infested.

PLAN OF EXPERIMENTS

The seed composites made from the apparently good seed and the apparently susceptible seed selections, together with the composites from all the original ears of each lot of seed, were planted in groups of four rows, the rows running north and south. Every alternate group of four rows was planted with the nearly disease-free check. In each row alternate groups of ten hills or rows, in some cases five hills, were inoculated at planting time with *Gibberella saubinetii,* the wheat scab organism, *Fusarium moniliforme,* and *Diplodia zeae,* thus making alternate bands of inoculated and uninoculated plots running east and west in the field. These inoculation studies were conducted in cooperation with Dr. James G. Dickson. When the corn was about 12 inches high, inoculations with *Cephalosporium acremonium* and *Aplanobacter stewarti* were made by Dr. Charles S. Reddy by means of hypodermic injections near the crown of the plant. The intervening groups of ten hills or rows were uninoculated and were used thruout the experiment as controls to measure the effect of the inoculations.

An early and a late planting were made on both clean and infested soil thus making four experiments. These four experiments were identical in arrangement of seed and inoculations, each being made up of 377 plots. The seed planted in each of these small plots was so selected that a few kernels were included from every one of the ears comprising the composite in question. For example three kernels from each of the 120 nearly disease-free ears were planted in every plot planted with check seed. The corn was dropped thru specially designed hand planters at the rate of three kernels per hill. All necessary precautions against contamination were taken in connection with planting the inoculated seed. The mean field stands secured from certain of the composites in each of the four experiments are given in Tables 72 and 73. Mean field stands in the check plots (Table 73) ranged from 92.0 ± 2.5 percent to 98.9 ± 0.2 percent.

DISCUSSION OF RESULTS

In the above experiments the plants from the apparently good seed and those from the apparently susceptible seed were affected very

TABLE 72.—FIELD STANDS FROM ORIGINAL COMPOSITES AND APPARENTLY SUSCEPTIBLE AND APPARENTLY GOOD SEED SELECTIONS, BLOOMINGTON, 1921

Soil infestation	Date of planting	Dates on which stands were taken	Number of plots	Seed	Mean field stand
					perct.
			15	Original composites	92.7 ± 0.9
	May 11	June 11-13	15	Apparently susceptible	90.6 ± 1.1
			15	Apparently good	94.4 ± 0.7
Clean					
			27	Original composites	92.1 ± 0.7
	May 28	June 16-21	27	Apparently susceptible	91.0 ± 0.7
			27	Apparently good	95.1 ± 0.4
			15	Original composites	94.0 ± 0.4
	May 10	June 14-16	15	Apparently susceptible	89.7 ± 0.8
			15	Apparently good	94.1 ± 0.5
Infested					
			27	Original composites	92.9 ± 0.5
	May 30	June 22-24	27	Apparently susceptible	89.8 ± 0.7
			27	Apparently good	95.4 ± 0.3

differently by the pure-culture inoculations, both in the clean soil and in the infested soil. The data are given in Table 74. Data from the experiments on the clean soil are summarized in Table 75 and presented graphically in Chart 31.

The selections of apparently good seed were much less susceptible than was the susceptible seed to injury following inoculations with both *Gibberella saubinetii,* a root-rotting organism, and *Cephalosporium acremonium,* an organism whose activities seem to be confined mostly to the stalk. In plantings on clean soil, total yields and yields of sound corn were affected in approximately the same way. The summaries given in Table 75 and Chart 31 show that the yield of sound corn grown from good-seed selections was reduced by inoculation only 5.9, 5.1, and 0.2 bushels, respectively, for each of the three lots of seed. Yields of sound corn grown from apparently susceptible seed selections were reduced 16.3, 17.0, and 12.7 bushels, respectively. Averaging all the plots represented in Table 74, inoculations reduced the yield of

TABLE 73.—FIELD STAND FROM NEARLY DISEASE-FREE CHECK SEED, BLOOMINGTON, 1921

Soil infestation	Date of planting	Date on which stands were taken	Number of check plots in section	Mean field stand
				perct.
			15	98.6 ± 0.3
			15	97.7 ± 1.0
			15	96.3 ± 0.8
Clean	May 11	June 11-13	15	94.2 ± 1.5
			15	94.1 ± 1.3
			15	92.0 ± 2.5
			15	94.0 ± 2.4
			15	98.2 ± 0.3
			15	97.0 ± 0.4
			15	97.1 ± 0.5
Clean	May 28	June 16-21	15	97.0 ± 0.7
			15	97.2 ± 0.3
			15	95.4 ± 0.4
			15	98.6 ± 0.2
			15	98.1 ± 0.4
			15	98.5 ± 0.1
			15	98.9 ± 0.2
Infested	May 10	June 14-16	15	97.7 ± 0.4
			15	96.0 ± 0.8
			15	96.1 ± 0.5
			15	96.8 ± 0.5
			15	96.8 ± 0.5
			15	98.2 ± 0.3
			15	98.2 ± 0.3
Infested	May 30	June 22-24	15	97.7 ± 0.3
			15	98.3 ± 0.3
			15	96.1 ± 0.4
			15	98.8 ± 0.3

TABLE 74.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF CORN FROM APPARENTLY GOOD SEED AND APPARENTLY SUSCEPTIBLE SEED SELECTIONS, TO PURE-CULTURE INOCULATIONS WITH *Gibberella saubinetii* AND *Cephalosporium acremonium*
Yellow dent corn grown on brown silt loam of high fertility, Bloomington, 1921

Source of seed	Apparent character of seed based on physical appearance	Inoculum used	Acre yield: Uninoculated, Total	Acre yield: Uninoculated, Sound	Acre yield: Inoculated, Total	Acre yield: Inoculated, Sound	Reduction following inoculation: Total		Reduction following inoculation: Sound	
Clean Soil (Virgin Prairie Sod)										
			bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
	Good	*Gibberella saubinetii*	92.3	72.0	80.6	63.7	11.7	12.7	8.3	11.5
	Susceptible	*Gibberella saubinetii*	88.3	63.4	65.2	43.8	23.1	26.2	19.6	30.9
	Difference		4.0	8.6	15.4	19.9				
Lot A	Good	*Cephalosporium acremonium*	96.5	66.5	92.3	63.1	4.2	4.4	3.4	5.1
	Susceptible	*Cephalosporium acremonium*	91.2	53.9	75.7	41.0	15.5	17.0	12.9	23.9
	Difference		5.3	12.6	16.6	22.1				
	Good	*Gibberella saubinetii*	81.7	60.6	83.0	63.0	−1.3	−1.6	−2.4	−4.0
	Susceptible	*Gibberella saubinetii*	79.5	57.6	62.7	43.9	16.8	21.1	13.7	23.8
	Difference		2.2	3.0	20.3	19.1				
Lot B	Good	*Cephalosporium acremonium*	86.0	60.2	78.3	47.6	7.7	9.0	12.6	20.9
	Susceptible	*Cephalosporium acremonium*	82.0	51.7	57.6	31.4	24.4	29.8	20.3	39.3
	Difference		4.0	8.5	20.7	16.2				
	Good	*Gibberella saubinetii*	81.8	60.0	80.8	63.3	1.0	1.2	−3.3	−5.5
	Susceptible	*Gibberella saubinetii*	80.4	57.5	74.7	53.1	5.7	7.1	4.4	7.7
	Difference		1.4	2.5	6.1	10.2				
Lot C	Good	*Cephalosporium acremonium*	81.6	57.6	73.8	53.9	7.8	9.0	3.7	6.4
	Susceptible	*Cephalosporium acremonium*	79.4	49.8	55.4	28.8	24.0	30.2	21.0	42.2
	Difference		2.2	7.8	18.4	25.1				
Nearly disease-free check		*Gibberella saubinetii*	91.0	73.1	89.0	71.2	2.0	2.2	1.9	2.6
		Cephalosporium acremonium	99.7	74.9	87.2	60.9	12.5	12.5	14.0	18.7
Infested Soil										
	Good	*Gibberella saubinetii*	83.3	62.3	77.4	60.8	5.9	7.1	1.5	2.4
Lot A	Susceptible	*Gibberella saubinetii*	75.8	48.6	74.0	49.3	1.8	2.4	−0.7	−1.4
	Difference		7.5	13.7	3.4	11.5				
	Good	*Gibberella saubinetii*	84.3	61.9	74.9	52.4	9.4	11.2	9.5	15.3
Lot B	Susceptible	*Gibberella saubinetii*	75.2	53.4	66.8	38.7	8.4	11.2	14.7	27.5
	Difference		9.1	8.5	8.1	13.7				
	Good	*Gibberella saubinetii*	81.2	64.0	74.9	67.1	6.3	7.8	−3.1	−4.8
Lot C	Susceptible	*Gibberella saubinetii*	77.3	60.0	69.6	47.7	7.7	10.0	12.3	20.5
	Difference		3.9	4.0	5.3	19.4				
Nearly disease-free check		*Gibberella saubinetii*	86.6	67.3	84.7	66.3	1.9	2.2	1.0	1.5

corn from the good-seed selections only 3.7 bushels, with odds of 9 to 1, while the same inoculations reduced the yield of corn from the susceptible-seed selections 15.4 bushels, with odds of 999 to 1 (Table 76 and Chart 32).

On none of the inoculated plots on clean soil were differences in total yields from the good-seed and from the susceptible-seed selections very large (Table 74). However, differences in total yield of corn grown from the same seed lots on the inoculated plots were very significant, ranging from 6.1 to 20.7 bushels. Differences in yield of

TABLE 75.—SUMMARY OF DATA FROM TABLE 74 SHOWING COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF PLANTINGS ON CLEAN SOIL

Source of seed	Character of seed selection	Acre yield				Reductions in sound corn following inoculation	
		Uninoculated		Inoculated			
		Total	Sound	Total	Sound		
		bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
Lot A	Good	94.4	69.3	86.5	63.4	5.9	8.5
	Susceptible	89.8	58.7	70.5	42.4	16.3	27.8
	Difference	4.6	10.6	16.0	21.0		
Lot B	Good	83.9	60.4	80.7	55.3	5.1	8.4
	Susceptible	80.8	54.7	60.2	37.7	17.0	31.1
	Difference	3.1	5.7	20.5	17.6		
Lot C	Good	81.7	58.8	77.3	58.6	0.2	0.3
	Susceptible	79.9	53.7	65.1	41.0	12.7	23.6
	Difference	1.8	5.1	12.2	17.6		

sound corn in the inoculated plots of the same experiment ranged from 10.2 to 25.1 bushels.

Corn grown from good seed of Lot C was little affected by inoculations with either organism, either on clean soil or on infested soil, but corn grown from the apparently susceptible seed was severely affected by inoculations with *Cephalosporium acremonium.* In the plots inoculated with this organism (Table 74) the difference in total yield between these two seed selections was 18.4 bushels; but in the adjacent uninoculated plots the difference was only 2.2 bushels. The difference in yield of sound corn was three times as large in the inoculated plots as in the uninoculated plots, or 25.1 bushels compared with 7.8 bushels.

Total yields from apparently good-seed and from apparently susceptible-seed selections were affected in about the same degree by inoculations with *Gibberella saubinetii* on infested soil. In Lot A corn grown from apparently susceptible seed proved to be very susceptible to injury from the unfavorable conditions encountered in the infested soil. The yield of sound corn was reduced from 63.4

bushels in clean soil to 48.6 bushels in infested soil. Seed inoculation with *Gibberella saubinetii* did not cause any further reduction. In Lots B and C on the infested soil inoculations with this organism caused considerably more reduction in yield of sound corn in plots

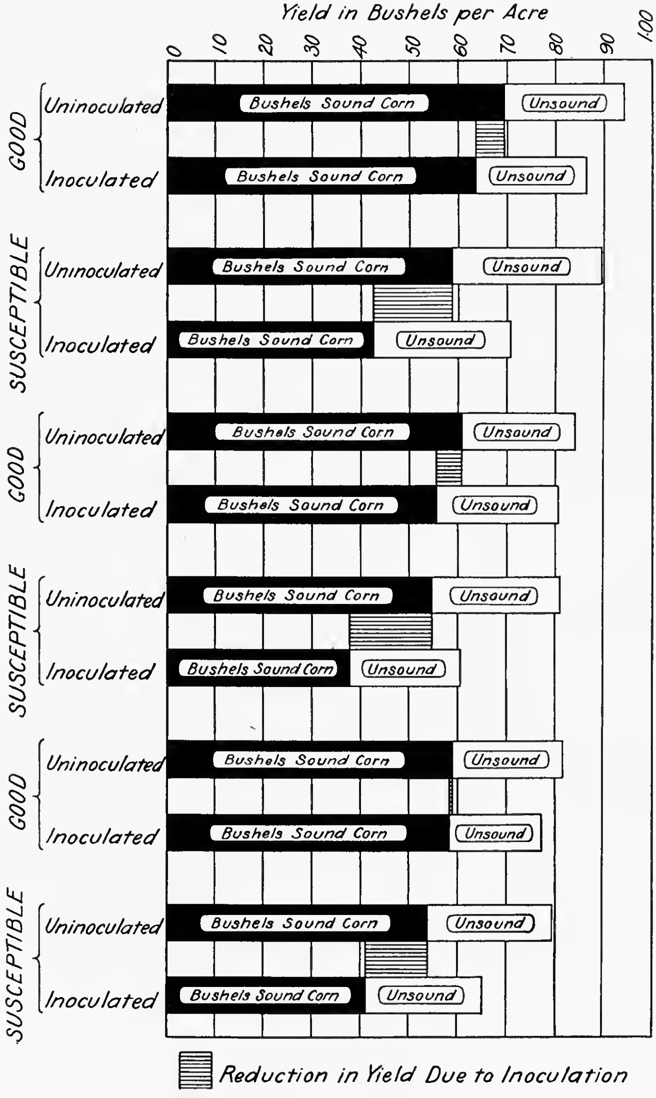


CHART 31.—COMPARATIVE EFFECT OF INOCULATION ON GOOD SEED SELECTIONS AND ON SUSCEPTIBLE SEED SELECTIONS (Table 75)

Yields from susceptible seed were reduced much more by artificial inoculations with parasitic organisms than yields from good seed.

TABLE 76.—SUMMARY OF DATA FROM TABLE 74 SHOWING COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF APPARENTLY GOOD SEED AND APPARENTLY SUSCEPTIBLE SEED SELECTIONS

Apparent character of seed based on physical appearance	Number of replications	Mean acre yield of sound corn		Reduction in sound corn following inoculation		
		Uninoculated	Inoculated			
		bu.	*bu.*	*bu.*	*perct.*	*odds*
Good	6	62.8	59.1	3.7	5.9	9:1
Susceptible	6	55.7	40.3	15.4	27.7	999:1

grown from apparently susceptible seed than in those grown from apparently good seed, the figures being 14.7 and 12.3 bushels as compared with 9.5 and an increase of 3.1 bushels. In Lot C the difference between the two seed selections in yield of sound corn in the uninoculated plot was 4.0 bushels, while in the inoculated plot the difference was 19.4 bushels, almost five times as much. These data emphasize the serious effect root rot diseases may have in increasing the percentage of chaffy ears, rotted ears, and nubbins, thus reducing the quality of the yield. These differences between strains in resistance and susceptibility are very significant. Furthermore these differences could not be measured by total yield only. The importance of taking cognizance of quality, as well as quantity, of yield is clearly evident.

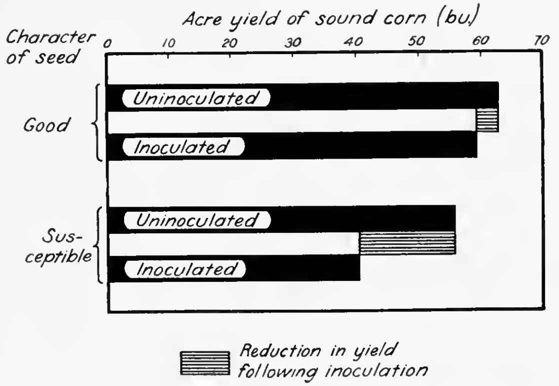


CHART 32.—COMPARATIVE SUSCEPTIBILITY TO INJURY FROM ARTIFICIAL INOCULATIONS (Table 76)

The yield from the good seed was reduced much less by artificial inoculation with corn rot parasites than was the yield from the susceptible seed.

The difference in the effect following the inoculations with *Gibberella saubinetii* and with *Cephalosporium acremonium* on corn grown from the nearly disease-free checks is worthy of consideration. On the clean soil the organism affecting the roots (*G. saubinetii*) caused a reduction of only 1.9 bushels in yield of sound corn. Six years' continuous plant and germinator selection apparently resulted in isolating an open-pollinated strain of corn highly resistant to this organism under the usual field conditions. However, this same strain of corn was susceptible to inoculation with *Cephalosporium acremonium,* an organism infecting the vascular bundles of the stalk. Plants and ears affected with this organism are not always easily avoided in the selection of good seed. During the earlier years of these investigations, when the symptoms of the black-bundle disease were not understood and the causal organism not known, it is very likely that many seed ears infected with *Cephalosporium acremonium* were included in the seed stock used for propagating this strain of corn. It would seem, therefore, that a program which aims to develop productive strains of corn possessing high degrees of disease resistance must consider all the factors concerned. Yield data from corn grown from the nearly disease-free check at many places in Illinois and under adverse conditions indicate, however, that continuous selection for production and freedom from disease in the field and vigor and freedom from infection on the germinator has been worth while and profitable. Complete resistance to all the known diseases and to injury from adverse conditions, combined with high grain production and maturity, probably can be attained only thru recombination of resistant inbred strains whose merit has been carefully determined. This program will be discussed in a following section.

Data are presented in Table 77 on resistance and susceptibility of the apparently good-seed and susceptible-seed selections as determined by early and late plantings on clean and infested soil of high fertility. Yields from the good-seed selection of Lot A were reduced much less by growing on infested soil than those from the apparently susceptible seed, the reductions of sound corn being 9.7 bushels in the early planting and 9.2 bushels in the late planting (Table 77) as compared with 14.8 and 20.9 bushels, respectively. Differences in resistance and susceptibility in the two selections of Lot B were not so marked, but were in favor of the good seed in both plantings. In Lot C the susceptible seed was only slightly below the good seed in yield from the early planting on both clean and infested soil, but the yields from the late planting from the same seed lots showed that the yield of sound corn grown from apparently susceptible seed was reduced 8.9 bushels, or 16.0 percent, on the infested soil. Under identical conditions the yield of sound corn grown from the apparently good seed was not affected. Corn apparently resistant under some conditions may be very susceptible under other conditions. From these results it would seem, therefore, that the *relative degrees of resistance and susceptibility possessed by different strains and selections of corn cannot always be determined accurately by plantings on one date in one locality involving only one set of environmental factors.*

Data on the yielding ability of the two selections from Lot A at three widely separated points in Illinois are given in Table 78 and Chart 33. At all the points mentioned the corn grown from the

TABLE 77.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF APPARENTLY GOOD SEED AND APPARENTLY SUSCEPTIBLE SEED SELECTIONS AS DETERMINED BY EARLY AND LATE PLANTINGS ON CLEAN AND INFESTED SOIL OF HIGH FERTILITY

Selections from different lots of yellow dent corn, Bloomington, 1921

Source of seed	Date of planting	Apparent character of seed based on physical selection	Acre yield: Clean soil: Total	Acre yield: Clean soil: Sound	Acre yield: Infested soil: Total	Acre yield: Infested soil: Sound	Reduction in yield on infested soil: Total		Reduction in yield on infested soil: Sound	
			bu.	bu.	bu.	bu.	bu.	perct.	bu.	perct.
Disease-free check	May 10-11		91.0	73.1	86.6	67.3	4.4	4.8	5.8	7.9
Lot A	May 10-11	Good	92.3	72.0	83.3	62.3	9.0	−9.8	9.7	13.5
		Susceptible	88.3	63.4	75.8	48.6	12.5	14.2	14.8	23.3
		Difference	4.0	8.6	7.5	13.7				
Lot B	May 10-11	Good	81.7	60.6	84.3	61.9	−2.6	−3.2	−1.3	−2.1
		Susceptible	79.5	57.6	75.2	53.4	4.3	5.4	4.2	7.3
		Difference	2.2	3.0	9.1	8.5				
Lot C	May 10-11	Good	81.4	60.0	81.2	64.0	0.2	0.2	−4.0	−6.7
		Susceptible	80.4	57.5	77.3	60.0	3.1	3.9	−2.5	−4.3
		Difference	1.0	2.5	3.9	4.0				
Disease-free check	May 28-30		93.8	72.3	86.8	63.4	7.0	7.5	8.9	12.3
Lot A	May 28-30	Good	88.9	65.4	78.4	56.2	10.5	11.8	9.2	14.1
		Susceptible	84.5	61.0	74.6	40.1	9.9	11.7	20.9	34.3
		Difference	4.4	4.4	3.8	16.1				
Lot B	May 28-30	Good	84.5	56.1	74.6	48.0	9.9	11.7	8.1	14.4
		Susceptible	78.9	50.3	71.9	40.7	7.0	8.9	9.6	19.1
		Difference	5.6	5.8	2.7	7.3				
Lot C	May 28-30	Good	83.4	55.4	80.1	55.1	3.3	0.4	0.3	0.5
		Susceptible	79.0	55.5	72.4	46.6	6.6	8.4	8.9	16.0
		Difference	4.4	−0.1	7.7	8.5				

TABLE 78.—ADDITIONAL DATA ON FIELD PERFORMANCE OF GOOD-SEED AND SUSCEPTIBLE-SEED SELECTIONS OF LOT A

Grown at three widely separated points in Illinois, 1921

Location of experiment (Illinois)	Date of planting	Previous crop	Acre yield				Reduction in sound corn following use of susceptible seed	
			Good seed		Susceptible seed			
			Total	Sound	Total	Sound		
			bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*
Peoria	May 12	Clover	74.6	56.7	72.2	51.6	5.1	9.0
Peoria	May 13	Corn	81.5	66.4	66.6	51.3	15.1	22.7
Virginia	May 23	Clover	67.1	55.5	51.1	38.0	17.5	31.5
Bloomington	May 10	Corn	83.3	62.3	75.8	48.6	13.7	22.0
Bloomington	May 30	Corn	78.4	56.2	74.6	40.1	16.1	28.6

apparently susceptible seed proved to be significantly inferior to that from apparently good seed, as measured in acre yields of sound corn.

An analysis of all the data presented up to this point indicates: (1) that there is usually a difference in general appearance between ears produced on diseased plants and those produced on healthy plants; (2) that infected ears often may be detected by certain physical characters found to be associated with seed infection by one or more of the organisms associated with these diseases; and (3) that fully matured and uninfected ears that have been borne on apparently healthy plants usually produce corn possessing considerable resistance both to these diseases and to unfavorable soil and weather conditions. The value of considering all these factors in selecting resistant and higher yielding seed will be discussed in the following section.

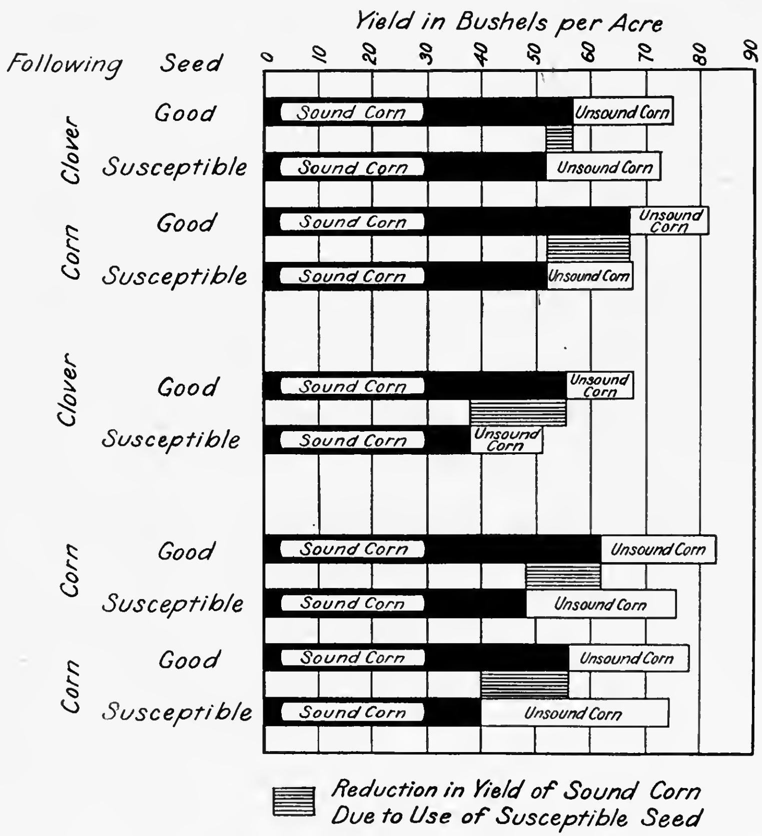


CHART 33.—YIELDS FROM GOOD-SEED SELECTIONS AND FROM SUSCEPTIBLE SEED SELECTIONS (Table 78)

Reductions in yield of corn following the use of susceptible seed selections, as compared with corn from good-seed selections, were significant in every experiment.

VALUE OF PHYSICAL APPEARANCE AS A BASIS FOR SELECTION

Data presented in the preceding section show that it is possible to choose from the same seed lots, on the basis of physical appearance alone, groups of ears the progeny of which will differ widely in resistance and susceptibility to the corn rot diseases (Table 74). The data also show that the better the strain upon which the selection is practiced, the greater the return for the effort involved, for it is only by selecting from a strain in which there is some corn that is resistant, that a strain having a high degree of resistance can be developed. In the same experiments from which these data were secured, corn grown from apparently good seed selected on the basis of physical appearance was compared with corn grown from the original composites.

Description of Seed

The original seed composites in all cases were made up from the seed lots as they were received, that is, before any selections were made. Hence they contained seed from good ears as well as from ears apparently susceptible to disease.

The selections of apparently good seed represented the best 50 to 90 ears from approximately 1,000 ears in each original seed lot of Lots A, B, and C. These good seed ears were chosen in much the same way that a successful live-stock man would choose the best breeders from a large number of animals. In selecting such animals many points would be considered and each given its proper weight before any individual would be taken for breeding purposes. Likewise, in selecting apparently good seed, due emphasis was given to those characters which have been found to be associated with disease resistance and freedom from infection (Tables 70 and 71). Characters given major emphasis were weight and size of ear, luster, appearance of shank attachment, nature of endosperm, covering of tip of ear, and kernel indentation. Altho a few of the ears selected were perfect in all these characters, no ears were included that were decidedly deficient in any particular, including those characters indicating that the ears had been borne on diseased plants. On the basis of the above physical characters alone, the apparently good seed ears were the best ears that could be picked out of each lot of seed. *In general appearance these good seed ears* (Tables 70 and 71 and Figs. 67, 68, and 70) *were mid-sized, heavy in weight, bright in luster, moderately horny to horny in kernel composition, and moderately smooth to smooth in indentation. Shank attachments were bright or only slightly discolored, and in no case was there evidence of rotting of the tissues at the butt of the cob. Tips of the ears had been covered by the husks or had been only slightly ex-*

TABLE 79.—COMPARATIVE RESISTANCE AND SUSCEPTIBILITY OF CORN FROM ORIGINAL COMPOSITES AND APPARENTLY GOOD SEED SELECTIONS, TO PURE-CULTURE INOCULATIONS WITH *Cephalosporium acremonium*, *Aplanobacter stewarti*, AND *Gibberella saubinetii*

Selections from three strains of yellow dent corn, Bloomington, 1921

Source of seed	Character of seed	Date of planting	Soil infestation	Inoculum used	Acre yield				Reduction following inoculation			
					Uninoculated		Inoculated		Total		Sound	
					Total	Sound	Total	Sound				
					bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Lot A	Original composite	May 11	Clean	*Cephalosporium acremonium*	87.9	57.6	77.2	47.3	10.7	12.2	10.3	17.9
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	96.5	66.5	92.3	63.1	4.2	4.4	3.4	5.1
	Increase in yield of good-seed selection over original composite				8.6	8.9	15.1	15.8				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	84.2	51.5	73.3	32.3	10.9	12.9	19.2	37.3
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	74.4	51.5	69.8	49.7	4.6	6.2	1.8	3.5
	Increase in yield of good-seed selection over original composite				−9.8	0.0	−3.5	17.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	86.5	59.3	79.2	56.5	7.3	8.4	2.8	4.7
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	93.1	69.5	80.2	61.5	12.9	13.9	8.0	11.5
	Increase in yield of good-seed selection over original composite				6.6	10.2	1.0	5.0				
	Original composite	May 10	Infested	*Gibberella saubinetii*	78.9	58.1	71.3	50.9	7.6	9.6	7.2	12.4
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	80.3	60.0	74.4	58.0	5.9	7.3	2.0	3.3
	Increase in yield of good-seed selection over original composite				1.4	1.9	3.1	7.1				
Lot B	Original composite	May 11	Clean	*Cephalosporium acremonium*	90.8	49.5	70.9	38.4	19.9	21.9	11.1	22.4
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	86.0	60.2	78.3	47.6	7.7	9.0	12.6	20.9
	Increase in yield of good-seed selection over original composite				−4.8	10.7	7.4	9.2				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	77.0	48.3	80.3	52.4	−3.3	−4.3	−4.1	−8.5
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	84.4	64.6	93.6	59.8	−9.2	−10.9	4.8	7.4
	Increase in yield of good-seed selection over original composite				7.4	16.3	13.3	7.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	83.1	61.4	73.8	51.8	9.3	11.2	9.6	15.6
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	81.1	60.4	83.0	61.7	−1.9	−2.3	−1.3	−2.2
	Increase in yield of good-seed selection over original composite				−2.0	−1.0	9.2	9.9				

TABLE 79—*Concluded*

Source of seed	Character of seed	Date of planting	Soil infestation	Inoculum used	Acre yield				Reduction following inoculation			
					Uninoculated		Inoculated		Total		Sound	
					Total	Sound	Total	Sound				
	Original composite	May 10	Infested	*Gibberella saubinetii*	bu. 75.5	bu. 51.7	bu. 64.2	bu. 45.7	bu. 11.3	perct. 15.0	bu. 6.0	perct. 11.6
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	81.3	58.5	74.9	54.7	6.4	7.9	3.8	6.5
	Increase in yield of good-seed selection over original composite				5.8	6.8	10.7	9.0				
Lot C	Original composite	May 11	Clean	*Cephalosporium acremonium*	72.7	42.8	57.2	30.3	15.5	21.3	12.5	29.2
	Good-seed selection	May 11	Clean	*Cephalosporium acremonium*	81.6	57.6	73.8	53.9	7.8	9.6	3.7	6.4
	Increase in yield of good-seed selection over original composite				8.9	14.8	16.6	23.6				
	Original composite	May 28	Clean	*Aplanobacter stewarti*	94.0	74.8	78.1	46.1	15.9	16.9	28.7	38.4
	Good-seed selection	May 28	Clean	*Aplanobacter stewarti*	93.4	68.5	91.7	68.5	1.7	1.8	0.0	0.0
	Increase in yield of good-seed selection over original composite				−0.6	−6.3	13.6	22.4				
	Original composite	May 11	Clean	*Gibberella saubinetii*	78.3	58.2	78.2	59.1	0.1	0.1	−0.9	−1.5
	Good-seed selection	May 11	Clean	*Gibberella saubinetii*	81.7	62.4	78.7	62.5	3.0	3.7	−0.1	−0.2
	Increase in yield of good-seed selection over original composite				3.4	4.2	0.5	3.4				
	Original composite	May 10	Infested	*Gibberella saubinetii*	80.3	57.4	80.9	54.6	−0.6	−0.7	2.8	4.9
	Good-seed selection	May 10	Infested	*Gibberella saubinetii*	81.2	64.0	74.9	67.1	6.3	7.8	−3.1	−4.8
	Increase in yield of good-seed selection over original composite				0.9	6.6	−6 0	12.5				

posed, as judged by the appearance of the ear and tip end of the cob. A very high percentage of the ears had bright kernels.

PLAN OF INOCULATIONS

Both the original composite and the selection of apparently good seed from each of Lots A, B, and C were inoculated with pure cultures of *Cephalosporium acremonium, Aplanobacter stewarti,* and *Gibberella saubinetii.* Inoculations with *C. acremonium* and *A. stewarti* were made by hypodermic injection when the corn was about two feet high. Inoculations with *G. saubinetii* were made by immersing the seed immediately before planting in a spore suspension of the organism.

Reddy and Holbert have shown that *C. acremonium* is the cause of the black-bundle disease of corn and that pure-culture inoculations with this organism are capable of producing heavy losses in both dent and sweet corn. Seed infected with this organism produces corn which under certain conditions, gives unsatisfactory yields. *A. stewarti* is responsible for the bacterial wilt disease of corn. *G. saubinetii,* the wheat scab organism, has been shown by Dickson,[18, 19] and by Koehler, Dickson, and Holbert,[61] to be capable of causing seedling blight of corn. Undoubtedly, under some conditions, this organism may cause considerable rotting of the roots.

Data showing the comparative resistance and susceptibility of the original composites and good-seed selections to inoculations with each of these pathogenic organisms are reported in Table 79.

DISCUSSION OF RESULTS

Corn grown from the original composite from Lot A was relatively very susceptible to inoculations with both *C. acremonium* and *A. stewarti.* Total yields were reduced 10.7 and 10.9 bushels, respectively, and yields of sound corn, 10.3 and 19.2 bushels. Good seed selected from this same lot, on the other hand, produced corn that was relatively resistant to inoculation with either of these organisms under the conditions encountered in these experiments. However, it was not nearly so resistant to injury from seed inoculation with *G. saubinetii,* a root-rotting organism, as it was to injury from the other two organisms. On clean soil the total yield was reduced from 93.1 to 80.2 bushels by inoculation with *G. saubinetii,* and the yield of sound corn from 69.5 to 61.5 bushels. Somewhat contrary to expectations, in early plantings on infested soil there was only a slight difference in the uninoculated plots, either in total yield or yield of sound corn, between the plots planted with the original composite and those planted with the good-seed selection, the figures being 78.9 as compared with 80.3 bushels total yield, and 58.1 compared with 60.0 bushels sound corn. Yields from good seed were reduced more by being planted on infested soil than were yields from the original composite, the reductions being

9.5 bushels as compared with 1.2 bushels, respectively. On infested soil reductions in sound corn following inoculation with *G. saubinetii* were less in the plots planted with the good-seed selection than in the plots planted with the original composite, the data being 2.0 bushels, or 3.3 percent, compared with 7.2 bushels, or 12.4 percent.

Considering yield of sound corn in the uninoculated plots, apparently good seed from Lot A was better than the original composite from that lot in every instance except one, where the yields were the same. In the inoculated plots, in three out of four cases, yields of sound corn from selected seed were much greater than those from the original composite. This suggests that *corn grown from apparently good seed from Lot A possessed, for the most part, more disease resistance than corn grown from the original composite.*

In Lot B the plants from both the original composite and the apparently good seed were rather susceptible to infection by inoculation with *C. acremonium* as measured by reduction in yield of sound corn. However, the total yield of the original composite was reduced more than that of the good-seed selection, the reduction being 19.9 bushels, or 21.9 percent, as compared with 7.7 bushels, or 9.0 percent.

Corn from the apparently good seed of Lot B was less affected by seed inoculation with *G. saubinetti,* both in total yield and in yield of sound corn, than that from the original composite. In clean soil the yield of sound corn from the original composite was reduced 9.6 bushels, or 15.6 percent, as compared with a slight increase of corn from the good-seed selection. In infested soil differences in resistance and susceptibility were not so large but were in favor of corn from the good seed. Yields of sound corn were consistently higher in the plots grown from selected seed than in those grown from the original composite, both in the inoculated and the uninoculated plots.

While the plants in Lot B were susceptible to inoculation with *C. acremonium* and *G. saubinetii,* they were apparently resistant to inoculation with *A. stewarti.* In the plots inoculated with this latter organism, the increase in total yield of corn grown both from original composites and from apparently good seed probably was due to the increase in suckering. Generally, however, hypodermic inoculations with this organism did not cause any appreciable increase in suckering. The fact that corn grown from Lot B was susceptible to injury when inoculated with *C. acremonium* and apparently resistant when inoculated with *A. stewarti* emphasizes a statement made previously in this bulletin that comparative resistance to one disease does not necessarily mean an equal resistance to other diseases (Table 74).

It will be remembered that Lot C came from a strain of yellow dent corn that had been selected over a period of years for heavy ears with moderately smooth dented, lustrous kernels. This selection undoubtedly eliminated most of the ears with starchy kernels and

TABLE 80.—SUMMARY OF DATA PRESENTED IN TABLE 79

Character of seed	Date of planting	Soil infestation	Inoculum used	Mean acre yield: Uninoculated Total	Uninoculated Sound	Inoculated Total	Inoculated Sound	Reduction following inoculation: Total		Sound	
				bu.	*bu.*	*bu.*	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Original composite...	May 11...	Clean.....	*Cephalosporium acremonium* .	83.8	50.0	68.4	38.7	15.4	18.4	11.3	22.6
Good-seed selection..	May 11...	Clean.....	*Cephalosporium acremonium* .	88.0	61.4	81.5	54.9	6.5	7.4	6.5	10.6
Increase in yield of good-seed selection over original composite........				4.2	11.4	13.1	16.2				
Original composite...	May 28...	Clean.....	*Aplanobacter stewarti*........	85.1	58.2	77.2	43.6	7.9	9.3	14.6	25.1
Good-seed selection..	May 28...	Clean.....	*Aplanobacter stewarti*........	84.1	61.5	85.0	59.3	−0.9	−1.1	2.2	3.6
Increase in yield of good-seed selection over original composite........				−1.0	3.3	7.8	15.7				
Original composite...	May 11...	Clean.....	*Gibberella saubinetii*.........	82.6	59.6	77.1	55.8	5.5	6.7	3.8	6.4
Good-seed selection..	May 11...	Clean.....	*Gibberella saubinetii*.........	85.3	64.1	80.6	61.9	4.7	5.5	2.2	3.4
Increase in yield of good-seed selection over original composite........				2.7	4.5	3.5	6.1				
Original composite...	May 10...	Infested...	*Gibberella saubinetii*.........	78.2	55.7	72.1	50.4	6.1	7.8	5.3	9.5
Good-seed selection..	May 10...	Infested...	*Gibberella saubinetii*.........	80.9	60.8	74.7	59.9	6.2	7.7	0.9	1.5
Increase in yield of good-seed selection over original composite........				2.7	5.1	2.6	9.5				

those produced on plants with badly rotted roots. But such a selection would not necessarily be effective in culling out ears from plants slightly affected with the black-bundle disease or any of the bacterial diseases. Corn grown from original composites of Lot C was very susceptible to inoculations with both *C. acremonium* and *A. stewarti.* Total yields were reduced 15.5 and 15.9 bushels, respectively, and yields of sound corn 12.5 and 28.7 bushels (Table 79). Corn from the carefully selected composite, however, apparently was resistant to inoculation with *A. stewarti.* It was also much less susceptible to injury from *C. acremonium* than corn from the original composite, the reduction in yield of sound corn being 3.7 bushels and 12.5 bushels, respectively.

On clean soil corn from neither the original composite nor the selected composite was affected appreciably by seed inoculation with the wheat scab organism, *G. saubinetii.* In comparing the differences between the yields of sound corn from the good-seed and from the original composite, it is found that in three out of four cases the differences are much greater in the inoculated than in the uninoculated plots. These data indicate that corn grown from the good-seed selection was more disease resistant and higher yielding than corn from the original composite.

The data presented in Table 79 are summarized in Table 80. It will be noted that the acre yield of sound corn grown from the good-seed selection was reduced less following each of the inoculations than was the acre yield of sound corn grown from the original selections.

Yields from a large number of plots planted with the original composites and good-seed selections are reported in Table 81. These data were secured from early and late plantings on both clean and infested soil of high fertility. Data from adjacent plots planted with nearly disease-free check seed are included in this table as a means of comparison.

Mention has been made regarding the preparation of nearly disease-free check seed for 1921. In this connection it is well to emphasize again the fact that this strain of corn had been selected continuously since 1916 for heavy grain production and apparent freedom from disease in the field, and for vigor and freedom from infection on the germinator. *In field selection special attention was given to taking only well-matured ears, which were neither small nor exceptionally large, on sound shanks* (Fig. 72) *at a convenient height, and from erect sturdy plants whose leaves were still partially green and free from chlorophyll reduction, spottings, streakings, rust, rolling, and crinkling. Ears from smutted plants were avoided because it has been shown that resistance and susceptibility to this fungous disease is inherited. Ears with starchy kernels were eliminated. On the germinator, seedling vigor was sought as much as freedom from*

FIG. 72.—A WELL MATURED EAR PRODUCED ON A HEALTHY STALK AND A SOUND, STIFF SHANK

disease. No attempt was made to have all seed ears conform to any previously determined standard of size or shape. Every year a large quantity of seed was selected from 40 to 80 acres of corn that had been planted with carefully prepared seed of this strain. The nearly disease-free check seed was prepared from these supplies of plant-selected material by a careful selection on the basis of physical appearance and performance on the germinator. Good seed remaining after experimental needs for the current season had been satisfied was planted in large isolated fields from which similar material could be secured the following year. In short, the nearly disease-free check seed used in the experiments reported in Tables 81 and 82 represented the best from a strain of corn the development of which embraced the practices of *plant selection, physical selection, and germinator selection, over a period of years, with every effort to insure broad breeding of the open-pollinated strain under development.*

In Lots A, B, and C, it will be recalled that selection of the good seed on the basis of physical appearance was confined to a consideration of the characters of the seed ear and represented only one year's work in that direction. These lots of corn, as well as Lot D, described and discussed later, probably are typical of many seed stocks found on farms of the corn belt.

The good-seed selection produced slightly higher field stands than the original composite in ten of the twelve comparisons reported in Table 81. Altho a *good field stand with reference to quantity is absolutely essential to satisfactory yield, within limits it is not so important as quality of stand as regards vigor and resistance of plants.* Plantings from good-seed selections not only resulted in somewhat better stands, but in stands with higher percentages of strong, vigorous plants. Data previously published indicate that this increase in percentages of strong, vigorous plants contributed much more to the higher yields in those plots than did the slightly increased stands.[48]

Field stands in plots planted with nearly disease-free check seed not only were high, ranging from 95.9 ± 0.5 to 98.2 ± 0.2 percent, but contained very few weak plants.

Data in Table 79 show that in most cases corn grown from good-seed selections was more resistant to inoculation with *G. saubinetii* and to hypodermic inoculations with *C. acremonium* and *A. stewarti* than was corn grown from the original composites. Undoubtedly, the different degrees of resistance possessed by corn grown from the original composites and from the good-seed selections would be very important contributing factors in determining their relative yielding abilities. With every condition favorable, the good-seed selections might not be expected to yield any more than the original composites, but under somewhat adverse conditions differences in yield would be greater, as judged on the basis of data on the behavior of nearly disease-free horny and starchy seed (Tables 57, 58, and 59) and also the performance of corn grown from apparently susceptible-seed selections and apparently good-seed selections as shown in Tables 74 and 77.

In Lot A (Table 81) corn grown from the good-seed selections was higher in yielding ability than corn grown from the original composites both in the plantings on clean soil and in the plantings on infested soil. The increase of 8.6 bushels in total yield, with odds of 113 to 1, is significant, as is the increase of 8.0 bushels with odds of 587 to 1. The increase of 1.6 bushels, with odds of 6 to 1, however, is not significant. Increases in yield of sound corn, 13.0, 12.6, and 15.1 bushels, with odds ranging from 587 to 1 to greater than 9999 to 1, beyond doubt are significant. The fact that the good-seed selection showed no increase on infested soil in the early planting is in accord with data presented in Table 75. It will be remembered that the good-seed selection was comparatively susceptible to *G. saubinetii*, an organism which is more pathogenic at the lower soil temperatures existing at the time of the early planting, May 10.

TABLE 81.—YIELDS FROM ORIGINAL COMPOSITES, APPARENTLY GOOD SEED SELECTIONS, AND NEARLY DISEASE-FREE CHECKS

Yellow dent corn grown on brown silt loam of high fertility, near Bloomington, 1921

Character of seed	Date of planting	Soil infestation	Field stand	Acre yield		Increase in acre yield of good-seed selection over original composite						Increase in acre yield of nearly disease-free check over good-seed selection					
				Total	Sound	Total			Sound			Total			Sound		
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Lot A Original composite.	May 11.	Cl. (5).	90.7 ± 2.0	85.5	59.0												
Lot A Good-seed selection	May 11.	Cl. (5).	95.0 ± 1.2	94.1	72.0	8.6	10.1	113:1	13.0	22.0	>9999:1						
Nearly disease-free check.	May 11.	Cl. (10).	96.2 ± 0.5	92.2	71.2							−1.9	−2.0	4:1	−0.8	−1.1	1:1
Lot A Original composite	May 10.	Inf. (5).	92.5 ± 0.3	78.2	57.5												
Lot A Good-seed selection	May 10.	Inf. (5).	95.5 ± 0.6	79.8	59.0	1.6	2.0	6:1	1.5	2.6	5:1						
Nearly disease-free check.	May 10.	Inf. (20).	98.1 ± 0.3	83.2	64.6							3.4	4.3	713:1	5.6	9.5	1666:1
Lot A Original composite.	May 28.	Cl. (9).	88.9 ± 1.2	80.0	49.7												
Lot A Good-seed selection	May 28.	Cl. (9).	95.0 ± 0.6	85.1	62.3	5.1	6.4	26:1	12.6	25.4	1666:1						
Nearly disease-free check.	May 28.	Cl. (18).	96.4 ± 0.3	88.9	68.4							3.8	4.5	624:1	6.1	9.8	3332:1
Lot A Original composite.	May 30.	Inf. (9).	91.4 ± 0.8	77.6	41.3												
Lot A Good-seed selection	May 30.	Inf. (9).	93.9 ± 0.8	85.6	56.4	8.0	10.3	587:1	15.1	36.6	587:1						
Nearly disease-free check.	May 30.	Inf. (18).	97.3 ± 0.2	93.2	67.2							7.6	8.9	4999:1	10.8	19.1	>9999:1
Lot B Original composite.	May 11.	Cl. (5).	95.8 ± 0.7	81.8	59.9												
Lot B Good-seed selection	May 11.	Cl. (5).	96.2 ± 0.9	78.0	58.5	−3.8	−4.6	8:1	−1.4	−2.3	2:1						
Nearly disease-free check.	May 11.	Cl. (10).	96.7 ± 0.4	87.6	68.1							9.6	12.3	>9999:1	9.6	16.4	>9999:1
Lot B Original composite.	May 10.	Inf. (5).	95.7 ± 0.6	75.9	51.4												
Lot B Good-seed selection	May 10.	Inf. (5).	92.8 ± 1.8	75.3	52.9	−0.6	−0.8	1:1	1.5	2.9	8:1						
Nearly disease-free check.	May 10.	Inf. (10).	97.8 ± 0.3	83.1	64.1							7.8	10.4	158:1	11.2	21.2	>9999:1
Lot B Original composite.	May 28.	Cl. (9).	94.6 ± 0.8	75.9	47.2												
Lot B Good-seed selection	May 28.	Cl. (9).	97.3 ± 0.3	82.2	53.7	6.3	8.3	999:1	6.5	13.8	59:1						
Nearly disease-free check.	May 28.	Cl. (18).	97.0 ± 0.3	93.3	71.9							11.1	13.5	>9999:1	18.2	33.9	>9999:1

TABLE 81.——*Concluded*

Character of seed	Date of planting	Soil infestation	Field stand	Acre yield		Increase in acre yield of good-seed selection over original composite						Increase in acre yield of nearly disease-free check over good-seed selection					
				Total	Sound	Total			Sound			Total			Sound		
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Lot B Original composite.	May 30.	Inf. (9).	95.8 ± 0.5	80.3	44.8												
Lot B Good-seed selection	May 30.	Inf. (9).	97.3 ± 0.3	78.6	50.8	−1.7	−2.1	4:1	6.0	13.4	35:1						
Nearly disease-free check.	May 30.	Inf. (18).	97.8 ± 0.3	87.5	63.9							8.9	11.3	>9999:1	13.1	25.8	>9999:1
Lot C Original composite.	May 11.	Cl. (5).	91.7 ± 1.3	78.5	57.6												
Lot C Good-seed selection	May 11.	Cl. (5).	92.0 ± 0.5	80.6	57.8	2.1	2.7	3:1	0.2	0.3	1:1						
Nearly disease-free check.	May 11.	Cl. (10).	95.9 ± 0.5	84.7	67.1							4.1	5.1	13:1	9.3	16.1	555:1
Lot C Original composite.	May 10.	Inf. (5).	93.7 ± 0.4	78.1	56.1												
Lot C Good-seed selection	May 10.	Inf. (5).	93.8 ± 0.7	78.8	60.2	0.7	0.9	1:1	4.1	7.3	3:1						
Nearly disease-free check.	May 10.	Inf. (10).	97.1 ± 0.5	83.3	63.6							4.5	5.7	17:1	3.4	5.6	3:1
Lot C Original composite.	May 28.	Cl. (9).	93.5 ± 0.8	86.2	58.7												
Lot C Good-seed selection	May 28.	Cl. (9).	92.9 ± 0.5	85.5	59.1	−0.7	−0.8	1:1	0.4	0.7	1:1						
Nearly disease-free check.	May 28.	Cl. (18).	98.2 ± 0.2	96.3	74.5							10.8	12.6	>9999:1	15.4	26.1	>9999:1
Lot C Original composite.	May 30.	Inf. (9).	89.6 ± 0.9	75.9	45.2												
Lot C Good-seed selection	May 30.	Inf. (9).	94.9 ± 0.5	77.2	53.3	1.3	1.7	1:1	8.1	17.9	16:1						
Nearly disease-free check.	May 30.	Inf. (18).	98.2 ± 0.2	84.6	62.3							7.4	9.6	>9999:1	9.0	16.9	>9999:1

TABLE 82.—SUMMARY OF DATA PRESENTED IN TABLE 81, SHOWING THE VALUE IN INCREASING YIELD OF SELECTING SEED ON THE BASIS OF PHYSICAL APPEARANCE

Character of seed	Soil	Number of plots	Mean acre yield: Total	Mean acre yield: Sound	Increase in yield of sound corn of good-seed selections over original composites: bu.	perct.	Increase in yield of sound corn of nearly disease-free checks over good-seed selections: bu.	perct.
			bu.	*bu.*	*bu.*	*perct.*	*bu.*	*perct.*
Original composites	Clean	42	81.1 ± 0.6	54.1 ± 0.8				
Good-seed composites	Clean	42	84.3 ± 0.6	59.9 ± 0.8	5.8 ± 1.1	10.7		
Nearly disease-free checks	Clean	84	91.1 ± 0.4	69.8 ± 0.6			9.9 ± 1.0	16.5
Original composites	Infested	42	77.7 ± 0.5	47.8 ± 0.9				
Good-seed composites	Infested	42	79.6 ± 0.7	55.1 ± 0.8	7.3 ± 1.2	15.3		
Nearly disease-free checks	Infested	84	86.4 ± 0.5	64.3 ± 0.5			9.2 ± 0.9	16.7

TABLE 83.—YIELDS FROM LOT D AND FROM THE NEARLY DISEASE-FREE CHECK SEED

Grown on brown silt loam of high fertility, Bloomington, 1921

Character of seed	Date of planting	Soil infestation	Field stand	Acre yield: Total	Acre yield: Sound	Increase in acre yield of selected composite over original composite: Total bu.	Total perct.	Total odds	Sound bu.	Sound perct.	Sound odds	Increase in acre yield of nearly disease-free check over selected composite: Total bu.	Total perct.	Total odds	Sound bu.	Sound perct.	Sound odds
			perct.	*bu.*	*bu.*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*	*bu.*	*perct.*	*odds*
Original composite	May 11	Cl. (5)	85.8 ± 1.4	77.0	47.0												
Selected composite	May 11	Cl. (5)	91.9 ± 0.8	76.0	44.1	−1.0	−1.3	1:1	−2.9	−6.2	2:1						
Nearly disease-free ch.	May 11	Cl. (10)	95.1 ± 0.8	89.4	71.4							13.4	17.6	>9999:1	27.3	61.9	>9999:1
Original composite	May 10	Inf. (5)	87.2 ± 0.5	73.4	44.6												
Selected composite	May 10	Inf. (5)	91.8 ± 0.9	77.2	49.0	3.8	5.2	6:1	4.4	9.9	6:1						
Nearly disease-free ch.	May 10	Inf. (10)	98.9 ± 0.4	87.2	68.2							10.0	13.0	>9999:1	19.2	39.2	>9999:1
Original composite	May 28	Cl. (9)	90.3 ± 1.0	93.0	52.5												
Selected composite	May 28	Cl. (9)	94.0 ± 0.8	92.7	56.0	−0.3	−0.3	1:1	3.5	6.7	4:1						
Nearly disease-free ch.	May 28	Cl. (18)	97.7 ± 0.2	101.1	79.8							8.4	9.1	>9999:1	23.8	42.5	>9999:1
Original composite	May 30	Inf. (9)	88.2 ± 1.0	74.7	35.5												
Selected composite	May 30	Inf. (9)	93.2 ± 0.8	74.7	41.0	0.0	0.0	......	5.5	15.5	57:1						
Nearly disease-free ch.	May 30	Inf. (18)	97.5 ± 0.2	81.4	59.2							6.7	9.0	>9999:1	18.2	44.4	>9999:1

In Lot B the good-seed selection gave no increase in yield over the original composite in the early plantings on either clean or infested soil. In late plantings, however, the good-seed selection produced a significant increase of 6.3 bushels in total yield and 6.5 bushels in sound corn. On infested soil there was an insignificant decrease in total yield, but a material increase in sound corn, 6.0 bushels, or 13.4 percent, with odds of 35 to 1.

In Lot C the good-seed selection yielded practically the same as the original composite in every instance except the late planting on infested soil. The increase in that plot of 8.1 bushels of sound corn, with odds of 16 to 1, is scarcely large enough, in consideration of the odds involved, to be very significant. Data presented in Table 79 show that the original composite, as well as the good-seed selection, was comparatively resistant to inoculations with *G. saubinetii.* Furthermore, Lot C came from a strain of corn that had been selected for several years for a heavy ear, with intermediate to smooth kernel indentation. In view of the fact that corn from the good-seed selection was much more resistant to inoculations with both *C. acremonium* and *A. stewarti* than corn from the original composite, plantings involving more adverse environmental conditions might have resulted in some advantage for corn grown from the good-seed selection.

Nearly disease-free composites from Lots A, B, and C, did not show any increase in either resistance or yielding ability over the good-seed selection. Yield data indicated that in these three lots of seed careful selection on the basis of physical appearance was as effective as selection on the basis of performance on the germinator in finding the more resistant and higher yielding corn in the original seed stocks. Using the original composite of each lot as a basis for comparison, selection on the basis of physical appearance did not decrease the yield of sound corn significantly in a single instance, and in six out of the twelve comparisons it resulted in material increases in yield, five of which were significant in consideration of the odds involved.

The data in Table 81 are summarized further in Table 82 and presented graphically in Chart 34. The increases in yield of sound corn from the good-seed selections over the original composites of 5.8 bushels on the clean soil and 7.3 bushels on the infested soil are very significant in terms of the probable errors involved. The increases in yield of sound corn of the nearly disease-free checks over the good-seed selections also are significant.

LIMITATION OF THE VALUE OF PHYSICAL SELECTION OF SEED EARS

Selection of seed on the basis of physical appearance has limitations as well as possibilities in that it presupposes not only a variation in the seed stock but also the fact that some of the ears are good for seed. Obviously good seed cannot be selected from a strain of corn that is uniformly susceptible to disease and to injury under unfavorable environment. Some strains of corn are so susceptible to disease and so deficient in those qualities which make for high yield of sound corn that *neither physical selection nor germinator selection can effect any improvement in either quality or quantity of the crop.* Several such strains of yellow dent from different farms thruout the corn belt have been encountered during the course of these investigations. Field data from Lot D, one of these strains apparently lacking possibilities for improvement, are reported in Table 83.

Lot D came from a strain of yellow dent corn that had been selected over a period of years for uniformity of type, an ideal

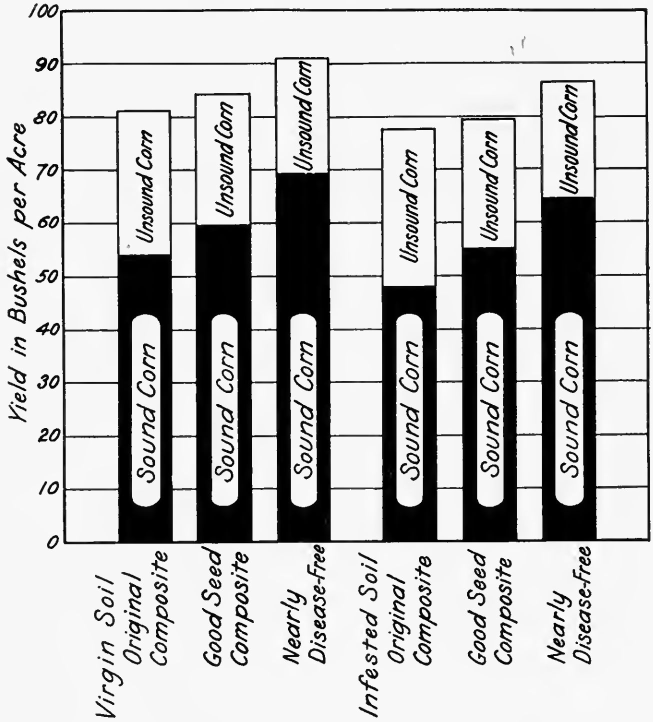


CHART 34.—VALUE OF SELECTING SEED ON THE BASIS OF PHYSICAL APPEARANCE (Table 82)

The selecting of seed ears on the basis of physical appearance is a very important operation in the preparation of seed corn. The nearly disease-free seed represented the best from a strain of corn the development of which embraced the practices of plant selection, physical selection, and germinator selection over a period of years.

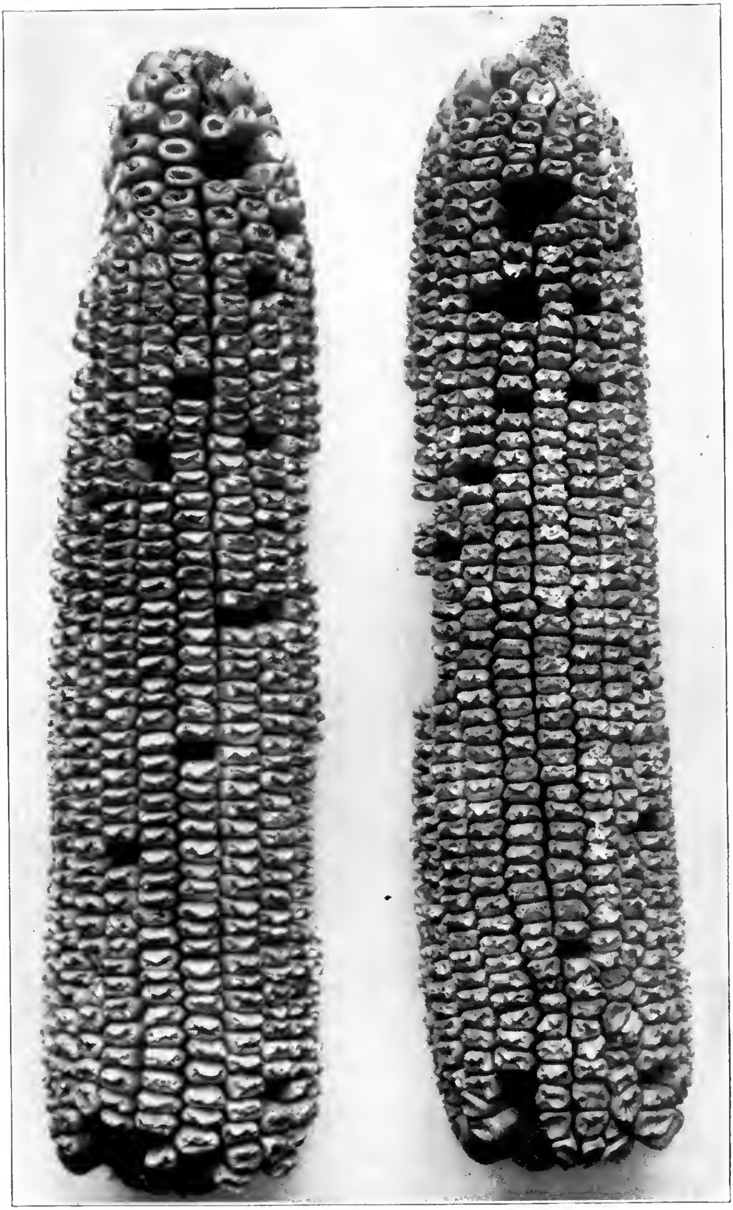


FIG. 73.—REPRESENTATIVE EARS FROM LOT D OF THE SELECTED COMPOSITE (See Table 83)

which the farmer had almost attained, but at the sacrifice of qualities more profitable. Two representative ears are shown in Fig. 73. Inasmuch as there were no ears in the seed lot that measured up to the standard used in selecting the apparently good seed from Lots A, B, and C, it was impossible to make such a selection from Lot D. All ears in the original composite were given three germination tests of ten kernels each and those showing the least infection and the most seedling vigor on the germinator were used in a selected composite.

The selected composite from Lot D in every case gave an appreciable increase in field stand over the original composite (Table 83). Increases in either total yield or yield of sound corn, however, were not significant except in one instance. Selection both on the basis of physical appearance and on performance on the germinator was ineffective in finding better seed in Lot D. The fault, however, probably lay in the corn rather than in the methods of selection.

In developing resistance to the stalk and root rot diseases and an increased productivity, a single year's selection on the basis of physical appearance could not be expected to be so effective as consistent selection toward the same goal over a period of years. The value of continuous selection over a period of years toward any one character is well proven in the corn-breeding experiments initiated by Dr. Cyril G. Hopkins and carried on by Dr. L. H. Smith. A comparison of field data from the apparently good-seed selection, which had had no previous selection toward disease resistance, and from the nearly disease-free check, which had been selected a number of years toward disease resistance, is interesting and instructive at this point. In ten of the twelve comparisons (Table 81) the increases in yield of sound corn from the nearly disease-free check were significant, the odds ranging from 555 to 1 to greater than 9999 to 1. Corn grown from the check seed also gave significant increases both in total yield and yield of sound corn over that grown from the composite selected out of Lot D (Table 83). *Corn grown from the nearly disease-free check seed yielded at a higher rate in every instance than corn grown from apparently good-seed selections.*

Altho selection of seed ears on the basis of physical appearance has its limitations, it is a fundamental operation in any program for the developing of a strain of corn which will be more highly resistant to disease and to injury under unfavorable weather and soil conditions. However, data indicate that the greatest improvement in resistance and productivity may be expected to accrue, not from physical selection of seed ears alone, but also from the continuous practice of plant selection and germinator selection, always beginning with a strain which has possibilities for improvement.

PART VII

A PROGRAM OF CORN IMPROVEMENT

During recent years important developments have occurred in the theory and practice of corn breeding. Investigations of inheritance in this plant have resulted in putting corn improvement on a more scientific basis. The once popular ear-to-row method, which was markedly effective in some cases, has been discarded by many practical corn breeders. The recent work on corn root, stalk, and ear rots has emphasized the necessity of considering disease resistance in any corn improvement program for the corn belt. The need for improvement and the opportunities in corn breeding are believed to be as great as ever. The time is considered opportune, therefore, for outlining briefly a corn-breeding program in the light of these developments.

The choice of the foundation stock for a program of corn improvement is essentially a choice of variety. Varieties differ greatly not only in such characters as color of grain, time of maturity, and tendency to sucker, but also in the degree of adaptation to certain soils and climatic conditions, and in the relative resistance to certain fungous diseases and insect pests. Even strains within a variety may show differences which, in some cases, are wider than those between so-called varieties.

A variety should be chosen that is well adapted to the local environmental conditions. It should mature well; it should be of a type that is not discriminated against commercially; and it should be sufficiently variable to show possibilities of improvement. The common varieties grown in the various sections of the country, in most cases, are well adapted to the conditions in those sections. Some strains, however, may have a low average production as compared with others, or may respond only feebly to a program of improvement. *Attention at the outset to the foundation stock to be used is essential to success.*

TWO METHODS OF IMPROVING CORN

Two methods for corn improvement are suggested. The first emphasizes the importance of *selection* as a method of improvement. It is particularly adapted to the corn grower who desires a simple but effective method of improving his own crop. It also is adapted to the seed-corn producer who has built up a trade in seed corn with his neighbors because of his integrity and his ability to select good seed, handle it properly, and sell it at a reasonable price. Many farmers do not care to take the trouble and time necessary to get good seed, and are quite willing to pay others to do it for them. The seed-corn grower can therefore be of distinct service to his community and at the same time develop a good business for himself.

The second is called the *pure-line method.* It is believed to have a distinct place in a program of corn improvement because of its possibilities. By this method it would appear possible to produce hybrid strains that are resistant to at least a majority of the diseases affecting corn; that are adapted to the special conditions obtaining in different sections of the state, such as soil types, soil acidity, dry weather, lengths of season, and insect attack (the chinch-bug and European corn borer); and that are adapted to special uses, such as for silage production, grain production, and manufacturing purposes (oil content). The pure-line method is fundamentally sound in theory, but the practical benefits from its use are, in the main, still to be realized.

THE SELECTION METHOD

Selection of seed is probably more effective in corn than in any other crop. This is due, no doubt, to the nature of the corn plant. Naturally cross-fertilized, it is continually producing hybrids, which, in turn, cross among themselves, giving rise to a multitude of types thru recombination of characters. Hence, in any cornfield a considerable array of different types is presented. Some of these are desirable because they are vigorous and productive; others are undesirable because they are weak in stalk and root, barren, or susceptible to diseases. It is this great amount of variation in the corn plant that furnishes an adequate basis for improvement.

Much can be accomplished in the improvement of corn by paying particular attention to the plant in the field and to the ear in the seed-house and on the germinator. Selection at these three stages plays the most important part in the process of securing seed for the following crop. If this work were carefully and intelligently done year after year on every farm, the average corn yield for the state would be materially increased.

Improvement of the corn crop by the method of selection suggested here is simply and easily accomplished. The method commends itself to corn growers who have neither the time nor the inclination to perform complicated experiments on their own farms. It involves no record-keeping and no harvesting of single rows or other small areas. It is effective, nevertheless, in improving the corn crop in total yield of grain because it results in the gradual elimination of weak types and of those susceptible to the corn rots.

In corn improvement, special emphasis should be placed on the *quality* of grain produced. What is most desired is not high yield alone but *high yield of high quality corn.* Selection for disease-resistant corn according to the method outlined below results not only in improvement in total yield, but also in an increase in the proportion of sound, marketable grain.

SELECTING THE PARENT PLANT

It has long been recognized that the parent plant, as well as the seed ear, should be considered in selecting seed corn (Fig. 74). Evidence presented in this bulletin has placed greater emphasis on this point. A diseased stalk is not likely to produce disease-resistant seed. Moreover, a study of the parent plant enables one to consider other characters, such as vigor and degree of maturity, which are especially important in production.

The parent plant should have an erect stalk, indicating a strong root system. It should be strong, vigorous, and healthy, free from smut, rust, and other diseases, with the leaves free from spottings, streakings, and purplings. The stalk and portions of the leaves should still be green. The husks should be dry and dead and they should be long enough to cover the tip of the ear completely. The ear should be borne at a height on the stalk convenient for husking, and on a strong shank of medium length. The angles which the ears form with the stalk should range from approximately 45° to 135°. Upright ears are likely to have large, coarse shanks, while ears hanging straight down are usually borne on small, weak, broken, or diseased shanks. Neither extreme is desirable.

A parent plant answering the above description is likely to be relatively free from infection by the corn-rot organisms and ordinarily will produce an ear which likewise is relatively disease-free.

SELECTING SEED EARS

Results of experiments conducted at this Station and elsewhere indicate that well-matured ears are best for seed, as their kernels are more likely not only to germinate well and produce strong plants but also to yield better than those from immature ears. In order to select such well-matured ears, and at the same time to give due attention to the parent plant with special reference to disease, *the field should be carefully inspected in the fall before a killing frost for the purpose of locating healthy, vigorous plants that are maturing normally.* If the field inspection is delayed until all the plants are dry and dead, it is difficult to distinguish those plants that matured normally. Ears selected from normally maturing plants will be found to be sounder and better matured, on the whole, than those from plants that are diseased.

The mere fact that ears are selected in the field prior to harvest, with some attention to the parent plant, is, however, no assurance that they will make better seed ears than those selected at harvest time or even from the crib, for much depends on the care exercised in selecting the plant and in the handling of the ears afterward. Furthermore, it must be recognized that the majority of corn growers pick their seed corn at the time of harvest, and that they have obtained good results

FIG. 74.—PLANT SELECTION—AN IMPORTANT OPERATION

Note the erect habit, the strong, vigorous, healthy appearance of the plants, and the manner in which the ears are borne, indicating healthy shanks. It has long been recognized that the parent plant, as well as the seed ear, should be considered in selecting seed corn.

from this practice. As this method is so practical and inexpensive, it no doubt will continue to be widely used; it should not be condemned so long as it results in the selection of normally matured ears that show good germination and relative freedom from disease. This method offers opportunity to choose from all the ears in the field, since all are actually seen and handled. Furthermore, many ears that would be

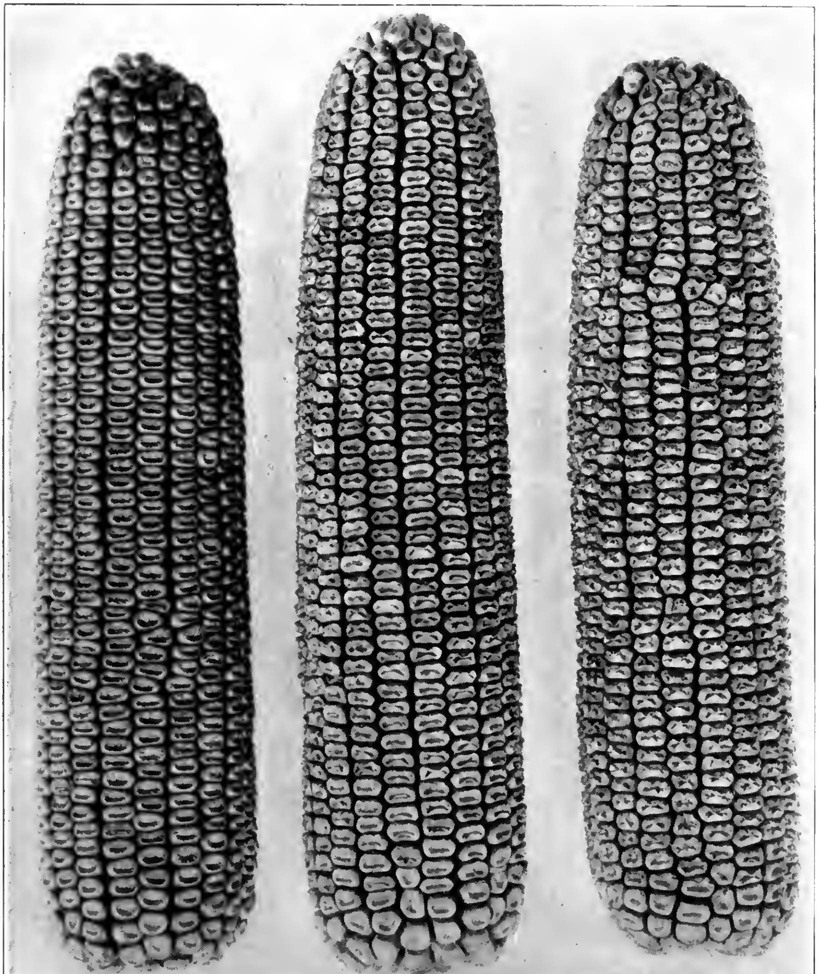


FIG. 75.—THREE DEGREES OF INDENTATION

The ear on the left represents the upper limit of the smooth class. The center ear represents the upper limit of the class variously called medium, intermediate, and mid-rough. Ears between these two in indentation would be classed as medium. The ear on the right illustrates the rough, starchy type. Avoid this type in ear selection.

taken for seed in the early fall would undoubtedly be rejected at the time of harvest because their seemingly good early appearance belied their appearance when fully matured. However, it is not advisable to select seed ears very late in the harvest period. Freezing temperatures, together with abundant moisture, especially if followed by warmer weather, will not only injure the germination of the seed but also provide favorable conditions for infection and growth of fungi. At just what date in the fall harvest selection of seed ears should be discontinued must be decided individually by each corn grower in the light of conditions affecting his own crop.

Four to five times as many ears should be picked for seed as will finally be used. This will allow the rejection of ears because of their appearance, or because of poor or weak germination, or the presence of disease. Much can be gained by having abundant opportunities to discard the less desirable ears in the final selection, and this is possible only in cases where large numbers of ears are on hand.

Characteristics of Good Seed Ears

That there is a relation between the general appearance of the ear and its ability to yield is shown by the results reported in this bulletin. This relationship appears to be based largely on resistance and susceptibility to the corn root, stalk, and ear rot diseases. Nearly disease-free ears ordinarily can be distinguished from diseased ears by their general appearance, for the presence of disease interferes with the normal activities of the plant, and this interference is reflected in the color, luster, texture, and indentation of the kernels. A knowledge of this relationship is of distinct value to the corn breeder, for by it he can examine in a short time a large number of ears and quickly eliminate from further handling all but the very best.

Disease-free or nearly disease-free ears have thick, plump, bright, clean kernels with well developed germs, intermediate to smooth indentation, and distinctly horny endosperm (Figs. 75 and 76). Such ears are sound and solid, have a bright, rather oily appearance, and give every evidence of complete and normal maturity. Shank attachments are white, bright, and free from any discoloration due to exposure or disease. All ears that do not measure up to these standards, or as many as the seed stock will allow, should be discarded, as they probably are more or less diseased.

In selecting corn for seed to continue the strain, *all* the points that are recognized as characteristics of good seed ears should be considered. Ears superior in one characteristic, such as shank attachments for example, may be inferior in kernel texture and luster. Such ears should be rejected in favor of ears which rank high in all three characteristics. When choosing an animal for breeding purposes, not one

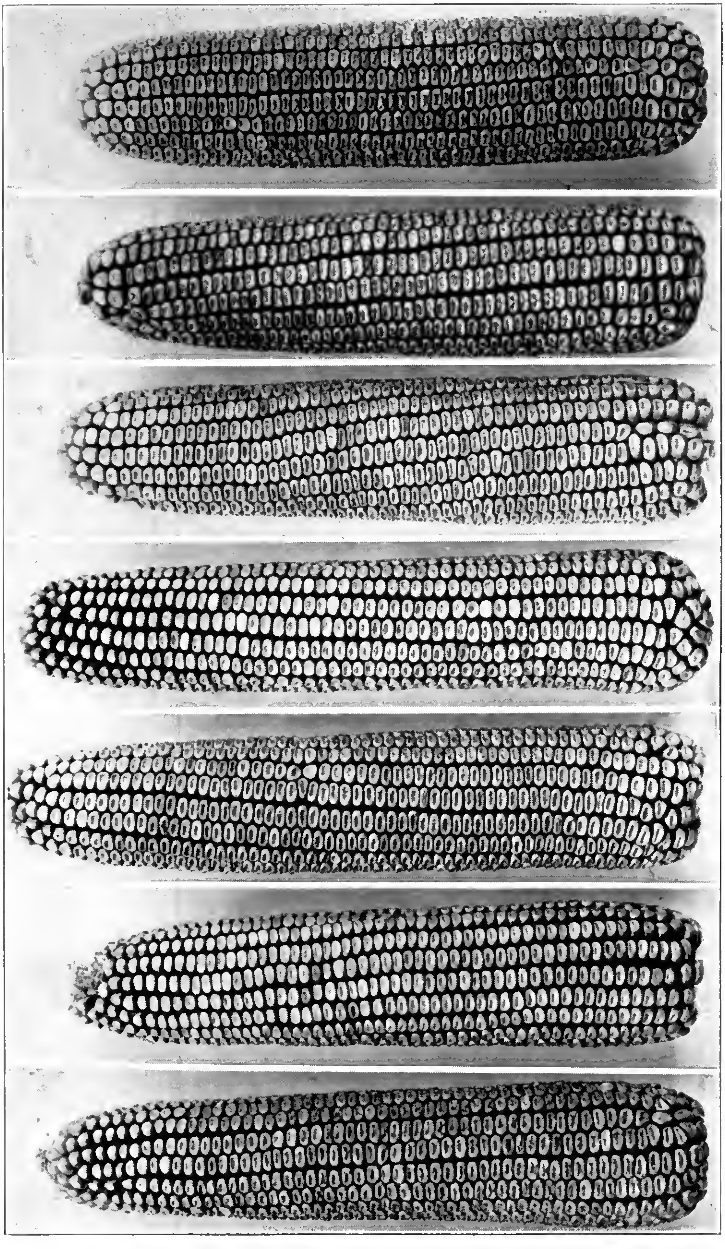


Fig. 76.—Desirable Seed Ears

These ears show a considerable range in indentation, length, kernel type, and other characteristics. It is considered unwise to select too closely toward a particular type. Not only one, but *all* points indicating good maturity and good health, should be noted.

but all the points commonly recognized as belonging to animals of merit are carefully considered. Straight back, strong, well-set legs, bright eyes, quality, intelligence, disposition, and like characteristics are noted with especial care. Superiority in all is desired because it is recognized that each plays its part in the making of a superior animal. The same principle holds true in the selection of grain of any kind that is to be used for seed.

VALUE OF GERMINATOR SELECTION

When circumstances permit, the ears that have been selected on the basis of their appearance should be tested on the germinator (preferably the lime-sawdust table germinator) in order to detect those ears that have high viability and seedling vigor and that are freest from the corn rot diseases.

There is considerable evidence that the germinator is especially useful also in detecting ears that are resistant to scutellum rot, resistance to which seems to be closely correlated with resistance to certain soil fungi and unfavorable environmental conditions. Thus the ger-

FIG. 77.—A PROFITABLE COMBINATION OF PROPER SEED SELECTION AND GOOD FARMING

A commercial field of corn grown from seed that had been carefully field selected from vigorous healthy stalks and severely culled on the basis of physical appearance. The selections were made from a strain of yellow dent that had been carefully selected over a period of years according to recommendations set forth in this bulletin. Farm of Mr. Ed. Main, Knox county.

mination test may be very helpful in determining which are the *best* ears to use for seed.

The germination test, to be reliable, must be conducted under reasonably uniform conditions of temperature and moisture, and the results must be rightly interpreted. Many corn growers either do not have the proper facilities for conducting such a test, or are unable to read and interpret the results correctly. Emphasis must then be placed on plant and ear selection.

Since ears that have been carefully selected in the field and properly cared for can usually be depended on to germinate well and to show relatively little disease, lack of facilities for the germination test should not be considered a great handicap. Moreover, the limitations of the germination test should be clearly recognized. The use of the germinator will not always lead to improvement in all strains of corn, for some strains are incapable of further improvement, either because of defective heredity or because of their being in a relatively homogeneous condition. Other strains may be but slightly infected with the root rot organisms because of light infestation of the soil in which they were grown or because of a partial resistance to such infection resulting from conscious or unconscious selection for resistance over a period of years. *The primary purposes of the germinator are to show the presence or absence of disease and the vigor or lack of vigor of the seedlings.* If these purposes are not accomplished, then the germinator is of no aid in the improvement of corn.

THE PURE-LINE METHOD

In the improvement of corn by the selection method just described, the ear was considered the basis of selection. Emphasis was placed on a careful study of the plant which produced the ear, i.e., the female parent; the individual male parents could not be studied because they are unknown.

It is commonly accepted that the male parent is equally important with the female so far as the transmission of hereditary characters is concerned. All the kernels on an ordinary ear of corn have the same female parent but not the same male parent. Some kernels may be the result of self-fertilization, others the result of fertilization by pollen from neighboring plants in the same or in adjacent hills, and still others may have resulted from fertilization by pollen brought by the wind from more distant plants. The several male parents of the kernels on an ear of corn presumably differ greatly in their hereditary constitution. Hence, it is clear that the kernels may be quite different from each other even tho borne on the same cob and by the same female parent.

Corn breeders are coming to recognize the need of making the individual kernel the basis of selection rather than the individual ear if progress in corn improvement is to be most rapidly and efficiently accomplished. This means that the pollen parent must not only be known but also controlled—the male as well as the female parent must be *selected.* In order to do this, it is necessary to control the pollen parent by artificial self-pollination.

As a result of continued self-fertilization, the vigor and yield decrease quite rapidly at first, then more and more slowly until finally a point is reached where no further deterioration is observed. The strain is then said to be pure, and it will continue to breed true thereafter for an indefinite period if no mixing occurs with other types.

A close study of the lines resulting from self-fertilization brings out the fact that some are good, others are poor, and still others are of indifferent value so far as capacity for production is concerned. Since all the plants in any one line are alike genetically, the corn breeder is confronted with the necessity of making a choice of the *best lines* rather than of the *best plants* as was the case in the selection method. Obviously, the best lines are those that possess characters favorable to production, such as resistance to disease and lodging, and that are themselves good producers of grain or of forage.

The next step toward improvement is to combine into one type the favorable factors which have been separated by self-fertilization. This is hybridization. A combination of two lines constitutes a single cross, four lines a double cross, and many lines a multiple cross. In the case of the single cross, best results are obtained by making the cross anew each year, while in the case of the double and multiple crosses it would appear possible to carry over the benefits of hybridization into the second, third, and subsequent hybrid generations by careful selection.

Briefly, then, the pure line method involves first the purifying of strains by inbreeding and then the building up of a new and vigorous strain by outcrossing with other desirable pure lines.

INBREEDING REVEALS TRUE CHARACTER OF STOCK

Self-fertilization (or inbreeding) furnishes a means of eliminating various weaknesses in the stock, such as susceptibility to smut and other diseases, weak root system (Fig. 78), blighting, rolling of leaves (Fig. 79), partial loss of chlorophyll and various other deficiencies that result in reduced growth and productiveness. Inbreeding reveals both the good and the bad characters. It spreads out before the corn breeder the characteristics of the stock so that he can study them, select the good, and discard the poor. It brings to light undesirable qualities that would otherwise be covered up by desirable ones. In thus showing the true character content of the stock, self-fertilization in corn is particularly valuable as a method of breeding (Figs. 80, 81, and 82).

In corn, self-fertilization usually, if not always, is accompanied by such deleterious effects as poor germination, reduced vigor of growth, disease susceptibility, and lessened production of pollen, all of which

FIG. 78.—ERECT AND BADLY LODGED INBRED STRAINS

Strains with inherently weak root systems may be eliminated by self-fertilization and selection.

contribute to the general effect of reduction in vigor and yield in plants that are otherwise normal. This general reduction in the plant's activities begins with the first year of self-fertilization and nearly always becomes more marked with subsequent self-fertilization. Some inbred strains become so weakened that they can be propagated only with difficulty, particularly if grown on soil infested with the corn rot organisms (Fig. 83). Other strains, however, show themselves to be inherently stronger and more resistant to disease, and are able not only to survive but also to produce fair yields of seed.

It must not be thought, however, that self-fertilization is in itself detrimental, or that it is the *cause* of the accompanying reduction in general vigor. The cause must be sought in deficiencies of various kinds naturally present in the stock, and in the principle that self-fertilization in a hybrid brings about a separation or assortment of favorable growth factors into different lines. When all such deficiencies have been eliminated and the growth factors have been rendered pure by repeated inbreeding, no further reduction in vigor occurs. Self-fertilization may be continued indefinitely thereafter with no further detrimental effects.

Recent observations and experiments are directing attention to the physiological behavior of selfed lines of corn. There are indications that some lines are able to make more efficient use of conditions of growth than others. For example, some are more efficient users of phosphorus. Some lines are able to resist chinch-bugs to a greater or less extent; others are resistant to prolonged drouth, on account of an extensive and efficient root system; still others show differences in proportion of grain to stover. As methods of testing selfed lines become more exact and refined, the corn breeder will be able to take advantage of all the variations in physiological behavior which Nature has provided, and to combine them in crosses to secure the best results.

FIG. 79.—LEAF ROLLING—A HERITABLE WEAKNESS
Leaf rolling is a weakness found in many open-pollinated strains.

FIG. 80.—A GOOD INBRED STRAIN OF FAMILY A

FIG. 81.—A GOOD INBRED STRAIN OF FAMILY B

Note the sturdiness of the stalks. If these were growing in a field of ordinary corn, one would have difficulty in distinguishing them from open-pollinated plants.

Valuable inbred strains may differ widely in their vegetative growth and general appearance.

The most difficult part of the pure-line method is the production of the selfed lines, and on account of the training, time, and equipment required, the work will probably be done largely by the Experiment Station and the professional plant breeder. However, since different lines are required for different sections of the state because of varying soil and climatic conditions, the task of finding lines adapted to them would be greatly aided if there were in each section at least one man having the requisite training for and inclination toward this special field of work.

HYBRIDIZATION OF INBRED STRAINS

Outcrossing is the normal habit of the corn plant. In the ordinary cornfield, cross-pollination (or hybridization) is the rule and self-fertilization the exception. Crossing between different plants is encouraged by: (1) the separation of tassels (male) and silks (female); (2) the difference in time of maturity of pollen and silks on the same plants; and (3) the fact that the pollen is so effectively scattered about

FIG. 82.—AN INBRED STRAIN CHARACTERIZED BY BROAD LEAVES

Inbreeding is valuable in bringing to light desirable characters such as this, which can be combined in crosses with others equally desirable.

the field by the wind. Nature, then, would appear to favor any method of improvement for corn which necessitates a considerable amount of outcrossing.

Just as self-fertilization in corn usually is accompanied by reduced vigor and yield, so the hybridized condition gives increased vigor and yield. Hybridization, therefore, is a means of restoring the vigor lost as a result of self-fertilization. Hybrids between self-fertilized lines (or "selfed" lines) usually exceed either parent in yield and oftentimes outyield even the variety from which the parent lines originated (Figs. 84, 85, and 86). However, hybrids between common varieties of corn that have not been subjected to inbreeding usually show very little or no increase unless they differ from each other in several characters, and even in such cases it is questionable whether they give sufficient increases to justify their use.

Experience has shown, as pointed out above, that it is possible to find selfed lines that show very little reduction in yield and vigor compared with the original strain or variety. These lines are good because they contain a sufficient number of genetic factors favorable for growth and productiveness. With continued self-fertilization they would be rendered genetically pure for the factors they contain. It is highly improbable that all factors possessed by any two such lines would be identical. If Type I contains factors A, B, and C, Type II might contain factor A but have factors D and E instead of B and C.

With the large number of factors responsible for vigor and productiveness in corn, it is quite possible to obtain many types that differ among themselves with respect to such factors. As a result of these differences in factors, the types themselves show differences in such characters as extent of root development, height of plant, general vigor of growth, and relative resistance to the corn rot diseases and to smut. One type may be particularly good in certain of these characters, another in others, and so on. If all such characters could be combined by crossing, the resulting type should be superior to all others in yield and vigor.

SINGLE CROSSES

The combination of any two lines into one results in what is known as a single cross. Oftentimes the hybrid is markedly superior to either of the lines composing it. This is particularly true if the parent lines differ from each other in several respects. In such case there are not only the beneficial effects in the hybrid of the bringing together of desirable characters, but also the stimulation, or hybrid vigor, which is generally so pronounced when unlike types are crossed. Some lines show relatively few obvious differences, yet when crossed the hybrid is far superior to either parent. This means that selfed lines may differ considerably in the genetic factors that control their response to environmental conditions without at the same time differing in appearance.

FIG. 83.—MISSING HILLS RESULTING FROM THE EARLY DEATH OF BLIGHTED AND BADLY DISEASED PLANTS

Some inbred strains become so weakened that they can be propagated only with difficulty, particularly if grown on soil infested with the corn-rot organisms.

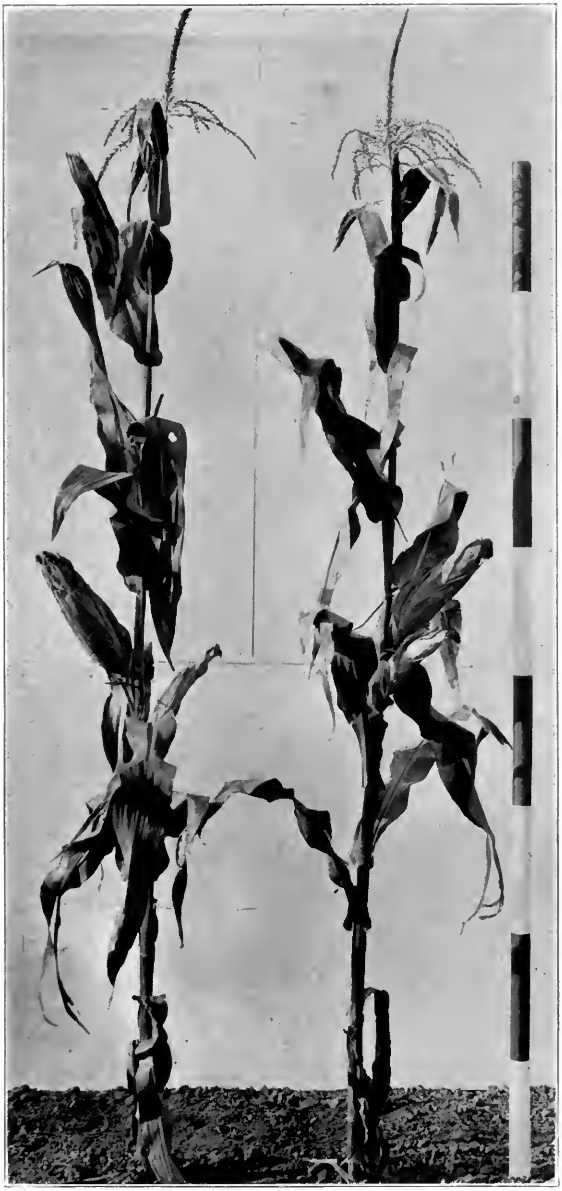


FIG. 84.—A GOOD CROSS OF TWO INBRED STRAINS

First-generation cross of the inbred strains illustrated in Figs. 80 and 81. Note the vigor and productivity.

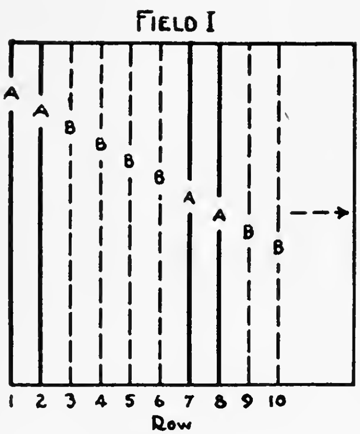
FIG. 85.—ANOTHER GOOD CROSS

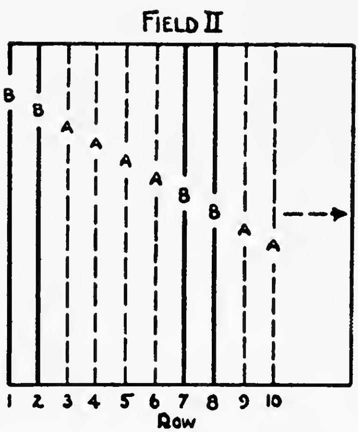
Note the low stalks and large ears. These plants represent a first-generation cross between the strain illustrated in Fig. 80 and an inbred strain of the Illinois High Yield.

On the other hand, it often happens that little is gained by crossing certain selfed lines. Such a result may be due to close relationship or to the fact that, even without close relationship, the lines happen to resemble each other too closely in their genetic constitution. The genetic factors for yield and vigor being largely the same in both parents, crossing accomplishes little more than self-fertilization. Also, some F 1's are vegetatively vigorous, but are susceptible to diseases and are low yielders of seed.

The problem of successfully crossing pure lines resolves itself into a choice of lines to use as parents. Without more information, it is possible to point out, in only a general way, the characteristics on which such a selection should be based: namely, the parental lines should be themselves fair producers of grain in order that they may be multiplied rapidly for crossing on a large scale; they should have the same grain color so that grain produced by the hybrid will be uniform in color (this, however, is not an important consideration if the grain is to be used for feeding live stock); and finally they should exhibit, so far as possible, the desirable plant and ear characteristics described in the first part of this section.

Obviously, the best results will be secured from the use of single crosses if they are made anew each year. The following plan may be suggested for producing the hybrid seed in quantity. Let one selfed line be designated by A, the other by B. Two fields are required, Field I and Field II, sufficiently isolated from each other to prevent cross-pollination. It is immaterial whether they are of the same size or not. In these fields, strains A and B are planted according to the following diagram:





In Field I, two rows of strain A alternate with four rows of strain B. All rows of strain B are detasseled, and being pollinated by A pollen produce hybrid seed only. Rows planted to strain A produce pure seed of A. In Field II, two rows of strain B alternate with four rows of strain A. All rows of strain A are detasseled, and being pollinated by B pollen produce hybrid seed only. Rows planted to strain B produce pure seed of B. Thus, this plan provides for the production of hybrid seed each year, as well as the production of pure seed of the two parental lines. Also, hybrid seed is produced on two-thirds of the total acreage while only one-third is devoted to continuing the strains.

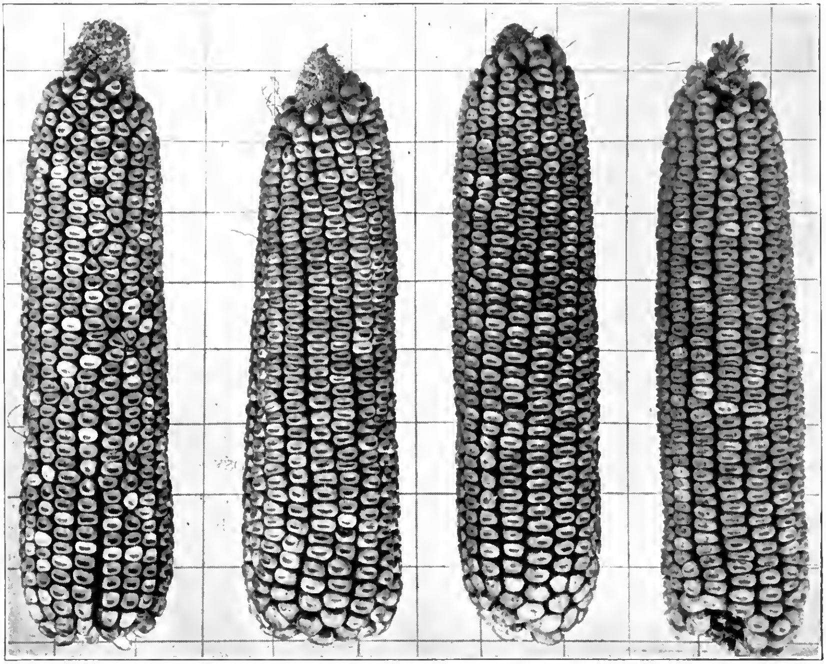
DOUBLE CROSSES

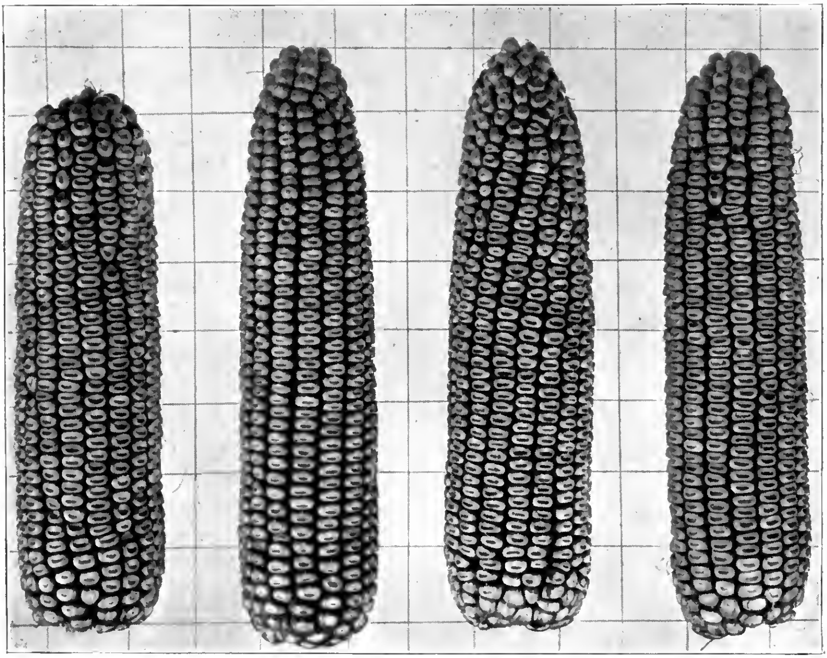
Since it is improbable that all desirable qualities will be found in any two lines, it would appear that the combination of several lines would produce a hybrid type superior to any single cross that could be made. That this result may reasonably be expected in certain cases is indicated by the work of Jones[54] on double crosses.

Let A, B, C, and D represent separate lines which have been rendered practically pure by inbreeding, and which possess individually one or more characters of outstanding importance, such as a strong root system or resistance to root and stalk rots. These strains would be combined into single crosses first and then into a double cross according to the following diagram:

Strains	A	B	C	D
Single crosses......	A × B		C × D	
Double cross........	(A × B) × (C × D)			

If the parent strains are pure, the plants of either single cross would show marked uniformity because they would all have the same genetic constitution. Variations among them would be due to environmental conditions. This cannot be said of the double cross, however. While in one sense it can be considered a first-generation hybrid, in another sense it represents, in its relation to the previous crossing, a second-generation hybrid. It will show, therefore, considerable variation because it consists of plants which differ genetically. Indeed, so great is the possible number of factors in which the parent lines may differ, that it is not far from the truth to state that scarcely any two plants would have exactly the same genetic constitution. This is believed to be a desirable situation. Numerous types, with varying capacities for utilizing the plant food and moisture at their disposal, often will produce better collectively than if the population consisted of but one type, all the plants of which were uniform in their capacity for development. It is likely, also, in view of the large amount of crossing that is continually taking place under field conditions, that the population might be continued for a few years, by careful selection, without any very noticeable decrease in yield.





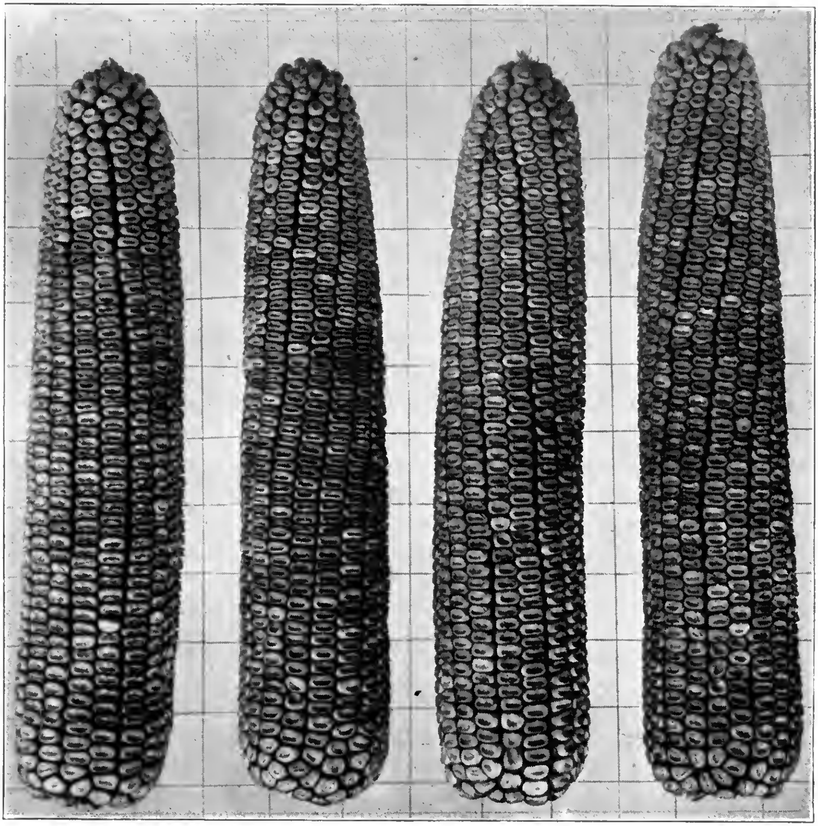


FIG. 86.—EARS PRODUCED IN THE PURE-LINE METHOD OF CORN BREEDING

Representative ears of inbred strain A (upper left), inbred strain B (lower left), and the single cross of A × B (upper right). This single cross yielded at the rate of 117.2 bushels per acre (Table 36). (The ears were photographed on 1-inch mesh screen.) Bloomington, 1923.

The pure-line method of corn breeding is believed to have a distinct place in this program because of its possibilities. It is fundamentally sound in theory. The practical benefits from its use are, in the main, still to be realized. Tho many problems remain to be worked out in regard to the utilization of inbred and hybrid strains, it is felt that enough is already known to justify considerable confidence in the importance and ultimate value of the method in corn production.

MULTIPLE CROSSES

Since good results have been obtained by combining four selfed lines into a double cross, probably still better results may be secured by combining many more such lines into what might be called a multiple cross. This is only suggestive, as no experimental data are available on this point. However, it would seem that the more lines there are entering into the cross, the better, because the result would be greater genetic diversity and variation, and consequently better response to seasonal, soil, and other conditions. Furthermore, the general superiority of the multiple cross could probably be continued

In the practical utilization of double or multiple crosses, the Experiment Station or the professional plant breeder must cooperate with the corn grower, the former furnishing the double or multiple-crossed seed, the latter continuing it by selection. After a time it may become necessary for the grower to return to the original supply for his hybrid seed because in spite of careful selection the proportion of plants possessing the genetic constitution of the original hybrids is likely gradually to decrease, and the yield will accordingly be reduced. The general average yield of the hybrid seed in this period, however, would probably be enough in excess of that given by ordinary varieties to warrants its use.

The method proposed above would have several advantages from the practical point of view. It would permit a fairly rapid increase of seed for general distribution. It would not be necessary for the seed-corn producer or corn grower to maintain isolated seed plots. There would be little danger, for some time at least, of securing uniformity at the sacrifice of productiveness because of the hybrid origin of the seed stock and the consequent recurrence of varying hereditary combinations. And finally, abundant material would be at hand at all times for selection.

PROBABLE USES OF THE TWO METHODS OF CORN IMPROVEMENT

The pure-line method is of incalculable value to the investigator. It provides him with a tool by means of which he can resolve the corn crop into its component elements and analyze them, saving what appears useful and discarding the rest. For example, he can isolate and recombine the genetic factors which affect root development and thus build up a type with a superior root system particularly adapted to drouth conditions.

Self-fertilization may be likened to the analytical method employed by the chemist. It is a breaking down process according to which the investigator takes the corn crop as Nature has given it to him and determines of what it is made up. Then he takes the parts he wants and builds up, synthetically, the particular type desired, by hybridization. Hence, *analysis* and *synthesis* are the keynotes of this method.

For a considerable time, probably, the method of careful *seed selections* will be largely used by the majority of seed producers and farmers in improving their corn. This must necessarily be the case, because of the length of time required to obtain tested lines for use in producing hybrid seed. However, as the superiority of hybrid seed becomes more firmly established, and information concerning it spreads among corn growers, there will result an increased demand for it. To meet this demand, hybrid seed production will have to be put on a commercial basis. While practical difficulties which have always been urged against this method are not believed to be insurmountable, the utilization of hybrid seed in corn production will be most efficient only when there is complete cooperation between the Experiment Station, the professional plant breeder, the seed producer, and the corn grower

SUMMARY

On the basis of the data reported in this bulletin, as well as of observations made thruout Illinois for a period of years, the authors feel that where inferior and infected seed is used, losses to the corn crop from disease, including smut and rust, can very conservatively be placed at 20 percent.

An adequate understanding of the causes of the corn root, stalk, and ear rot diseases, and variations in susceptibility of different strains of corn to these diseases, can be obtained only by a consideration of all the influencing factors.

Planting of Diplodia-infected and Gibberella-infected seed always has resulted in a reduced stand, many blighted and weak plants, and a lowered vigor and vitality of those plants which survive.

Good seed corn of strong vitality and free from infection will grow under a wider range of temperature and moisture and can be planted with safety much earlier than infected seed or seed affected with scutellum rot.

In general appearance, good seed ears are mid-sized, heavy in weight, bright in luster, moderately horny to horny in kernel composition, and moderately smooth to smooth in indentation. Shank attachments are bright or only slightly discolored, and in no case is there evidence of rotting of the tissues at the butt of the cob. Tips of the ears have been covered by the husks or only slightly exposed. Starchy seed, regardless of its germination record, is very likely to produce corn more or less susceptible to the attack of certain parasitic fungi and to injury from unfavorable weather or soil conditions.

An important consideration in corn production is disease resistance, a condition which, up to the present time, the authors have not found associated with starchy seed or infected horny seed, but rather generally associated with seed from apparently healthy plants that shows vigor and freedom from disease on the germinator and that is horny in composition.

Nearly disease-free seed of a susceptible strain or selection may yield even less than moderately diseased seed selected from apparently good plants of a highly resistant strain, thus suggesting the advantage of selecting seed in the field from standing plants and the value of the germination test in securing seed which will produce plants more highly resistant.

Some strains of corn are so susceptible to disease and so deficient in those qualities which make for high yield of sound corn that neither physical nor germinator selection can effect any improvement in either quality or quantity of the crop.

The relative degree of resistance and susceptibility possessed by different strains and selections of corn cannot always be determined accurately by plantings on one date in one locality involving only one set of environmental factors.

The greatest improvement in resistance and productivity may be expected to accrue, not from physical selection of seed ears alone, but also from the continuous practice of plant selection and germintor selection, always beginning with a strain which has possibilities for improvement.

Altho variations in disease resistance are greater in open-pollinated corn than in uniform inbred strains, yet there are open-pollinated strains that are highly resistant to certain of the corn rot diseases. This resistance can be maintained by constant selection. Complete resistance or immunity to a majority of the corn rot diseases seems possible only by the recombination of two or more highly resistant and reasonably productive inbred strains which nick together in a compatible way.

The data that have been presented on disease resistance and susceptibility furnish strong arguments for the use of resistant strains of corn and of approved rotations in which there is a more liberal use of legumes.

Data from rotation experiments up to the present time indicate that crop rotation is as important a factor in determining yield of corn as are soil treatments.

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