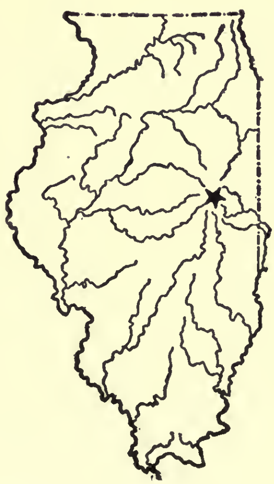
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 266

FACTORS INFLUENCING LODGING IN CORN

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

By Benjamin Koehler, G. H. Dungan,
and J. R. Holbert



URBANA, ILLINOIS, MAY, 1925

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FACTORS INFLUENCING LODGING IN CORN

By Benjamin Koehler, George H. Dungan, and James R. Holbert[a]

Corn (*Zea mays indentata*), like other cereal crops, is subject to lodging. The relative amount of lodging in different cornfields sometimes varies considerably, and speculations on the cause of these differences have not answered the question satisfactorily.

From the time corn root rot investigations were first inaugurated in 1917 by one of the authors, Mr. Holbert, data on lodging were recorded in order to determine whether or not this condition was augmented by seed infection with some of the corn rot organisms. Recently many corn growers and investigators have gained the conception that lodging in corn is caused principally by the corn root rot diseases. The data, however, have not always verified this belief. This has led to a larger study of the problem, including a study of some cultural and other non-parasitic factors involved as well as of the inheritance of tendencies toward weak roots.

METHODS OF EXPERIMENTATION

Most of the experimental plots on which data on leaning and broken stalks were obtained were located near Bloomington, McLean county, Illinois, and Urbana, Champaign county, Illinois. Some data also were obtained in Knox, Macon, Rock Island, DeKalb, Lee, and Clark counties in Illinois. All the corn was grown on Brown Silt Loam with the exception of that in Clark county, which was grown on Yellow Silt Loam.

The data were obtained from hand-planted, carefully controlled experiments conducted on uniform soil. Each experiment included a considerable number of individual plots planted alternately with nearly disease-free and with diseased seed. The individual plots usually were four rows wide by ten hills long, but in some cases they were larger. The total plant population of all replications within each experiment, as well as the percentage of a perfect stand, is given in each table in this bulletin. The rate of planting varied with the soil productivity; three kernels a hill was the usual number, but some were planted at the rate of two kernels a hill. All the plants in each plot were included in the data on leaning and broken stalks.

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The entire plant population within each experiment was used in obtaining yield data except in a few experiments in which only the central two rows of each individual plot were used. Yield data are included in most of the tables to show the significance of seed infection or seed inoculation. Total yields, including marketable and unmarketable grades, are given. If only marketable corn were being considered, the difference between the yields in each comparison usually would be somewhat greater.

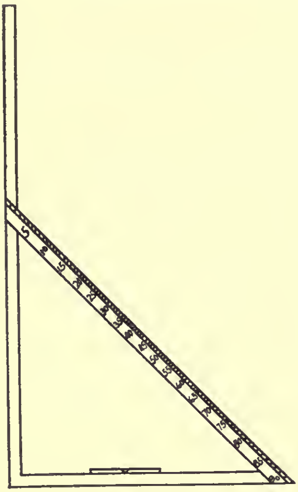

FIG. 1.—PROTRACTOR USED IN MEASURING THE ANGLES OF DEVIATION OF CORN STALKS

Nearly disease-free seed and diseased seed used in each experiment were selected not only from the same strain but from stalks that were grown from the same seed lot and in the same field during the previous year. Methods used in making these selections in the field, on the curing racks, and on the germinator are given in detail by Holbert et al.[4] Except when specifically stated that certain diseased seed composites were comparatively starchy, the comparisons were made between nearly disease-free and diseased composites that were similar in appearance in respect to composition, both being horny. The diseased seed was not infected very severely. Only ears that were practically 100 percent in viability on the germinator were used for seed. As a result the percentage of infection ranged not higher than 40 to 70 percent. If ears with a higher percentage of infection had been selected, it would have been impossible to obtain enough seed ears that were practically free from dead kernels.

The diseased seed used in these experiments is very similar to that which is used on the farms where a germination test has been made to discard the dead ears. However, in the latter case a mixture of infection is usually present, while in the work herein presented, corn infected with the several organisms has been separated in order to study the symptoms individually. Ears with mixed infection were discarded.

Two conditions, apparently independent of each other, were recognized in lodged corn. The stalks either were broken, the base in that case usually being erect, or the entire stalk inclined because of weak root anchorage. Occasionally the base of broken stalks also inclined. Such plants were recorded as both leaning and broken.

In nearly every case, the data on leaning and broken stalks were obtained during the month of September.

The inclination of the stalk as used in these data indicates its deviation from a vertical position. Fig. 1 illustrates the type of protractor used in measuring the angles. It is composed of three strips of wood arranged to form a right-angled triangle. The strip forming the hypotenuse carries the degree marks, and a spirit level is attached to the bottom piece. The two legs of the triangle are each thirty inches long, but the upright one has an extension for a handle.

Plants leaning 30 degrees or more were counted as leaning plants (Fig. 2); those leaning less than 30 degrees were disregarded. During the first several years of these investigations the actual inclination of each plant was recorded. In this way the average inclination of the plants, as well as the percentage of plants leaning beyond any certain angle, could be calculated. This method consumed a great deal of time, both in recording the data in the field and in summarizing them afterward. Analysis of the data (Table 1) showed that when comparing plant populations grown from nearly disease-free seed with those grown from moderately diseased seed, the ratio (1 to 1.52) in average inclination per plant was practically the same as the ratio (1 to 1.55) in percentage of plants leaning 30 degrees or more. By recording field data according to the latter system only, approximately four times as large a population could be covered in the time it would have taken by the first method. In this way greater accuracy was obtained because larger populations could be worked.

Average differences in leaning stalks and broken stalks have been analyzed by Student's method[9] to obtain the odds of probability. Odds of 30 to 1 or more are considered significant.

Note.—In the tables, reference is made by symbols, abbreviations, and numbers to the various strains of corn used. The following key explains them:

BW. A strain of Burr's White.
BB. A strain of Bloody Butcher.
F-90. Funk 90-Day.
HY. A high-yielding strain developed from Reid's Yellow Dent by the University of Illinois.
K. Funk 176-A developed from Reid's Yellow Dent.
C. Griffin's selection from Reid's Yellow Dent.
P. Paris' selection from Reid's Yellow Dent.
G. Gulick's selection from Reid's Yellow Dent.
M. McKeighan's selection from Reid's Yellow Dent.
A. Atwood and Hauser's selection from Reid's Yellow Dent.
B. Reid's Yellow Dent supplied by LaSalle County Farm Bureau.
D. Fox's selection from Reid's Yellow Dent.
S. Sommer's selection from Reid's Yellow Dent.
77. A low-yielding strain of Reid's Yellow Dent from Woodford County Farm Bureau.
120. Another low-yielding strain of Reid's Yellow Dent from Woodford County Farm Bureau.
62. A high-yielding strain of Reid's Yellow Dent from Woodford County Farm Bureau.
101. Another high-yielding strain of Reid's Yellow Dent from Woodford County Farm Bureau.

TABLE 1.—RATIOS OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND FROM MODERATELY DISEASED SEED

Determined by average inclination of plants, and percentages of plants leaning 20°, 30°, 45°, and 60°, respectively

Exp. No.	Condition of seed	Stand	Average degrees leaning per stalk	Percentage of stalks leaning 20° or more	Percentage of stalks leaning 30° or more	Percentage of stalks leaning 45° or more	Percentage of stalks leaning 60° or more
30	Nearly disease-free.........	1 038	3.06	6.13	3.87	2.69	1.85
	Moderately diseased.......	922	6.00	10.86	7.50	4.92	3.51
	Ratio..............................		1:1.96	1:1.77	1:1.92	1:1.83	1:1.90
34	Nearly disease-free.........	1 413	6.30	14.40	8.50	4.62	2.60
	Moderately diseased.......	1 322	7.33	16.35	9.80	7.24	3.80
	Ratio..............................		1:1.16	1:1.14	1:1.15	1:1.57	1:1.46
38	Nearly disease-free.........	290	12.20	31.72	18.60	8.33	2.04
	Moderately diseased.......	275	17.59	46.23	29.51	14.54	7.60
	Ratio..............................		1:1.44	1:1.46	1:1.59	1:1.75	1:3.73
	Average ratio........................		1:1.52	1:1.46	1:1.55	1:1.72	1:2.36

LEANING STALKS IN CORN GROWN FROM INFECTED SEED

SEED NATURALLY INFECTED WITH *Fusarium moniliforme*

Internal seed infection with *Fusarium moniliforme* Sheldon is very common thruout the corn belt. The fungus is of a pale salmon color and grows rapidly. It can easily be detected when corn has been tested for a period of seven to eight days on a good germinator[4]. Infected ears frequently have an excellent appearance and many pass as good seed ears unless a careful germination test is made.

When corn infected with this organism is grown under field conditions, a slight reduction in stand (Table 2) and early vigor[3] can be noted. In seventeen experiments, extending over three years, the yield was reduced in nearly every instance, the average being 68.0 bushels per acre for corn grown from nearly disease-free seed, and 63.8 bushels for corn grown from Fusarium-infected seed. This was a difference of 4.2 bushels with odds of 832 to 1, or a reduction of 6.2 percent.

The percentage of leaning plants, however, was not materially increased by seed infection with *Fusarium moniliforme*. In the plots planted with nearly disease-free seed, 23.4 percent of the plants leaned 30 degrees or more, while in the plots planted with Fusarium-infected seed 24.3 percent of the plants leaned to the same extent. The difference of 0.9 with odds of 7 to 1 is not very significant. It seems evident that this fungus is not operative as a root rot organism to the extent that it weakens the anchorage of the plant in the soil.

SEED NATURALLY INFECTED WITH *Diplodia zeae*

Diplodia zeae (Schw.) Lev. causes the common dry rot of corn. Only a small proportion of the infected ears, however, become badly

TABLE 2.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND SEED INFECTED WITH *Fusarium moniliforme*

Year	Exp. No.	County in which located (Illinois)	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
			Nearly disease-free seed		Fusarium-infected seed		Nearly disease-free seed	Fusarium-infected seed		Nearly disease-free seed	Fusarium-infected seed	
			No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1921	48a	McLean	1 145	91.6	1 139	91.1	73.6	67.5	−6.1	51.1	50.6	−0.5
	48b	McLean	1 170	93.5	1 125	90.0	82.7	74.7	−8.0	32.8	29.6	−3.2
	57	Champaign	592	92.5	646	80.8	55.4	44.9	−10.5	16.6	25.9	+9.3
1922	73	Champaign	3 816	88.4	1 790	82.9	36.1	33.8	−2.3	52.1	48.8	−3.3
	74	Champaign	3 874	90.2	1 635	85.3	58.5	49.5	−9.0	6.6	5.3	−1.3
	75	Champaign	3 340	87.0	1 701	88.6	56.7	51.8	−4.9	26.3	31.3	+5.0
	78	Knox	6 187	93.7	1 532	92.8	74.6	68.9	−5.7	9.1	9.0	−0.1
	81	McLean	5 709	90.7	922	87.8	100.0	98.2	−1.8	1.4	1.2	−0.2
		Manhattan[a] (Kansas)	279	93.2	246	82.0	44.6	31.8	−12.8	64.9	65.8	+0.9
1923	85	Champaign	10 659	92.5	3 294	85.8	54.4	53.8	−0.6	14.6	13.0	−1.6
	86	Champaign	10 501	91.1	3 354	87.4	52.1	49.7	−2.4	31.8	32.5	+0.7
	87	Champaign	9 959	86.5	3 071	80.0	57.5	52.2	−5.3	13.1	15.5	+2.4
	88	Champaign	10 683	92.7	3 365	87.6	66.0	63.9	−2.1	16.5	18.9	+2.4
	89	McLean	4 098	94.9	1 619	93.6	72.4	69.2	−3.2	17.3	17.7	+0.4
	90	McLean	1 384	96.1	448	93.3	92.1	88.9	−3.2	22.1	20.5	−1.6
	91	McLean	2 340	97.5	912	95.0	95.2	95.2	0.0	13.9	16.1	+2.2
	93	McLean	2 517	74.9	713	74.3	83.5	91.2	+7.7	8.3	11.8	+3.5
Grand average			......	91.0	......	87.0	68.0	63.8	−4.2 Odds = 832:1	23.4	24.3	+0.9 Odds = 7:1

[a]Data supplied by C. O. Johnston.

rotted. Very often infection is difficult to detect, and frequently it becomes evident only in the germination test.[4] Infection of seed corn with this organism results in a greater reduction in yield than infection with any other organisms herein reported.

FIG. 2.—TWO PHASES OF LODGING: A LEANING STALK AND A BROKEN STALK

The leaning stalk, shown at the left, was inclining exactly 30 degrees. Stalks leaning to this extent and more were counted as leaning, while those not leaning to this extent were not counted as such. The broken stalk shown here illustrates a typical condition. The break may occur, however, anywhere along the length of stalk. When only the tassel was broken, the stalk was not counted as broken.

Only seed of good viability was used in these experiments, but many seedlings succumbed to the organism on the germinator when the plumule was only an inch or two in length. Similarly, after planting in the field plots, many seedlings died before or soon after coming thru the ground. This caused a considerable reduction in stand in every case, as shown in Table 3. Plants that lived thru the seedling

TABLE 3.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND SEED INFECTED WITH *Diplodia zeae*

Year	Exp. No.	County in which located (Illinois)	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
			Nearly disease-free seed		Diplodia-infected seed		Nearly disease-free seed	Diplodia-infected seed		Nearly disease-free seed	Diplodia-infected seed	
			No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1921	48a	McLean	1 169	93.5	577	46.2	73.6	42.8	−30.8	41.5	45.7	+4.2
	48b	McLean	1 160	92.8	669	53.5	82.7	54.4	−28.3	34.0	42.9	+8.9
	53	Champaign	2 785	92.8	1 192	79.4	68.2	58.3	−9.9	18.5	35.9	+17.4
	54	Champaign	2 751	91.9	1 057	70.4	64.5	51.1	−13.4	25.2	45.0	+19.8
	57	Champaign	592	92.5	424	66.3	55.4	43.2	−12.2	16.6	22.1	+5.5
1922	71	Champaign	1 119	93.2	771	64.3	67.0	43.9	−23.1	0.3	2.1	+1.8
	73	Champaign	4 371	85.4	1 147	44.8	35.4	19.5	−15.9	46.3	62.7	+16.4
	74	Champaign	4 484	87.6	1 302	50.9	60.5	38.1	−22.4	6.5	21.4	+14.9
	75	Champaign	3 356	87.4	934	48.7	58.9	36.2	−22.7	26.9	23.3	−3.6
	78	Knox	6 187	93.5	1 110	67.3	74.6	58.1	−16.5	9.1	9.9	+0.8
	81	McLean	5 709	90.7	648	61.7	100.0	78.9	−21.1	1.4	4.6	+3.2
		Manhattan[a] (Kansas)	279	93.2	182	60.3	44.6	25.4	−19.2	64.9	80.2	+15.3
1923	85	Champaign	10 659	92.5	1 720	44.8	54.4	27.5	−26.9	14.6	27.4	+12.8
	86	Champaign	10 501	91.1	1 765	45.9	52.1	24.7	−27.4	31.8	47.5	+15.7
	87	Champaign	9 959	86.5	1 655	43.1	57.5	25.0	−32.5	13.1	28.2	+15.1
	88	Champaign	10 683	92.7	1 821	47.4	66.0	31.7	−34.3	16.5	40.0	+23.5
	89	McLean	4 098	94.9	1 204	69.7	72.7	61.1	−10.6	17.3	20.3	+3.0
	90	McLean	1 384	96.1	349	72.7	90.2	64.9	−25.3	22.1	31.5	+9.4
	91	McLean	2 340	97.5	717	74.7	96.3	80.5	−15.8	13.9	14.3	+0.4
	92	McLean	1 359	94.3	355	73.9	93.6	66.6	−27.0	15.8	25.9	+10.1
	93	McLean	1 605	79.6	213	37.0	83.5	49.1	−34.4	7.1	23.5	+16.4
Grand average			......	91.4	......	58.2	69.1	46.7	−22.4 Odds = > 9999:1	21.1	31.2	+10.1 Odds = > 9999:1

[a]Data supplied by C. O. Johnston.

stage usually developed to maturity, but they did not produce a high average yield per plant commensurate with their increased opportunity due to a thin stand. In twenty-one experiments extending over three years, the plots grown from nearly disease-free seed averaged 69.1 bush-

FIG. 3.—EFFECT OF DIPLODIA-INFECTED SEED ON LODGING

A—A plot of corn grown from Diplodia-infected seed, in which 13.7 percent of the plants were leaning 30 degrees or more.

B—A plot grown from nearly disease-free seed of the same strain and adjacent to the one shown in A. Only 1.1 percent of the plants leaned 30 degrees or more.

els per acre, while those grown from Diplodia-infected seed averaged 46.7 bushels per acre. This is a difference of 22.4 bushels with odds greater than 9999 to 1, or a reduction of 32.4 percent, a very serious loss.

In every experiment except one (Table 3) an increase in the percentage of leaning plants in the corn grown from Diplodia-infected seed as compared with that grown from disease-free seed was found (Fig. 3). In the latter, 21.1 percent of the plants leaned 30 degrees or more, while in the populations grown from Diplodia-infected seed 31.2 percent leaned to the same extent, an average difference of 10.1 with odds

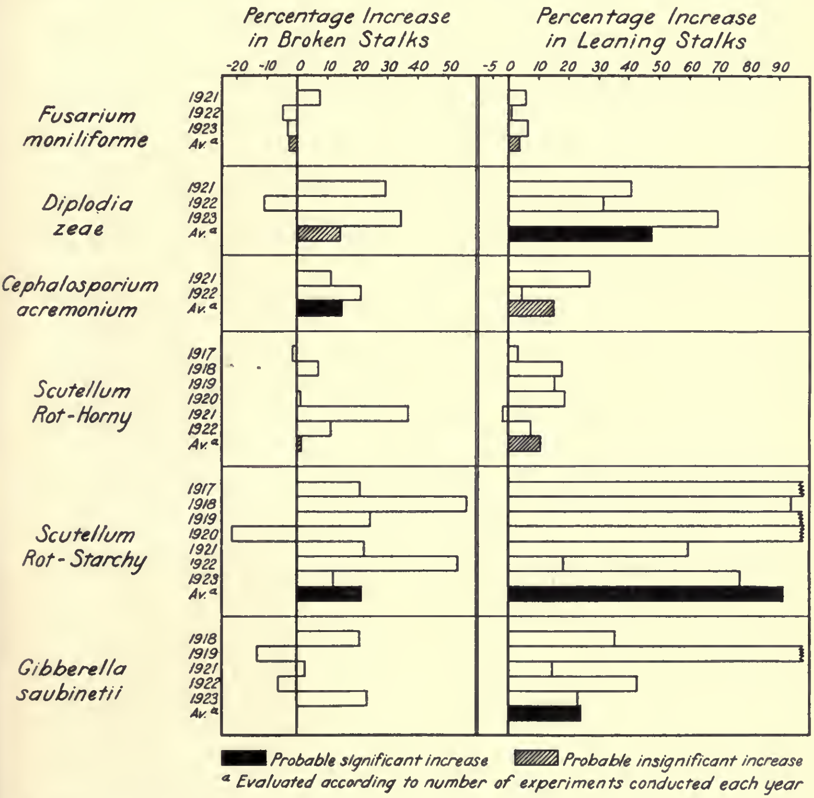

FIG. 4.—PERCENTAGE INCREASE IN BROKEN AND LEANING STALKS IN CORN GROWN FROM INFECTED SEED AS COMPARED WITH CORN GROWN FROM NEARLY DISEASE-FREE SEED

greater than 9999 to 1, or an increase of 47.8 percent (Fig. 4). Diplodia-infected seed caused a considerable reduction in stand, but as shown later in this paper, a reduction in stand would tend to decrease the percentage of leaning plants, and not to increase it.

Diplodia zeae readily causes root rot of seedlings in the field, as well as on the germinator. In nearly every case infection also occurs along the base of the plumule on the part that later becomes the mesocotyl. Many plants die at this stage. Those that survive long enough to develop secondary roots at the first node are quite likely to live thruout the season. In most cases, however, the mesocotyl becomes completely rotted during the young plant stage. The primary roots (those emerging directly from the kernel) then are no longer able to function and often they too have rotted by that time. This causes a pronounced stunting of the infected plants early in their development and such

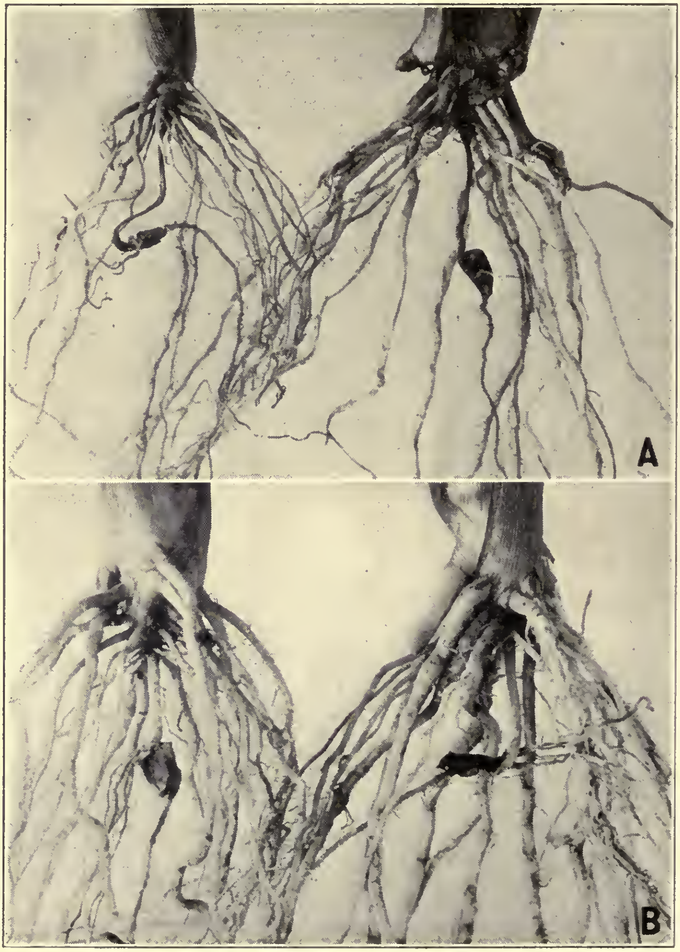

FIG. 5.—ROOT INJURY CAUSED BY SEED INFECTION WITH *Diplodia zeae*

A—The crowns of two corn plants grown from Diplodia-infected seed, sixty days after planting. The mesocotyl, as well as the primary roots, are brown and shriveled. The secondary roots are spindly and comparatively few in number. Such plants would be expected to blow over easily.

B—The crowns of two corn plants grown from nearly disease-free seed and the same age as shown above. The mesocotyls are bright and functioning, and all the roots are in a vigorous, healthy condition.

plants naturally do not develop as many or as strong secondary roots as normal plants. Fig. 5 illustrates the reduction in size and number of roots that ordinarily occurs when Diplodia-infected seed is used. The rotting and shriveling of the mesocotyl and primary roots shown in this photograph are very characteristic.

As one would expect from the foregoing, corn plants grown from Diplodia-infected seed are more easily pulled up from the soil than

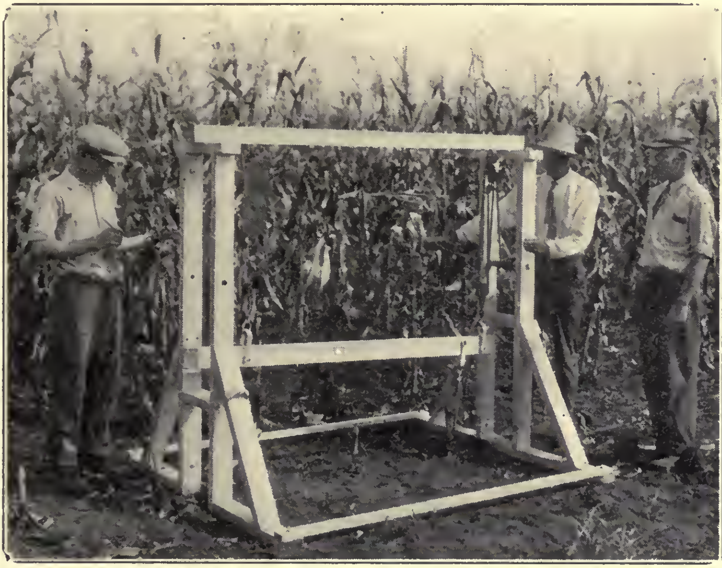

FIG. 6.—PULLING MACHINE USED IN DETERMINING THE RELATIVE ROOT ANCHORAGE OF VARIOUS KINDS OF CORN

The essential feature of this machine is a cross beam with three axes which divide it in the ratio of 1 to 9. The distal axis on the long arm of the beam is hung to a spring balance scale, the stalk is fastened to the second axis, and a steady pull is exerted on the other distal axis. The scale readings are then multiplied by 10 to obtain the actual pulling resistance of the roots.

plants grown from disease-free seed. A machine has been described by Holbert and Koehler[5] by which corn plants can be pulled up easily and the pulling resistance of the plants measured in pounds (Fig. 6.). In an experiment of twenty-six plots, half the plots being planted with Diplodia-infected seed and the alternate half with nearly disease-free seed, 15 hills of two plants each were pulled in each plot. The average pulling resistance for plants grown from Diplodia-infected seed was 313 pounds and for plants grown from nearly disease-free seed, 337—a difference of 24 pounds per plant, with odds of 100 to 1 in favor of the latter.

The rotting of the primary roots and mesocotyl, with a resulting under-development of the secondary root system, seems to be the explanation for the occurrence of increased percentages of leaning plants when Diplodia-infected seed is planted.

TABLE 4.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND SEED INFECTED WITH *Cephalosporium acremonium*

Year	Exp. No.	County in which located (Illinois)	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
			Nearly disease-free seed		Cephalosporium-infected seed		Nearly disease-free seed	Cephalosporium-infected seed		Nearly disease-free seed	Cephalosporium-infected seed	
			No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1922	73a	Champaign	2 056	88.0	1 230	85.5	36.1	31.2	−4.9	34.2	44.2	+10.0
	73b	Champaign	2 054	87.8	1 278	88.8	40.9	38.4	−2.5	36.0	47.3	+10.7
	74a	Champaign	2 107	90.1	1 230	85.4	61.0	55.5	−5.5	2.0	2.0	0.0
	74b	Champaign	2 022	86.5	1 282	89.0	65.4	62.9	−2.5	2.2	1.7	−0.5
	81	McLean	5 709	90.7	928	88.4	100.0	97.0	−3.0	1.4	1.5	+0.1
1923	85	Champaign	10 659	92.5	2 295	89.7	54.4	51.6	−2.8	14.6	19.5	+4.9
	88	Champaign	10 683	92.7	2 374	92.7	66.0	61.7	−4.3	16.5	18.1	+1.6
	89	McLean	4 098	94.9	1 636	94.7	72.1	69.6	−2.5	17.3	19.9	+2.6
	90	McLean	1 384	96.1	450	93.8	92.9	93.5	+0.6	22.1	19.3	−2.8
	92	McLean	1 359	94.3	460	95.8	93.6	94.1	+0.5	15.8	13.9	−1.9
Grand average			......	91.4	......	90.4	68.2	65.5	−2.7 Odds = 868:1	16.2	18.7	+2.5 Odds = 14:1

SEED NATURALLY INFECTED WITH *Cephalosporium acremonium*

A recently discovered corn disease known as the black-bundle disease has been described by Reddy and Holbert.[7] It is caused by *Cephalosporium acremonium* Corda, a very small, delicate fungus. The organism is carried over from year to year in the vegetative stage within the seed. During the germination process the fungus fructifies on the surface of the kernels and an experienced person can readily identify infected kernels by the use of a microscope. The symptoms of diseased plants become more or less evident after the ears have reached the milk stage. The most constant symptom is the presence within the stalk of several to many blackened vascular bundles. Other symptoms of the disease are purple midribs of leaves, purple stalks, barrenness, nubbin ears, and multiple or prolific attempts at ear formations.

Two years' data on the relation of seed infection with *Cephalosporium acremonium* to leaning stalks were obtained. In the ten experiments (Table 4) the average reduction in yield was 2.7 bushels with odds of 868 to 1. The percentage of leaning stalks, however, was not uniformly affected. In five experiments infected seed apparently caused an increase in the percentage of leaning stalks, while in the other five the plants behaved in that respect very much like those grown from nearly disease-free seed. On the whole, plant populations from nearly disease-free seed averaged 16.2 percent leaning stalks, while those from infected seed averaged 18.7 percent, a difference of 2.5 with odds of 14 to 1. From the two years' data obtained it does not seem likely that corn grown from seed infected with *Cephalosporium acremonium* is very apt to incline to a greater extent than corn grown from healthy seed.

SEED SUSCEPTIBLE TO SCUTELLUM ROT

Most seed that has not had rigid selection for resistance to scutellum rot is susceptible to this disease. It is the most common disease in field corn. Scutellum rot is not caused by an organism within the seed as in the three previously discussed diseases. The organisms, *Rhizopus spp.* and some others, adhere to the exterior of the kernels and gain entrance during the germination process. They are facultative parasites that are common everywhere, and perhaps no seed corn is entirely free from them. During the process of germination, corn susceptible to invasion by these organisms becomes discolored and rotted in the scutellar region. Susceptible kernels often are covered by a mass of Rhizopus mycelium when the germination test is completed and can be detected on sight. Frequently, however, scutellum rot can be detected only by bisecting the kernels after germination and examining the scutellum.[4]

TABLE 5.—FIELD STANDS, ACRE YIELDS, AND PERCENTAGE OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND FROM SEED SUSCEPTIBLE TO SCUTELLUM ROT: SUMMARY OF FIVE YEARS' DATA

Year	Exp. No.	County in which located (Illinois)	Strain	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
				Nearly disease-free seed		Scutellum-rot susceptible seed		Nearly disease-free seed	Scutellum-rot susceptible seed		Nearly disease free seed	Scutellum-rot susceptible seed	
				No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1917	1	McLean	K	2 604	94.7	2 481	90.3	76.4	68.2	−8.2	5.8	6.0	+0.2
1918	2	McLean	K	1 822	91.1	857	86.5	65.0	63.7	−1.3	26.1	30.8	+4.7
1920	18	McLean	K	578	96.3	569	94.8	64.6	55.1	−9.5	17.8	29.1	+11.3
	23	Rock Island	K	2 905	88.1	2 718	82.3	43.8	41.1	−2.7	0.2	0.8	+0.6
	26	Champaign	K	6 417	89.0	5 714	79.3	78.4	68.1	−10.3	2.5	4.0	+1.5
	27	Champaign	K	2 390	88.5	2 140	79.3	81.7	67.8	−13.9	4.2	4.8	+0.6
	28	Macon	K	1 967	82.0	1 932	80.5	64.0	59.3	−4.7	23.0	20.7	−2.3
	30	McLean	K	1 038	86.5	922	76.7	61.7	52.9	−8.8	3.9	7.5	+3.6
	33	McLean	K	2 246	91.3	2 098	85.2	83.6	70.9	−12.7	8.0	9.7	+1.7
	36	McLean	K	1 556	91.2	1 449	84.9	81.7	71.4	−10.3	7.9	19.4	+11.5
1921	48	McLean	K	4 654	93.0	2 091	83.7	78.2	69.5	−8.7	39.9	36.0	−3.9
	55	Champaign	K	3 450	95.8	3 190	88.6	60.0	52.9	−7.1	16.5	12.9	−3.6
	56	Champaign	K	7 295	94.9	6 727	87.6	95.2	83.2	−12.0	16.3	17.7	+1.4
1922	72	Champaign	K	6 354	88.3	5 841	81.2	49.0	44.8	−4.2	16.3	11.4	−4.9
	73	Champaign	K	3 385	88.2	2 212	86.5	34.9	25.4	−9.5	47.0	43.9	−3.1
	74	Champaign	K	3 519	92.1	2 373	92.7	59.9	52.4	−7.5	7.1	6.6	−0.5
	75	Champaign	K	1 694	88.2	1 535	79.9	57.9	50.7	−7.2	27.9	23.1	−4.8
	78	Knox	K	6 187	93.7	1 442	87.4	74.6	69.1	−5.5	9.1	13.1	+4.0
	79	McLean	K	1 583	87.9	1 584	88.0	50.1	46.5	−3.6	26.7	37.6	+10.9
	80	Lee	K	569	75.9	559	74.5	96.8	82.8	−14.0	17.7	32.5	+14.8
Grand average				......	89.8	......	84.5	67.9	59.8	−8.1 Odds = >9999:1	16.2	18.4	+2.2 Odds = 17:1

The yields of plots planted with seed susceptible to scutellum rot have practically always been considerably less than the yields of similar plots planted with nearly disease-free seed. A summary of the stand, acre yield, and leaning plants in experiments conducted with strain K (Funk's 176-A) yellow dent seed is given in Table 5. This strain is very popular in the central portion of the corn belt; it is the same strain that was used in the experiments reported in Tables 1, 2, 3, and 4. The acre yield was reduced from 67.9 bushels in plots planted with nearly disease-free seed to 59.8 bushels in plots planted with seed susceptible to scutellum rot. This is a difference of 8.1 bushels with odds greater than 9999 to 1, or a reduction of 11.9 percent. There seems to be no doubt but that decided reductions in yield are caused by this disease. Nevertheless, the percentage of leaning stalks was increased very little, if any, as compared with the nearly disease-free checks. In twenty experiments, leaning was increased thirteen times and decreased seven times. The average difference in percentage of leaning stalks was only +2.2 with odds of 17 to 1, which is hardly significant.

Experiments with seed susceptible to scutellum rot in other miscellaneous strains of yellow dent corn are summarized in Table 6. The key to these strains is given on page 313 under "Methods of Experimentation." On the average they have behaved exactly like strain K summarized in Table 5. The average acre yield was reduced from 69.5 bushels to 60.7 bushels, a difference of 8.8 bushels with odds greater than 9999 to 1, or a reduction of 12.7 percent. The average percentage of leaning stalks was increased from 22.9 to 24.9, a difference of 2.0 with odds of 16 to 1. Here again the difference in percentage of leaning stalks is hardly significant.

In all the experiments reported above, the diseased and nearly disease-free seed had very nearly the same appearance in respect to horniness. None of it could be classed as starchy.[4,10] In these investigations starchy seed has practically always proved to be susceptible to scutellum rot. Occasionally a starchy ear will appear to be disease-free after a germination test, but when the kernels of such an ear are sprayed with a spore suspension of *Rhizopus spp.* before the test is made, scutellum rot develops in abundance. When disease-resistant horny seed is sprayed and germinated in the same way, scutellum rot usually does not develop.

Table 7 gives a summary of twenty experiments over a period of seven years on the comparative field performance of nearly disease-free horny seed, and starchy seed susceptible to scutellum rot. The average acre yield was reduced from 71.1 bushels to 59.6 bushels, a difference of 11.5 bushels with odds greater than 9999 to 1, or a reduction of 16.2 percent. It should be noted that the decrease in yield was not much greater than it was when horny seed susceptible to scutel-

TABLE 6.—FIELD STANDS, ACRE YIELDS, AND PERCENTAGE OF LEANING STALKS IN MISCELLANEOUS STRAINS OF YELLOW DENT CORN GROWN FROM NEARLY DISEASE-FREE SEED AND FROM SEED SUSCEPTIBLE TO SCUTELLUM ROT: SUMMARY OF FOUR YEARS' DATA

Year	Exp. No.	County in which located (Illinois)	Strain	Total field stand of all replications: Nearly disease-free seed		Total field stand of all replications: Scutellum-rot susceptible seed		Average acre yield: Nearly disease-free seed	Average acre yield: Scutellum-rot susceptible seed	Difference in acre yield	Average percentage of stalks leaning 30° or more: Nearly disease-free seed	Average percentage of stalks leaning 30° or more: Scutellum-rot susceptible seed	Difference in percentage of leaning stalks
				No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1919	13	Champaign	HY	2 031	92.4	1 952	88.8	85.6	72.5	−13.1	37.3	40.8	+3.5
	14	McLean	F-90	316	87.7	286	79.4	73.6	51.4	−22.2	27.4	34.1	+6.7
1920	15	DeKalb	F-90	1 952	93.8	1 950	93.7	66.0	59.1	−6.9	4.7	4.0	−0.7
	16	Clark	F-90	2 126	92.5	2 014	87.6	38.3	31.1	−7.2	39.5	52.2	+12.7
	17	Knox	M	1 259	81.9	1 082	70.4	72.4	67.0	−5.4	25.5	23.2	−2.3
	19	McLean	F-90	293	88.8	292	88.5	43.1	29.7	−13.4	37.5	45.9	+8.4
	20	Macon	G	800	88.9	764	84.9	61.0	53.2	−7.8	34.4	34.3	−0.1
	20	Macon	P	841	93.5	778	86.5	72.3	64.1	−8.2	23.9	20.2	−3.7
	22	McLean	G	1 233	93.4	1 057	80.1	64.4	45.4	−19.0	13.1	19.9	+6.8
	22	McLean	P	1 242	94.1	1 143	86.6	62.5	54.1	−8.4	8.2	7.2	−1.0
1921	49	McLean	A	2 682	93.1	2 536	88.0	84.8	80.2	−4.6	26.1	24.9	−1.2
	49	McLean	B	2 782	96.6	2 669	92.7	81.8	77.2	−4.6	34.1	34.4	+0.3
	49	McLean	C	2 728	94.8	2 465	85.7	86.7	79.1	−7.6	13.1	17.3	+4.2
1922	79	McLean	C	571	95.2	449	74.9	47.6	44.2	−3.4	41.6	37.4	−4.2
	80	Lee	M	1 328	88.5	1 287	85.7	87.3	84.3	−3.0	0.1	1.3	+1.2
	80	Lee	S	1 329	88.5	1 238	82.5	85.0	79.1	−5.9	0.8	1.7	+0.9
Grand average				......	91.5	......	84.8	69.5	60.7	−8.8 Odds = > 9999:1	22.9	24.9	+2.0 Odds = 16:1

TABLE 7.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF LEANING STALKS IN SEVERAL STRAINS OF DENT CORN GROWN FROM NEARLY DISEASE-FREE HORNY SEED AND FROM STARCHY SEED SUSCEPTIBLE TO SCUTELLUM ROT: SUMMARY OF SEVEN YEARS' DATA

Year	Exp. No.	County in which located (Illinois)	Strain	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
				Nearly disease-free horny seed		Scutellum-rot susceptible starchy seed		Nearly disease-free horny seed	Scutellum-rot susceptible starchy seed		Nearly disease-free horny seed	Scutellum-rot susceptible starchy seed	
				No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1917	1	McLean	K	2 568	93.4	2 470	89.8	74.4	70.3	−4.1	5.2	11.2	+6.0
1918	2	McLean	K	1 822	91.1	875	87.5	65.0	68.2	+3.2	26.1	41.5	+15.4
	6	McLean	F-90	670	93.0	653	90.7	66.8	56.8	−10.0	14.6	17.6	+3.0
	9	McLean	K	1 026	82.1	1 247	84.9	68.2	54.7	−13.5	5.7	30.9	+25.2
	10	McLean	K	815	90.6	895	89.5	62.0	57.1	−4.9	6.7	13.3	+6.6
1919	11	McLean	BW	2 013	96.0	1 960	93.4	54.6	54.0	−0.6	14.1	66.6	+52.5
	12	McLean	K	230	92.0	163	65.2	125.0	90.0	−35.0	4.1	4.4	+0.3
1920	35	McLean	K	1 330	86.6	1 208	78.8	75.3	70.5	−4.8	4.8	11.1	+6.3
	36	McLean	K	2 246	91.8	2 240	91.5	76.0	68.0	−8.0	8.0	26.4	+18.4
1921	53	Champaign	K	2 749	88.1	1 330	85.3	72.5	65.5	−7.0	15.5	25.1	+9.6
	54	Champaign	K	2 737	87.7	1 209	77.5	63.0	56.4	−6.6	28.6	45.4	+16.8
1922	76	Knox	C	1 538	93.1	1 245	75.4	78.7	68.3	−10.4	0.4	2.5	+2.1
	79	McLean	C	1 100	91.6	893	74.5	40.7	35.8	−4.9	28.9	32.2	+3.3
1923	85	Champaign	K	10 659	92.5	2 670	69.5	54.4	39.3	−15.1	14.6	27.5	+12.9
	86	Champaign	K	10 501	91.1	2 762	71.9	52.1	35.9	−16.2	31.8	45.4	+13.6
	87	Champaign	K	9 959	86.5	2 642	68.8	57.5	41.6	−15.9	13.1	25.8	+12.7
	88	Champaign	K	10 683	92.7	2 676	69.7	66.0	41.8	−24.2	16.5	36.5	+20.0
	91	McLean	K	2 340	97.5	855	89.1	92.4	77.8	−14.6	13.9	21.1	+7.2
	92	McLean	K	1 359	94.3	400	83.3	93.6	76.6	−17.0	15.8	24 5	+8.7
	93	McLean	K	1 605	79.6	373	64.7	83.5	64.3	−19.2	7.1	19.0	+11.9
Grand average					90.6	......	80.1	71.1	59.6	−11.5 Odds = > 9999:1	13.8	26.4	+12.6 Odds = > 9999:1

lum rot was compared with nearly disease-free horny seed (Tables 5 and 6). But unlike the results obtained with horny seed susceptible to scutellum rot, the plants grown from starchy seed susceptible to scutellum rot leaned considerably more than those from nearly disease-free horny seed (Table 7, Fig. 4). The difference in percentage of leaning stalks was 12.6 with odds greater than 9999 to 1. Trost[10] has published data showing an increase of 3.14 percent leaning stalks and 53.0 percent down stalks when corn grown from disease-susceptible starchy seed was compared with that grown from disease-free horny seed.

As starchy seed susceptible to scutellum rot could not be compared with starchy seed resistant to this disease, it could not be determined whether the disease was the principal factor in producing the increase in percentage of leaning plants. But when comparisons were made between resistant and susceptible seed that was horny in composition, all other factors being as comparable as could be obtained, this widespread disease, even tho highly detrimental to yield, was not manifested to any appreciable extent in the form of leaning stalks.

SEED INOCULATED WITH *Gibberella saubinetii*

Gibberella saubinetii (Mont.) Sacc. is the principal organism causing wheat scab. It also is a very important corn root parasite.[a]

In Illinois the organism is not usually seed-borne on corn to an important extent. Instead, infection occurs principally from the fungus overwintering on crop refuse on and in the soil. For that reason, up to the season of 1924, infected seed was not used in these studies, but experiments were conducted by inoculating the seed with a pure culture of the organism and planting on virgin soil. At planting time the seed to be inoculated was moistened with a spore suspension of the organism. Different strains of corn exhibiting various conditions of seed infection were used.

Leaning data were obtained on nearly all of the inoculation experiments and these, as well as stand and yield data, are summarized in Table 8. In each experiment where nearly disease-free seed and diseased seed of the same strain were planted in comparative tests, the diseased seed usually was affected to a greater extent by inoculation with *Gibberella saubinetii* than was nearly disease-free seed. This seems to indicate that seed resistant to certain other common diseases also is more resistant to injury by *Gibberella saubinetii.*

The grand average of all the data in Table 8 shows a considerable reduction in stand and yield on the inoculated plots, and an increase in the percentage of leaning stalks. The stand was reduced 9.8 percent. This reduction in stand alone probably would not have greatly influ-

[a]Corn disease experiments with this organism have been conducted at Bloomington, Illinois, for a number of years in cooperation with Dr. J. G. Dickson, of the Office of Cereal Investigations. General results have been published by Holbert, Dickson, and Biggar,[2] Koehler, Dickson, and Holbert,[6] and Holbert et al.[3, 4].

enced the yield, as all these plots were planted at the rate of three kernels per hill. The yield, nevertheless, was reduced 10.8 bushels with odds of 9999 to 1 or 12.9 percent.

The percentage of leaning stalks was increased from 12.4 in the control plots to 15.4 in the inoculated plots, a difference of 3.0 with odds of 2000 to 1, or an increase of 24.2 percent. In the foreground of Fig. 7, a row of Funk's 90-Day corn is illustrated. At planting time the kernels in every alternate hill had been heavily inoculated with *Gibberella saubinetii.*. With very few exceptions, the plants grown from the inoculated kernels leaned considerably while the controls stood erect.

FIG. 7.—SEED INOCULATED WITH *Gibberella saubinetii*

A row of corn in which every alternate hill was heavily inoculated at planting time with *Gibberella saubinetii.* When the corn had reached the hard dough stage, nearly all the plants grown from inoculated seed went down in a rain storm while nearly all the control plants remained erect.

When germination studies were made of the 1923 corn crop at Bloomington, an unusual amount of seed infection with *Gibberella saubinetii* was noted. A considerable number of ears showing a high percentage of infection but possessing good viability was selected. A composite was made of this seed and tests were made in comparison with nearly disease-free checks.

Altho only one year's results have been obtained with this type of seed infection, the experiments were conducted in three widely separated counties within the state and the results check closely. The data are given in Table 9. In each case the stand was considerably reduced by seed infection, with results similar to those when seed was naturally infected with *Diplodia zeae* (Table 3). Seed infection also caused an increase in the percentage of leaning stalks in every instance, the grand average being raised from 25.7 percent in the nearly disease-

TABLE 8.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF LEANING STALKS IN SEVERAL STRAINS OF YELLOW DENT CORN, PART OF EACH SERIES INOCULATED AT PLANTING TIME WITH *Gibberella saubinetii*, BLOOMINGTON: SUMMARY OF FIVE YEARS' DATA

Year	Exp. No.	Strain	Condition of seed	Total field stand of all replications				Average acre yield		Average difference in acre yield	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
				Control		Inoculated		Control	Inoculated		Control	Inoculated	
				No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1918	5	BB	From apparently disease-free stalks	240	85.7	208	79.3	56.9	56.5	−0.4	15.3	14.3	−1.0
			From apparently diseased stalks	65	81.2	50	62.5	44.7	25.4	−19.3	19.4	36.0	+16.6
	6	F-90	Nearly disease-free[a]	670	93.0	642	89.2	66.8	60.3	−6.5	14.6	16.7	+2.1
			Scutellum-rotted, starchy	653	90.7	586	81.4	56.8	58.9	+2.1	17.6	23.2	+5.6
1919	12	K	Nearly disease-free	230	92.0	120	48.0	125.0	63.0	−62.0	4.1	9.2	+5.1
			Scutellum-rotted, starchy	163	65.2	123	49.2	90.0	51.0	−39.0	4.4	11.1	+6.7
1921	51	K	Nearly disease-free	5 239	97.4	3 301	93.1	91.0	90.7	−0.3	12.5	12.5	0.0
	51	A	Nearly disease-free	689	95.8	424	88.3	93.3	80.8	−12.5	23.0	24.8	+1.8
			Moderately diseased[b]	674	93.6	385	80.0	87.5	74.0	−13.5	20.0	14.5	−5.5
	51	B	Nearly disease-free	693	96.3	450	93.7	81.4	80.3	−1.1	29.1	34.3	+5.2
			Moderately diseased[b]	692	96.2	432	90.0	80.9	69.3	−11.6	42.2	41.0	−1.2
	51	C	Nearly disease-free	666	92.5	447	91.2	81.6	77.6	−4.0	16.6	21.9	+5.3
			Moderately diseased[b]	659	91.5	399	83.1	79.3	75.9	−3.4	15.2	24.5	+9.3
	51	D	Nearly disease-free	672	93.3	416	86.7	77.8	77.9	+0.1	14.6	15.5	+0.9
			Moderately diseased[b]	638	88.6	340	70.8	81.0	69.5	−11.5	16.0	27.8	+11.8

[a]Unless otherwise stated, all the seed was horny.
[b]Principally affected with scutellum rot.

TABLE 8.—*Concluded*

Year	Exp. No.	Strain	Condition of seed	Total field stand of all replications: Control		Total field stand of all replications: Inoculated		Average acre yield: Control	Average acre yield: Inoculated	Average difference in acre yield	Average percentage of stalks leaning 30° or more: Control	Average percentage of stalks leaning 30° or more: Inoculated	Difference in percentage of leaning stalks
				No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*
1922	81	K	Nearly disease-free	4 201	93.4	1 637	91.0	107.6	102.6	−5.0	1.3	1.7	+0.4
			Nearly disease-free, starchy	657	87.6	248	82.7	109.6	85.2	−24.4	1.5	2.0	+0.5
			Affected with scutellum-rot	644	85.9	256	85.4	101.7	92.6	−9.1	0.5	0.8	+0.3
			Infected with *Diplodia zeae*	476	63.5	172	57.4	83.6	79.1	−4.5	3.8	8.7	+4.9
			Infected with *Cephalosporium acremonium*	663	88.2	265	88.3	107.7	99.0	−8.7	1.2	2.3	+1.1
	82	77	Moderately diseased[b]	645	86.0	256	85.3	75.6	71.9	−3.7	6.4	3.1	−3.3
	82	120	Moderately diseased[b]	591	78.8	256	85.3	87.3	81.8	−5.5	2.2	3.5	+1.3
	82	101	Moderately diseased[b]	655	87.3	260	86.7	89.1	81.7	−7.4	2.7	5.8	+3.1
	82	62	Moderately diseased[b]	627	83.6	267	89.0	87.2	91.3	+4.1	5.7	7.9	+2.2
1923	93	K	Nearly disease-free	1 605	79.6	912	67.9	83.5	78.8	−4.7	7.1	10.4	+3.3
			Nearly disease-free, starchy	437	75.8	228	59.4	87.5	73.6	−13.9	14.4	12.7	−1.7
			Affected with scutellum-rot	456	79.1	235	61.2	84.9	69.1	−15.8	7.5	11.5	+4.0
			Affected with scutellum-rot, starchy	373	64.7	149	38.8	64.3	48.5	−15.8	19.0	25.5	+6.5
			Infected with *Diplodia zeae*	213	37.0	124	32.3	49.1	39.7	−9.4	23.5	24.2	+0.7
			Infected with *Fusarium moniliforme*	455	79.0	258	67.1	91.2	75.1	−16.1	9.7	15.5	+5.8
Grand average					84.1	.....	75.5	83.5	72.7	−10.8 Odds = 9999:1	12.4	15.4	+3.0 Odds = 2000:1

[b]Principally affected with scutellum rot.

free checks to 31.9 percent in the corn grown from Gibberella-infected seed, a difference of 6.2 with odds of 77 to 1, or an increase of 24.1 percent. The least difference in percentage of leaning stalks occurred in Experiment No. 98 in Rock Island county. Here the stand was cut the most by Gibberella infection.[1] Thinness of stand has a tendency

TABLE 9.—FIELD STANDS AND AVERAGE PERCENTAGES OF LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND FROM SEED INFECTED WITH *Gibberella saubinettii*, 1924

Exp. No.	County in which located (Illinois)	Total field stand of all replications				Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
		Nearly disease-free seed		Gibberella-infected seed		Nearly disease-free seed	Gibberella-infected seed	
		No.	*perct.*	*No.*	*perct.*	*perct.*	*perct.*	*perct.*
94	McLean	2 028	87.9	1 693	73.5	39.8	41.1	+1.3
95	McLean	1 948	84.5	1 664	72.2	33.5	41.0	+ 7.5
96	McLean	1 826	86.7	847	40.2	29.8	43.1	+13.3
97	McLean	1 901	90.3	922	43.8	33.2	44.1	+10.9
98	Rock Island	1 424	73.3	429	33.1	7.0	7.2	+ 0.2
99	Christian	2 949	81.9	1 806	50.2	11.1	14.7	+ 3.6
Grand average		....	84.1	.....	52.2	25.7	31.9	+ 6.2 Odds=77:1

to make the plants stand more erect and thus offset the leaning tendency (Table 12). If the stands had been equal in all the experiments, the differences in percentage of leaning stalks would no doubt have been still larger.

The results shown here indicate clearly that corn root rot caused by *Gibberella saubinetii* produces an increase in the percentage of leaning stalks. It does not matter whether the organism is placed in contact with the surface of clean seed as was done in the inoculation experiments, the effect being comparable to soil infection, or whether the organism is seed-borne from infection that occurred while the ear was on the mother plant. Dickson[1] has shown that when corn is inoculated at planting time with a spore suspension of *Gibberella saubinetii,* and grown in virgin soil, considerable root rotting may take place in the seedling stage. It is not yet known whether this organism continues its activity as a root rot organism thruout the season or whether its work is confined to the young plants. Root lesions on older plants usually are not abundant and isolations from them have not given conclusive results. It is probable that the increase in leaning stalks is caused primarily by a deficiency in the number or extent of the roots, due to root rot in the seedling stage.

BROKEN STALKS IN CORN GROWN FROM INFECTED SEED

While some of the corn diseases caused considerable increases in the percentages of leaning plants, usually no corresponding increase in the percentage of broken stalks was found (Table 10). A significant increase in percentage of broken stalks occurred in only two cases, namely, when seed was infected with *Cephalosporium acremonium* and when starchy seed was susceptible to scutellum rot (Fig. 4). No significant increase in percentage of broken stalks resulted from the use of seed infected with *Fusarium moniliforme* or *Diplodia zeae*, horny

TABLE 10.—EFFECT OF SEED INFECTION AND SEED INOCULATION ON PERCENTAGE OF BROKEN STALKS: SUMMARY

Same plant populations as in Table No.	Strain	Condition of seed	Broken stalks	Difference in percentage of broken stalks	Odds of probability
			perct.	*perct.*	
2	K	Nearly disease-free	3.9		
2	K	Infected with *Fusarium moniliforme*	3.8	−0.1	1:1
3	K	Nearly disease-free	3.5		
3	K	Infected with *Diplodia zeae*	4.0	+0.5	20:1
4	K	Nearly disease-free	4.0		
4	K	Infected with *Cephalosporium acremonium*	4.6	+0.6	34:1
5	K	Nearly disease-free	5.7		
5	K	Affected with scutellum-rot	6.2	+0.5	5:1
6	Miscellaneous	Nearly disease-free	6.5		
6	Miscellaneous	Affected with scutellum-rot	6.2	−0.3	2:1
7	Miscellaneous	Nearly disease-free, horny	3.7		
7	Miscellaneous	Scutellum-rotted, starchy	4.5	+0.8	32:1
8	Miscellaneous	Control	4.2		
8	Miscellaneous	Inoculated with *Gibberella saubinetii*	4.2	0.0	

seed susceptible to scutellum rot, or seed inoculated with *Gibberella saubinetii*.

With one exception, none of the organisms concerned in these seed infections has been found to invade the stalk higher than the first node immediately above the mesocotyl, as long as the plant is green. Invasion at the nodes may be caused by *Fusarium moniliforme, Gibberella saubinetii, Diplodia zeae*, and other organisms, but this is due to secondary infection from spores that are washed down between the stalk and leaf sheath, and is not concerned with seed infection. No doubt these local infections are responsible for a considerable amount of broken stalks, but no specific data on these relationships have been obtained.

The black-bundle disease caused by *Cephalosporium acremonium* is systemic, and seed infection with this organism was found to increase the percentage of broken stalks. From infected seed this organism may invade the vascular bundles thruout the whole length of the stalk during the active growing period. Affected vascular strands become disorganized. One would expect this to reduce the breaking strength of the stalks. Furthermore, at times a more or less local decomposition of the pith may occur, caused perhaps by secondary organisms. This causes a very pronounced weakening of the stalk.

The cause of more broken stalks in corn populations grown from starchy seed affected with scutellum rot than in corn populations grown from nearly disease-free, horny seed has not been fixed very definitely. It is known, however, that such corn is also more susceptible to some other diseases, including smut. A smut boil on a stalk causes a local weakening at which point it is apt to break. The significance of the data on the increase in broken stalks may also be questioned, as in twenty experiments over a period of seven years the odds are only 32 to 1.

As the other organisms do not invade the stalk, no increase in the percentage of broken stalks would be expected except, perhaps, as the plants are affected by malnutrition. Malnutrition, however, seems to result not so much in decreasing the size or strength of the mature stalks as it does in reducing the yield.

Rosen[8] described a bacterial disease that attacks the stalks, as well as the roots, and causes many stalks to break over. However, as yet he has published no data on broken stalks obtained from inoculation studies or otherwise. Apparently this disease is seldom found in central Illinois, and the writers were not able to obtain any data on what its effects might be.

NONPARASITIC FACTORS INFLUENCING LODGING

Some of the nonparasitic factors influencing lodging are so well recognized that no data need be presented in that connection. Among these are seasonal and climatic variations. No direct comparisons can be made between the percentage of leaning plants in one year with those in another year, nor can direct comparisons be made between plots that are located at some distance from each other in the same year. For that reason it is necessary to have a well-organized system of checks within each experiment. Differences between the checks and the corn that is being tested can then be compared with differences obtained in other years or in different locations within the same year.

A number of nonparasitic factors other than seasonal and climatic variations which are not so well recognized by the average corn grower have also been found by the writers to have a profound influence on lodging. A discussion and some data on these factors are presented here.

Differences in Commercial Strains

Various strains of corn within the yellow dent group exhibit marked differences in the way they stand up. A number of strains have been tested in carefully controlled experimental plots. Nearly disease-free selections and also diseased selections of these strains were used.

In Experiment 20 (Table 6) two strains, G and P, were used. Grown from nearly disease-free seed, G leaned 44 percent more than P; from diseased seed G leaned 69 percent more than P. The same strains were also used in Experiment 22 (Table 6), located in another county and about fifty miles north of Experiment 20. The results were quite similar; from nearly disease-free seed, G leaned 60 percent more, and from diseased seed G leaned 176 percent more than P.

In Experiment 49 (Table 6) strains A, B, and C were used in a comparative test. Grown from nearly disease-free seed, the percentages of leaning plants were respectively: 26.1, 34.1, and 13.1; from diseased seed they were 24.9, 34.4, and 17.3. Thus strain C stood the most erect and strain B inclined the most. The same strains were also used in Experiment 51 (Table 8). The plots of this experiment were near those of Experiment 49 and the results were very similar; C stood the most erect and B leaned the most.

The data on rate of planting in Table 12 cover seventeen different commercial strains of yellow dent corn. When these are compared with each other it is seen that their behavior, in respect to percentage of broken and leaning stalks, varies greatly.

Fig. 8 illustrates the conditions of two strains of corn at harvest time. Both are well known strains of the corn belt that mature in about 100 days. Only nearly disease-free seed of both strains had been selected, they were planted at the same time, and were grown adjacent to each other on the same kind of soil. There was very little difference in the stand. Climatic conditions had been very conducive to lodging during the season (1924), but many strains, such as the one shown in Fig. 8A, stood up well, while some others, such as that shown in Fig. 8B, went down almost flat to the ground.

It is evident that when two strains of corn are grown in the same field, decided differences in the percentage of leaning plants may occur, owing to the nature of the plants. As corn is an open-fertilized plant, it is easily changed by selection; in fact, every corn grower who has systematically selected his own seed corn over a period of years has a distinct strain of his own. Frequently such strains show differences in respect to percentages of leaning or broken stalks.

Different strains may differ in their susceptibility to disease, and this alone might account for differences in lodging. However, differences in lodging also often result from factors within the strains entirely independent of the disease factor. This is clearly shown by the data in Table 6 in which nearly disease-free selections of various strains are compared with each other, and scutellum-rotted selections of the same strains also are compared with each other. Further on in this bulletin some of these genetical differences will be discussed.

Time of Planting

Different dates of planting, ranging from early to late, may have a marked influence on the percentage of leaning plants (Table 11). It is well known that late-planted corn usually does not yield so well as that planted at an intermediate or early date. This decrease is not attributed to increased susceptibility to disease but chiefly to seasonal

TABLE 11.—FIELD STANDS, ACRE YIELDS, AND AVERAGE PERCENTAGES OF BROKEN AND LEANING STALKS IN STRAIN K, YELLOW DENT CORN, GROWN FROM NEARLY DISEASE-FREE SEED AND FROM SEED SUSCEPTIBLE TO SCUTELLUM ROT PLANTED ON VARIOUS DATES AT URBANA: SUMMARY OF THREE YEARS' DATA

Year	Date of planting	Total field stand of 4 replications				Average acre yield		Average percentage of broken stalks		Average percentage of stalks leaning 30° or more	
		Nearly disease-free seed		Scutellum-rot susceptible seed		Nearly disease-free seed	Scutellum-rot susceptible seed	Nearly disease-free seed	Scutellum-rot susceptible seed	Nearly disease-free seed	Scutellum-rot susceptible seed
		No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*	*perct.*
1920	May 19	2 231	93.0	2 044	85.2	79.7	73.4	4.1	6.9	0.2	0.2
	May 26	2 150	89.6	1 926	80.3	79.3	65.8	5.0	9.6	2.4	3.3
	June 2	2 136	89.1	1 844	76.8	77.8	61.9	6.3	12.3	4.8	8.5
1921	May 2	1 836	95.6	1 694	88.2	100.7	90.9	1.0	3.3	4.6	5.2
	May 10	1 854	96.5	1 658	86.3	99.8	86.3	0.3	1.3	11.0	10.1
	May 20	1 794	93.4	1 654	86.1	90.5	77.0	0.2	0.5	21.2	25.2
	May 31	1 784	92.9	1 695	88.3	89.9	79.0	0.2	0.2	22.2	23.3
1922	May 4	435	90.6	405	84.4	59.2	57.5	([a])	([a])	29.5	29.4
	May 13	464	96.6	443	92.3	58.3	54.6	([a])	([a])	47.8	38.4
	May 22	434	90.4	409	85.2	56.1	44.7	([a])	([a])	26.2	26.7
	May 31	341	85.2	278	69.5	53.0	41.0	([a])	([a])	8.0	8.5
1923	May 2	5 056	87.8	1 096	85.6	60.1	57.4	7.0	5.3	13.9	13.0
	May 14	5 101	88.6	1 036	80.9	60.7	53.9	4.4	5.2	17.4	20.6
	May 21	5 326	92.4	1 245	97.3	58.7	56.0	3.4	2.3	24.3	25.4
	May 31	4 977	86.5	1 099	85.3	50.6	49.2	3.5	3.7	34.1	35.0

[a]No data obtained.

conditions, such as a shorter maturing period and insufficient depth of the root system when the summer drouths occur. Data given by Dickson[1] and Holbert et al[4] show that root rot by *Gibberella saubinetii* is most severe when corn is planted early. The scutellum-rot disease is severe in both early and late planted corn.

FIG. 8.—SOME VARIETIES OF CORN LODGE MORE THAN OTHERS

These illustrations (A and B) show two varieties of corn in November, 1924, both grown from nearly disease-free seed which was planted on the same day and on the same kind of soil. Both varieties are of the 100-day class, and are used extensively within the corn belt.

It is quite evident that the great increase in percentage of leaning plants in late corn as compared with early corn in 1920, 1921, and 1923 (Table 11) was not due to disease but to other factors. In 1922, this condition was reversed, the smallest percentage of leaning plants occurring in the last planting. In 1920, the percentage of broken stalks increased with the later dates of planting, but this condition was reversed in 1921 and 1923. Evidently it is not possible to predict with any certainty whether late-planted corn will lodge more or less than early-planted corn, but a difference may be expected. Just what factors are operative in producing these differences is not definitely known, but no doubt the stage of development of the corn when heavy rains or drouths occur is largely responsible.

Two adjoining fields of commercial corn are seldom planted at the same time. Often a ten-day interval may elapse. When this is the case, considerable differences in the percentages of leaning plants may result even tho the same strain of seed was used and all of it tested nearly disease-free. Too often in trying out new seed a farmer does not plant it at the same time as the corn with which he will make the comparison and later draws erroneous conclusions when he finds that one strain stands up much better than the other.

RATE OF PLANTING

Many people have observed that the rate of planting may materially influence the amount of lodging in small grains; the more seed used to the acre, the more lodging is likely to occur. The present writers have made some similar observations in respect to corn, from an experiment conducted by J. W. Whisenand, farm adviser, and certain other members of the Henry County Farm Bureau (Table 12). Tests for rate of planting were conducted with seventeen miscellaneous strains. The corn was planted at the rate of two and three kernels to a

TABLE 12.—PERCENTAGES OF BROKEN AND LEANING STALKS IN MISCELLANEOUS STRAINS OF CORN, EACH HAVING BEEN PLANTED AT THE RATE OF TWO AND THREE KERNELS PER HILL IN PARALLEL SERIES. CAMBRIDGE, 1923

Strain No.	Field stand				Broken stalks		Difference in percentage of broken stalks	Stalks leaning 30° or more		Difference in percentage of leaning stalks
	2 kernels per hill		3 kernels per hill		2 kernels	3 kernels		2 kernels	3 kernels	
	No.	*perct.*	*No.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
1....	76	95.0	112	93.3	2.6	6.2	+3.6	13.2	17.0	+3.8
2....	73	91.2	105	87.5	13.7	12.4	−1.3	13.7	14.3	+0.6
3....	73	91.2	102	85.1	8.2	13.7	+5.5	15.1	24.5	+9.4
4....	77	96.2	114	95.0	14.3	7.0	−7.3	18.2	15.8	−2.4
5....	74	92.4	104	86.7	10.8	22.1	+11.3	2.7	17.3	+14.6
6....	52	65.0	92	76.7	19.2	12.0	−7.2	10.8	19.6	+8.8
7....	75	93.7	105	87.5	5.3	17.1	+11.8	8.0	7.6	−0.4
8....	79	98.8	115	95.8	6.3	12.2	+5.9	7.6	23.5	+15.9
9....	78	97.5	108	90.1	16.7	9.3	−7.4	12.8	16.7	+3.9
10....	77	96.2	114	95.0	7.8	14.9	+7.1	2.7	10.5	+7.8
11....	78	97.5	112	93.3	5.1	9.8	+4.7	14.1	14.3	+0.2
12....	78	97.5	113	94.2	9.0	10.6	+1.6	9.0	17.7	+8.7
13....	75	93.7	111	92.5	6.7	9.0	+2.3	14.7	44.1	+29.4
14....	79	98.8	115	95.8	8.9	11.3	+2.4	15.2	20.9	+5.7
15....	78	97.5	114	95.0	15.4	17.6	+2.2	19.2	27.2	+8.0
16....	77	96.2	101	84.2	6.5	6.9	+0.4	19.5	32.7	+13.2
17....	80	100.0	119	99.2	11.3	3.4	−7.9	17.5	29.4	+11.9
Average		94.0		91.0	9.9	11.5	+1.6 Odds = 5:1	12.6	20.8	+8.2 Odds = 4999:1

hill, in alternate groups of four rows each. Records were taken on only the two central rows of each group. Thus each hill on which data were secured was completely surrounded by hills planted at the same rate.

The difference in rate of planting between two and three kernels to a hill had practically no effect on the percentage of broken stalks, the odds of the difference being only 5 to 1. But the percentage of leaning stalks was considerably influenced, being raised from 12.6 percent to 20.8 percent, a difference of 8.2 with odds of 4999 to 1.

These data are especially significant in connection with data on increases in percentages of leaning stalks due to diseased conditions, when certain kinds of infected seed were used. These diseases, especially the Diplodia seedling rot, cause a reduction in stand. The reduction in stand alone would tend to reduce the percentage of leaning plants. So when, instead of this decrease, a decided increase in percentage of leaning plants is found, the increase is of even greater importance than the figures would seem to indicate.

PREVIOUS CROPPING

The nature of the previous cropping may have a profound influence on the way the corn stands up. A comparison of corn plots grown in 1921 on virgin blue-grass sod with similar plots planted at the same time in a rotation which was 75 percent corn is given in Table 13. The latter plots had received an application of bone meal and the yields were nearly equal to those on virgin sod. Not much difference occurred in the percentage of broken stalks, but the percentage of leaning plants was much higher on the plots on old soil. The fifteen checks averaged 22.3 percent leaning plants on the virgin soil plots and 32.5 percent on the old soil plots. This is a difference of 10.2 with odds of 327 to 1, or an increase of 46 percent. The average of the fourteen alternate miscellaneous strains gives nearly the same result.

Table 14 gives a comparison of two series of plots in 1920, one following two years of clover, the other having previously been cropped with badly scabbed spring wheat in 1919 and corn in 1918. Ten seed composites were used and, with only one exception, each produced a smaller average percentage of leaning plants on the plots following clover. When all ten strains were averaged together a significant difference with odds of 150 to 1 was found, owing to differences in previous cropping.

At Urbana, nearly disease-free seed and seed susceptible to scutellum-rot were planted in comparative plots in two rotation systems for three years. In one system (North-Central) the rotation is corn, corn, small grains, and clover; and in the other (South-Central) it is corn, corn, corn, and soybeans. Data on the leaning proclivities of the former are given in Table 15 and Fig. 9. On the three-year average, corn after clover had 5.5 percent leaning plants, while second-year corn

TABLE 13.—BROKEN AND LEANING STALKS IN CORN GROWN FROM NEARLY DISEASE-FREE STRAIN K, YELLOW DENT SEED (CHECK), AND FROM YELLOW DENT SEED COMPOSITES OBTAINED FROM VARIOUS SOURCES IN ILLINOIS

All seed planted at the same time in adjacent duplicate plots. One plot was virgin prairie sod; the other a field that had previously been in a four-year crop rotation which included three years of corn and had been fertilized so that the yields on the two were nearly alike. Bloomington, 1921

Seed composite No.	Total field stand of 9 replications where the previous crops were: Virgin sod		Previously cropped to corn		Average acre yield: Virgin sod	Previously cropped to corn	Average percentage of broken stalks: Virgin sod	Previously cropped to corn	Difference in percentage of broken stalks	Average percentage of stalks leaning 30° or more where the previous crops were: Virgin sod	Previously cropped to corn	Difference in percentage of leaning stalks
	No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Check	1 037	96.0	1 050	97.2	83.9	85.3	2.7	3.4	+0.7	22.0	59.9	+37.9
1	943	87.3	1 006	93.1	81.5	77.3	3.9	4.6	+0.7	16.4	51.9	+35.5
Check	1 000	92.6	1 040	96.2	91.9	85.1	3.0	2.5	−0.5	17.7	49.4	+31.7
2	934	86.4	966	89.4	74.7	73.8	3.7	5.7	+2.0	19.8	39.5	+19.7
Check	1 015	94.0	1 049	97.1	90.8	86.7	4.0	3.7	−0.3	19.7	46.2	+26.5
3	1 005	93.0	1 003	92.9	83.9	78.1	3.6	5.2	+1.6	20.0	40.8	+20.8
Check	1 021	94.5	1 039	96.2	89.1	84.3	4.3	4.1	−0.2	24.4	40.8	+16.4
4	1 003	92.8	1 027	95.1	85.3	76.5	4.2	3.5	−0.7	30.4	43.9	+13.5
Check	1 019	94.4	1 056	97.7	90.3	82.8	3.5	3.2	−0.3	27.8	35.0	+7.2
5	1 021	94.4	1 015	94.0	81.0	75.3	6.1	4.7	−1.4	37.8	43.6	+5.8
Check	1 040	96.3	1 050	97.2	92.0	87.9	2.7	3.1	+0.4	33.4	36.1	+2.7
6	1 006	93.0	966	89.4	72.0	72.2	6.2	4.6	−1.6	39.0	41.2	+2.2
Check	1 021	94.5	1 038	96.1	84.6	87.4	2.2	2.5	+0.3	31.6	36.8	+5.2
7	1 022	94.5	1 015	94.0	80.0	77.0	5.8	3.8	−2.0	29.8	40.8	+11.0
Check	1 033	95.7	1 046	96.8	89.8	81.4	2.7	2.9	+0.2	26.7	32.4	+5.7
8	1 022	94.5	1 050	97.2	78.6	82.2	3.6	4.2	+0.6	33.5	44.2	+10.7

TABLE 13—*Concluded*

Seed composite No.	Total field stand of 9 replications where the previous crops were: Virgin sod		Previously cropped to corn		Average acre yield: Virgin sod	Previously cropped to corn	Average percentage of broken stalks: Virgin sod	Previously cropped to corn	Difference in percentage of broken stalks	Average percentage of stalks leaning 30° or more where the previous crops were: Virgin sod	Previously cropped to corn	Difference in percentage of leaning stalks
	No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Check	1 027	95.1	1 055	97.6	94.1	84.6	1.5	1.8	+0.3	21.5	25.0	+3.5
9	979	90.5	995	92.0	78.3	81.0	2.4	2.6	+0.2	18.7	17.2	−1.5
Check	1 036	95.9	1 041	96.4	93.7	85.5	1.6	2.3	+0.7	18.1	24.8	+6.7
10	928	85.8	933	86.4	74.3	70.8	3.5	3.3	−0.2	15.9	16.7	+0.8
Check	1 016	94.1	1 039	96.1	80.2	86.5	3.2	2.9	−0.3	23.6	25.1	+1.5
11	984	91.0	1 007	93.3	79.3	77.7	3.1	2.5	−0.6	17.8	22.6	+4.8
Check	1 027	95.1	1 048	97.1	86.9	84.0	2.7	3.1	+0.4	20.9	25.2	+4.3
12	986	91.2	1 032	95.6	76.0	79.0	1.5	1.7	+0.2	16.5	17.3	+0.8
Check	1 008	93.3	1 051	97.3	87.2	88.1	2.7	3.1	+0.4	13.9	16.4	+2.5
13	906	83.8	935	86.5	75.3	74.6	2.7	2.4	−0.3	18.5	20.7	+2.2
Check	1 016	94.1	1 048	97.1	86.3	88.7	1.5	3.4	+1.9	12.0	15.7	+3.7
14	983	90.9	981	90.8	79.7	75.4	2.9	2.6	−0.3	13.4	19.9	+6.5
Check	1 043	96.3	1 042	96.4	74.5	88.1	2.3	3.0	+0.7	21.2	19.1	−2.1
Average of all checks					87.8	85.8	2.7	3.0	+0.3 Odds = 24:1	22.3	32.5	+10.2 Odds = 327:1
Average of various composites					78.6	76.5	3.8	3.7	−0.1 Odds = 1:1	23.4	32.9	+9.5 Odds = 480:1

after clover had 11.6 percent, a difference of 6.1 with odds of 160 to 1, or an increase of 110 percent.

Similar data on the plants grown in the corn-soybean rotation are given in Table 16 and Fig. 10. With the exception of the second series

TABLE 14.—LEANING CORN PLANTS GROWN FROM SEED COMPOSITES OF YELLOW DENT OBTAINED FROM VARIOUS SOURCES IN ILLINOIS

All seed planted at the same time in adjacent duplicate plots. One plot was on land that had been in clover during the two previous years, the other on land that had been cropped with badly scabbed wheat in 1919 and corn in 1918. Bloomington, 1920

Seed composite No.	Field stand where the previous crops were: Clover 1919 Clover 1918		Spring wheat 1919 Corn 1918		Percentage of stalks leaning 30° or more where the previous crops were: Clover 1919 Clover 1918	Spring wheat 1919 Corn 1918	Difference in percentage of leaning stalks
	No.	*perct.*	*No.*	*perct.*	*perct.*	*perct.*	
1......	902	85.4	951	90.0	17.1	35.7	+18.6
2......	852	80.7	938	88.8	9.6	29.1	+19.5
3......	908	86.1	926	87.7	4.7	11.2	+6.5
4......	860	81.5	866	82.0	7.0	15.1	+8.1
5......	897	85.0	857	81.1	2.6	7.0	+4.4
6......	853	80.8	860	81.5	8.8	10.5	+1.7
7......	733	69.5	779	73.7	7.8	8.3	+0.5
8......	840	79.6	849	80.4	4.2	3.8	−0.4
9......	795	75.3	825	78.1	5.9	10.4	+4.5
10......	820	77.7	766	72.5	10.8	15.4	+4.6
Average	846	80.1	861	81.6	7.9	14.7	+6.8 Odds = 150:1

in 1921, the data are very consistent. Corn after soybeans stood most erect, second-year corn after soybeans had a higher percentage of leaning plants, and third-year corn after soybeans had a much higher per-

TABLE 15.—PERCENTAGES OF LEANING PLANTS IN STRAIN K, YELLOW DENT CORN, WHEN GROWN THE FIRST YEAR AFTER CLOVER, AND THE SECOND YEAR AFTER CLOVER: SUMMARY OF THREE YEARS' DATA

Rotation of clover, corn, corn, and spring grains, at Urbana

Year	Condition of seed	Percentage of stalks leaning 30° or more: Previous crop was clover (A)	Second-year corn after clover (B)	Increase of B over A
		perct.	*perct.*	
1920	Nearly disease-free....................	3.7	9.8	+6.1
	Affected with scutellum rot.............	4.2	10.6	+6.4
	Nearly disease-free....................	4.2	4.7	+0.5
	Affected with scutellum rot.............	6.0	6.6	+0.6
1921	Nearly disease-free....................	7.7	26.7	+19.0
	Affected with scutellum rot.............	8.5	18.8	+10.3
	Nearly disease-free....................	6.3	20.3	+14.0
	Affected with scutellum rot.............	7.6	22.5	+14.9
1922	Nearly disease-free....................	5.7	9.0	+3.3
	Affected with scutellum rot.............	2.7	2.0	−0.7
	Nearly disease-free....................	4.3	7.4	+3.1
	Affected with scutellum rot.............	5.2	1.0	−4.2
Average for all plots		5.5	11.6	+6.1 Odds = 160:1

centage of leaning plants. The average of the three years' data is 9.5, 15.6, and 24.6 percent leaning plants, respectively, for first-, second-, and third-year corn after soybeans. The odds of the differences are

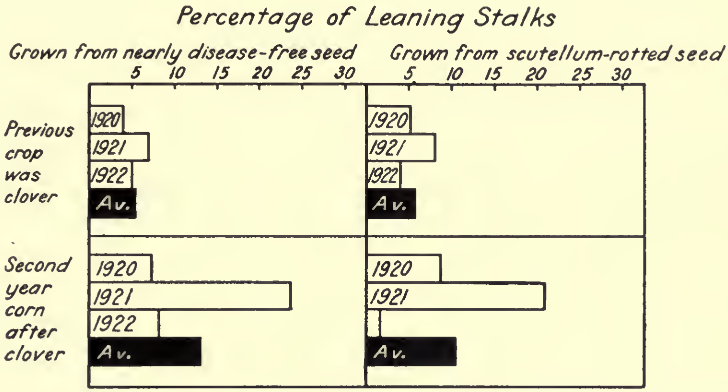

FIG. 9.—PERCENTAGES OF LEANING STALKS WHEN CORN FOLLOWED A PREVIOUS CROP OF CORN

large enough to remove any doubt as to whether the differences may be due to chance.

The percentages of broken stalks on the corn-soybean rotation varied only slightly in reference to previous cropping. The differences were not great enough in any case to mean anything in terms of odds of probability.

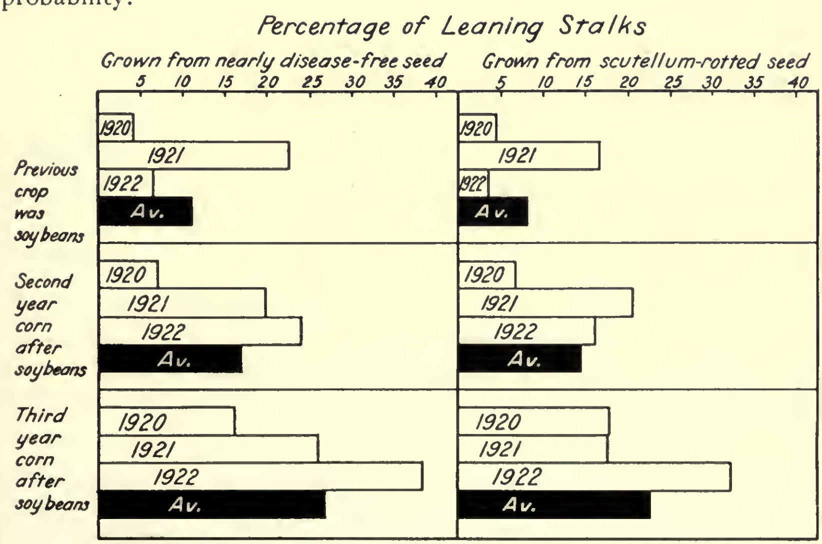

FIG. 10.—PERCENTAGE OF LEANING STALKS WHEN CORN FOLLOWED SOYBEANS, WHEN CORN FOLLOWED A PREVIOUS CORN CROP, AND WHEN CORN FOLLOWED TWO SUCCESSIVE CORN CROPS

Increases in leaning plants on land that has previously been cropped with corn or scabby wheat may be due in part to root rot by *Gibberella saubinetii,* but this fact hardly gives a complete explanation. This organism causes wheat scab and corn root rot. Koehler, Dickson and Holbert[6] have shown that the yield of disease-susceptible corn was greatly reduced when this corn was grown after scabbed wheat. Disease-resistant corn was not affected in the same way. The nature of the previous cropping, however, affects the leaning of corn grown from nearly disease-free (disease-resistant) seed as well as that grown from diseased seed.

TABLE 16.—PERCENTAGES OF LEANING PLANTS OF STRAIN K, YELLOW DENT CORN, WHEN GROWN THE FIRST, SECOND, AND THIRD YEARS AFTER SOYBEANS: SUMMARY OF THREE YEARS' DATA

Rotation of soybeans and three years' corn, at Urbana

Year	Condition of seed	Percentage of stalks leaning 30° or more			Increase of B over A	Increase of C over A
		Previous crop was soybeans (A)	Second year corn after soybeans (B)	Third year corn after soybeans (C)		
		perct.	*perct.*	*perct.*	*perct.*	*perct.*
1920	Nearly disease-free	4.4	9.1	15.9	+4.7	+11.5
	Affected with scutellum rot	4.6	8.2	18.5	+3.6	+13.9
	Nearly disease-free	3.9	4.7	16.1	+0.8	+12.2
	Affected with scutellum rot	4.2	5.2	17.3	+1.0	+13.1
1921	Nearly disease-free	9.5	17.6	35.3	+8.1	+25.8
	Affected with scutellum rot	9.5	22.5	20.6	+13.0	+11.1
	Nearly disease-free	35.5	22.0	16.5	−13.5	−19.0
	Affected with scutellum rot	23.5	18.6	14.6	−4.9	−8.9
1922	Nearly disease-free	3.7	21.7	40.6	+18.0	+36.9
	Affected with scutellum rot	2.1	15.6	37.5	+13.5	+35.4
	Nearly disease-free	8.9	26.0	35.7	+17.1	+26.8
	Affected with scutellum rot	4.6	16.8	27.0	+12.2	+22.4
Average for all plots		9.5	15.6	24.6	+6.1 Odds = 40:1	+15.1 Odds = 207:1

The disease-free seed corn selections used in these experiments have shown considerable disease resistance when inoculated with pure cultures of *Gibberella saubinetii.* Nevertheless, plants grown from this seed behaved very differently in respect to percentages of leaning plants when grown in different crop sequences. For that reason it is not believed that the disease factor is the only one operative in this connection.

SOIL TREATMENTS

The application of agricultural limestone to the soil at the rate of 4 tons or more per acre resulted in a marked decrease in the percentage of leaning plants. Unburnt, finely ground limestone was applied at the rate of 4 tons per acre in all the experiments except numbers 30 to 36 inclusive (Table 17). In these the applications were made at the rate of 2, 4, 8, 12, and 16 tons per acre. The 2-ton application did not produce much effect and the data from that plot are not included in the summaries given in Table 17. The applications of 4, 8, 12, and 16 tons per acre produced similar results and the data from these experiments were averaged together.

In Champaign county the experiments were conducted on long established lime plots of the Experiment Station. Experiment 47 in McLean county was conducted on plots that had been established the previous year. All the others are first-year results, the lime having been applied in the spring previous to planting the corn.

A summary of the effect of lime on the stand, yield, broken stalks, and leaning plants of corn grown from nearly disease-free and from diseased seed is given in Table 17. The stand was not affected to any appreciable extent, nor was the yield increased to a marked extent by lime. In Experiment 20, conducted in Macon county in 1920, there was a decided increase in yield due to lime. Unfortunately, the soil plots in that experiment were laid out with only one no-treatment check plot and hence there may be some question in regard to soil uniformity. Practically all the other experiments were laid out so that a number of lime plots and no-treatment plots were alternated.

On the whole, yields from nearly disease-free seed were but slightly affected by lime. The average increase in yield from nearly disease-free seed was only 3.1 bushels per acre with odds of 11 to 1, which is hardly significant. Yields from diseased seed were increased 3.6 bushels per acre with odds of 127 to 1. This is a small but numerically significant increase.

The percentage of broken stalks was not influenced by the application of lime.

The striking effect of lime was the decrease in percentage of leaning stalks. In practically every experiment the plants stood more erect on the lime plots. In the grand average of all experiments the percentage of leaning stalks from nearly disease-free seed was 16.8 on the no-treatment plots and 12.6 on the limed plots, a difference of 4.2 with odds of 876 to 1, or a reduction of 25 percent (Fig. 11). When diseased seed was used the percentage of leaning plants was reduced even more, the difference in percentage of leaning plants being 6.5 with odds of 9999 to 1, or a decrease of 29.8 percent (Fig. 12).

Data on leaning and broken stalks also have been obtained on soil plots treated with rock phosphate, acid phosphate, bone meal (Fig. 13) sodium nitrate, and potassium sulfate, but no consistent differences in percentage of leaning plants or broken stalks were found. Under certain conditions rock phosphate evidently was an important factor in reducing the percentage of leaning plants, but under other conditions no such effect was observed. On the other hand, the data from

TABLE 17.—EFFECT OF LIMING SOIL ON PERCENTAGE OF BROKEN AND LEANING STALKS IN SEVERAL STRAINS OF YELLOW DENT CORN GROWN FROM NEARLY DISEASE-FREE SEED AND FROM DISEASED SEED: SUMMARY OF FOUR YEARS' DATA

Year	Exp. No.	County in which located (Illinois)	Strain	Condition of seed	Total field stand of all replications				Average acre yield		Difference in acre yield	Average percentage of broken stalks		Difference in percentage of broken stalks	Average percentage of stalks leaning 30° or more		Difference in percentage of leaning stalks
					No lime		Limed		No lime	Limed		No lime	Limed		No lime	Limed	
					No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
1919	13	Champaign	HY	Nearly disease-free	405	92.0	408	92.8	75.4	83.6	+8.2	2.1	2.4	+0.3	43.6	27.0	−16.6
				Affected with scutellum rot	387	87.9	395	89.8	57.2	73.6	+16.4	2.9	2.3	−0.6	53.9	30.4	−23.5
1920	17	Knox	M	Nearly disease-free	315	82.0	317	82.5	72.2	63.1	−9.1	5.1	5.9	+0.8	28.7	23.6	−5.1
				Affected with scutellum rot	274	71.4	272	70.8	62.8	63.6	+0.8	5.1	4.1	−1.0	28.7	28.1	−0.6
	20	Macon	G	Nearly disease-free	397	88.2	403	89.5	43.4	64.3	+20.9	21.7	18.3	−3.4	37.8	31.0	−6.8
				Affected with scutellum rot	379	84.2	385	85.6	41.8	60.5	+18.7	21.1	20.0	−1.1	36.6	32.0	−4.6
	20	Macon	P	Nearly disease-free	417	92.7	424	94.2	62.1	82.7	+20.6	14.5	18.0	+3.5	23.6	24.1	+0.5
				Affected with scutellum rot	387	86.0	391	86.9	55.8	67.6	+11.8	14.0	15.1	+1.1	26.8	13.7	−13.1
	20	Macon	K	Nearly disease-free	327	90.9	335	93.0	59.0	68.4	+9.4	15.0	15.0	0.0	28.9	21.3	−7.6
				Affected with scutellum rot	326	90.5	333	92.5	50.9	66.4	+15.5	21.8	14.9	−6.9	27.1	18.9	−8.2
	22	McLean	G	Nearly disease-free	488	84.7	496	86.1	66.3	61.5	−4.8	1.3	1.9	+0.6	12.9	9.1	−3.8
				Affected with scutellum rot	407	70.7	434	75.3	42.9	46.5	+3.6	2.4	2.5	+0.1	25.9	13.8	−12.1
	22	McLean	P	Nearly disease-free	519	90.1	482	83.7	64.3	59.7	−4.6	1.6	1.5	−0.1	5.3	6.1	+0.8
				Affected with scutellum rot	431	74.8	428	74.3	51.7	51.0	−0.7	1.2	2.3	+1.1	6.1	6.2	+0.1
	24	Knox	K	Nearly disease-free	454	94.6	423	88.1	[a]	[a]	....	5.5	5.3	−0.2	2.7	2.4	−0.3
				Affected with scutellum rot	405	84.4	443	92.3	[a]	[a]	....	6.4	5.2	−1.2	5.7	2.9	−2.8
	30	McLean	K	Nearly disease-free	405	90.0	422	93.7	62.9	61.7	−1.2	0.6	0.6	0.0	4.6	3.8	−0.8
				Affected with scutellum rot	372	82.7	376	83.5	55.0	52.7	−2.3	2.1	1.5	−0.6	8.8	6.8	−2.0
	33	McLean	K	Nearly disease-free	884	92.2	888	92.6	88.7	87.9	−0.8	0.6	0.3	−0.3	8.7	0.6	−8.1
				Affected with scutellum rot	821	85.6	852	88.8	76.5	82.8	+6.3	1.9	2.1	+0.2	13.3	1.9	−11.4
	35	McLean	K	Nearly disease-free, horny	390	86.7	404	89.8	75.0	69.1	−5.9	0.0	0.2	+0.2	4.1	1.3	−2.8
				Scutellum rotted, starchy	387	85.0	364	80.9	69.0	67.0	−2.0	0.0	1.0	+1.0	8.0	4.9	−3.1
	36	McLean	K	Nearly disease-free, horny	597	88.9	604	89.9	83.8	87.9	+4.1	0.6	0.3	−0.3	8.7	1.4	−7.3
				Scutellum rotted, starchy	590	87.8	588	87.5	80.8	85.8	+5.0	2.3	1.0	−1.3	26.1	9.5	−16.6

[a]No yield data obtained.

TABLE 17—*Concluded*

Year	Exp. No.	County in which located (Illinois)	Strain	Condition of seed	Total field stand of all replications: No lime		Total field stand of all replications: Limed		Average acre yield: No lime	Average acre yield: Limed	Difference in acre yield	Average percentage of broken stalks: No lime	Average percentage of broken stalks: Limed	Difference in percentage of broken stalks	Average percentage of stalks leaning 30° or more: No lime	Average percentage of stalks leaning 30° or more: Limed	Difference in percentage of leaning stalks
					No.	*perct.*	*No.*	*perct.*	*bu.*	*bu.*	*bu.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
1921	47	McLean...	K	Nearly disease-free..............	1 166	93.4	1 174	94.0	75.4	75.6	+0.2	3.0	3.0	0.0	38.4	27.6	−10.8
				Affected with scutellum rot.......	541	86.7	549	88.0	64.0	66.6	+2.6	3.5	3.9	+0.4	31.7	23.0	−8.7
				Infected with *Diplodia zeae*.......	329	52.7	340	54.5	44.7	47.0	+2.3	3.1	2.7	−0.4	50.4	33.8	−16.6
				Infected with *F. moniliforme*......	571	91.5	554	88.8	69.4	66.2	−3.2	3.8	4.4	+0.6	30.9	28.2	−2.7
	56	Champaign	K	Nearly disease-free..............	3 688	96.0	3 607	93.9	94.6	95.7	+1.1	0.5	0.3	−0.2	17.9	11.5	−6.4
				Affected with scutellum rot.......	3 378	87.9	3 349	87.2	82.9	83.5	+0.6	1.5	1.2	−0.3	19.4	12.5	−6.9
1922	75	Champaign	K	Nearly disease-free..............	2 489	86.5	2 562	89.1	54.1	61.6	+7.5	4.8	4.6	−0.2	25.7	28.6	+2.9
				Affected with scutellum rot.......	768	80.1	767	80.0	47.9	53.5	+5.6	6.4	5.1	−1.3	26.5	19.7	−6.8
				Infected with *Diplodia zeae*.......	499	52.0	435	45.3	35.8	36.7	+0.9	4.7	7.0	+2.3	26.8	19.8	−7.0
				Infected with *F. moniliforme*......	847	88.3	854	89.0	49.1	54.5	+5.4	4.5	5.6	+1.1	31.6	30.9	−0.7
	76	Knox.....	C	Nearly disease-free, horny.........	753	91.3	785	95.1	75.1	81.7	+6.6	11.4	12.8	+1.4	0.7	0.0	−0.7
				Scutellum rotted, starchy..........	620	75.1	625	75.7	65.1	66.0	+0.9	17.1	16.0	−1.1	2.7	1.0	−1.7
	76	Knox.....	K	Nearly disease-free, horny........	1 174	96.6	1 168	96.2	77.8	78.2	+0.4	19.3	15.8	−3.5	2.0	1.0	−1.0
				Disease-susceptible, starchy.......	1 130	93.0	1 110	91.4	72.7	70.6	−2.1	15.8	20.3	+4.5	1.4	0.5	−0.9
				Nearly disease-free..............	1 537	91.5	1 549	92.1	74.3	74.7	+0.4	9.7	7.7	−2.0	8.4	7.6	−0.8
				Affected with scutellum rot........	360	85.7	362	86.1	68.0	68.9	+0.9	10.0	5.2	−4.8	10.2	9.4	−0.8
				Infected with *Diplodia zeae*.......	284	67.6	276	65.7	59.5	53.4	−6.1	6.3	9.3	+3.0	12.8	9.3	−3.5
				Infected with *F. moniliforme*......	375	89.3	386	91.9	68.9	71.1	+2.2	8.2	4.0	−4.2	12.6	10.0	−2.6
Grand average...............				Nearly disease-free..............		90.5		90.9	70.8	73.9	+3.1 Odds = 11:1	6.5	6.3	−0.2 Odds = 2:1	16.8	12.6	−4.2 Odds = 876:1
Grand average................				Disease.........................		80.8		81.3	59.7	63.3	+3.6 Odds = 127:1	6.9	6.5	−0.4 Odds = 3:1	21.8	15.3	−6.5 Odds = 9999:1

FIG. 11.—EFFECT OF LIMESTONE ON CORN GROWN FROM NEARLY DISEASE-FREE SEED

A—One of the series of plots of yellow dent corn grown from nearly disease-free seed, on Brown Silt Loam in Knox county. The soil tested slightly acid. In this series 5.7 percent of the plants leaned 30 degrees.

B—One of the series of plots of the same kind of corn grown alternately with those described above, but on soil which had received an application of crushed limestone at the rate of 4 tons per acre. In these plots only 2.9 percent of the plants leaned 30 degrees or more.

FIG. 12.—EFFECT OF LIMESTONE ON CORN GROWN FROM STARCHY SEED SUSCEPTIBLE TO SCUTELLUM ROT

A—A plot of yellow dent corn grown from starchy seed susceptible to scutellum rot, on Brown Silt Loam in McLean county. This soil gave no acid reaction. Plants from this type of seed are likely to lodge; in this plot 18.2 percent of the plants leaned 30 degrees or more.

B—A plot of yellow dent corn of the same strain and character as that above and grown adjacent to the same, but the soil had received 8 tons of crushed limestone per acre. In this plot 6.3 percent of the plants leaned 30 degrees or more.

FIG. 13.—EFFECT OF BONE MEAL ON CORN GROWN FROM SEED SUSCEPTIBLE TO SCUTELLUM ROT

A—One of a series of plots of yellow dent corn grown from seed susceptible to scutellum rot that was comparatively horny in composition. The soil was a Brown Silt Loam that tested slightly acid. On these plots 28.7 percent of the plants leaned 30 degrees or more.

B—One of a series of plots of the same kind of corn grown alternately with those described above, but on soil which had received an application of steamed bone meal at the rate of 350 pounds per acre. In these plots only 12.9 percent of the plants leaned 30 degrees or more.

lime applications were quite consistent for all conditions under which these investigations were conducted.

It is evident from the foregoing that the presence or absence of certain soil treatments may be just as important factors in causing variations in the percentage of leaning plants as any of the corn rot diseases. It is not known why lime causes a more erect stand. It apparently does not control corn root rot. On the no-treatment plots the yields from nearly disease-free seed averaged 70.8 bushels while the yields from diseased seed averaged 59.7 bushels, a reduction of 11.1 bushels. On the limed plots the yields from nearly disease-free seed averaged 73.9 bushels while the yields from diseased seed averaged 63.3 bushels, a reduction of 10.6 bushels. The reductions in yield from diseased seed, therefore, were practically as great on the limed plots, and little disease control by lime was evident.

YIELD

On first thought one might expect barren plants to stand more erect than those that bear heavy ears. Small grains lodge to a much greater extent when the heads are heavy. Similarly the limbs of fruit trees bend down and are likely to break when heavily loaded with fruit. This analogy, however, usually will not hold for corn. In a number of experiments (Table 18) the plants were classified according to whether they bore ears or nubbins or were barren, and the percentage of leaning plants was calculated for each separately. In only one experiment out of five did the barren plants stand most erect, and that experiment embodied the smallest populations within the group. When the

TABLE 18.—LEANING CORNSTALKS CLASSIFIED ACCORDING TO WHETHER THEY BORE EARS OR NUBBINS OR WERE BARREN

Ears = 6 ounces or over; nubbins = less than 6 ounces

Year	Experiment No.	Variety	Classification of stalks according to yield	Number of stalks	Percentage of stalks leaning 30° or more
				No.	*perct.*
1917	1	Yellow dent	Ear-bearing	17 902	3.3
			Nubbin-bearing	1 185	2.5
			Barren	2 213	2.9
1918	5	Bloody Butcher	Ear-bearing	4 325	3.2
			Nubbin-bearing	847	4.6
			Barren	96	14.6
1918	6	Yellow dent	Ear-bearing	11 766	15.2
			Nubbin-bearing	3 944	17.0
			Barren	471	62.8
1918	7	Yellow dent	Ear-bearing	2 025	9.3
			Nubbin-bearing	1 303	6.4
			Barren	510	13.1
1921	58	Yellow dent	Ear-bearing	800	32.8
			Nubbin-bearing	209	33.2
			Barren	86	26.7
Average			Ear-bearing	......	12.8
			Nubbin-bearing	......	12.7
			Barren	......	24.0

TABLE 19.—PERCENTAGE OF LEANING PLANTS, AVERAGE PULLING RESISTANCE PER PLANT, AND ACRE YIELD OF THE "A" AND "B" SELF-FERTILIZED STRAINS GROWN IN 1923

Similar data on the ancestors of these plants, dating back to the second year of their inbred history. Discontinued lines of these families are not shown.

1919				1920				1921			1922				1923				
Pure-line No.	No. of plants	Stalks leaning 30° or more	Acre yield	Pure-line No.	No. of plants	Stalks leaning 30° or more	Acre yield	Pure-line No.	No. of plants	Stalks leaning 30° or more	Pure-line No.	No. of plants	Stalks leaning 30° or more	Average pulling resistance per plant	Pure-line No.	No. of plants	Stalks leaning 30° or more	Average pulling resistance per plant	Acre yield
		perct.	*bu.*			*perct.*	*bu.*			*perct.*			*perct.*	*lbs.*			*perct.*	*lbs.*	*bu.*
B-1-1	113	7.1	58.1	B-1-1-1	148	10.1	57.6	B-1-1-1-R	72	83.3	B-1-1-1-R-8	36	33.3	144.2	B-1-1-1-R-8-1	239	82.6	148.5	44.0
															-2	289	90.5	84.5	48.4
															-3	223	93.5	115.7	25.3
								B-1-1-1-1	45	84.4	B-1-1-1-1-5	82	45.1	174.0	B-1-1-1-1-5-1	133	94.2	183.9	44.0
											B-1-1-1-1-6	101	9.2	183.8	B-1-1-1-1-6-1	90	85.5	.....	....
															-2	93	79.6	.....	....
															-3	91	77.8	.....	....
															-4	61	73.8	.....	....
											B-1-1-1-1-7	117	47.5	177.4	B-1-1-1-1-7-2	140	35.3	312.4	50.5
															-3	152	47.8	323.5	52.6
															-4	149	50.2	241.1	52.8
															-5	214	56.1	303.3	63.8
											B-1-1-1-1-8	68	23.5	90.5	B-1-1-1-1-8-1	148	81.3	175.1	51.5
															-2	132	62.2	136.6	39.6
															-3	93	87.2	156.0	31.2
															-4	132	79.7	122.7	40.7
				B-1-1-3	145	2.2	32.1	B-1-1-3-R	140	81.2	B-1-1-3-R-7	41	2.4	.....	B-1-1-3-R-7-1	314	28.8	274.7	72.6
															-2	265	35.7	180.9	66.0
															-3	293	40.2	354.0	78.2
															-4	245	51.2	.....	....
											B-1-1-3-R-10	79	0.0	166.1	B-1-1-3-R-10-1	115	16.5	259.0	72.6
															-2	123	42.3	.....	....
															-4	102	9.8	.....	....
Average...	.....	7.1	58.1	....	...	6.2	44.9	....	...	83.0	....	...	23.0	156.0	....	...	60.9	206.2	52.1

TABLE 19—*Concluded*

A-1-1	99	0.0	49.5	A-1-1-1	107	0.0	43.2	A-1-1-1-R	119	24.1	A-1-1-1-R-4	72	0.0	176.3	A-1-1-1-R-4-1	125	36.0	.....	....
															-2	126	19.8	.....	....
															-3	123	31.7	.....	....
								A-1-1-1-1	66	21.2	A-1-1-1-1-4	37	0.0	.....	A-1-1-1-1-4-1	124	42.7	.....	....
				A-1-1-2	71	2.8	64.8	A-1-1-2-R	96	31.2	A-1-1-2-R-1	40	2.5	295.8	A-1-1-2-R-1-1	135	5.2	.....	....
															-2	96	12.5	.....	....
															-3	147	41.4	249.7	55.0
															-4	126	40.5		
											A-1-1-2-R-3	138	0.0	273.0	A-1-1-2-R-3-1	174	43.6	185.6	64.9
															-2	108	2.8	286.0	....
															-3	75	34.7	.....	....
															-4	200	33.2	252.7	66.0
															-6	152	11.5	379.1	80.3
															-7	196	20.6	273.5	71.5
															-8	178	39.5	326.4	55.0
															-9	172	0.0	398.3	52.8
															-10	88	9.8	.....	....
															-11	102	3.9	.....	....
											A-1-1-2-R-4	67	1.5	246.5	A-1-1-2-R-4-1	81	42.0	.....	....
															-2	119	58.0	.....	....
															-3	91	78.0	.....	....
															-4	98	81.6	.....	....
															-5	115	41.7	.....	....
															-6	85	72.9	.....	....
				A-1-1-3	147	0.7	66.9	A-1-1-3-R	48	45.9	A-1-1-3-R-3	82	0.0	140.3	A-1-1-3-R-3-1	125	19.8	117.7	44.0
															-2	89	3.3	223.7	31.9
															-3	129	4.1	252.7	52.8
															-4	111	2.1	175.5	42.9
															-5	111	12.1	159.7	28 6
															-6	130	11.9	210.3	22.0
															-7	140	27.1	191.9	48.4
				A-1-1-4	146	0.0	40.0	A-1-1-4-1	51	7.8	A-1-1-4-1-2	80	0.0	.....	A-1-1-4-1-2-1	117	27.4	.....	....
															-2	92	30.5	.....	....
											A-1-1-4-1-8	73	0.0	.....	A-1-1-4-1-8-1	119	9.2	.....	....
											A-1-1-4-1-9	36	0.0	.....	A-1-1-4-1-9-1	86	32.6	.....	....
															-2	103	10.7	.....	....
															-3	119	16.0	.....	....
															-4	125	41.6	.....	....
															-5	113	9.7	.....	....
											A-1-1-4-1-11	40	0.0	232.2	A-1-1-4-1-11-1	119	11.8	.....	....
															-2	105	21.0	.....	....
Average...	.....	0.0	49.5	....	...	0.9	53.7	....	...	26.0	....	...	0.4	227.4	....	...	26.7	245.5	51.2

five experiments are averaged, the results are as follows: ear plants, six ounces or over, 12.8 percent leaning; nubbin plants, less than six ounces, 12.7 percent leaning; and barren plants, 24.0 percent leaning. It seems evident that in these corn plots conditions usually were such that those factors which caused barren plants also caused weak root anchorage.

Variations in yield seldom are correlated with similar variations in the percentage of leaning plants. It already has been shown that altho all the previously discussed corn diseases cause reductions in yield, not all of these diseases cause an increase in the percentage of leaning plants. On the other hand, in some cases the yields under two different conditions may be the same while the difference in percentage of leaning plants is large. In 1920 (Table 11) early and late corn planted with nearly disease-free seed yielded nearly the same, but the latter leaned much more. Table 13 gives data on two series of plots, one on virgin soil, the other on a rotation which was 75 percent corn. The yield on the two was practically the same, but the percentage of leaning plants on the latter was much higher.

To a certain extent, those conditions that produce a high yield often also produce a high percentage of erect plants. There are, however, many exceptions to this statement, and on the whole, differences in percentage of leaning plants are not very closely associated with differences in yield.

COMPARISONS OF LODGING IN SELF-FERTILIZED STRAINS

Nature and Behavior of Strains Used

This discussion will be confined primarily to four strains which form two very interesting pairs for comparison. Strains A and B originated from two selfed plants of Reid's Yellow Dent in 1917. Undesirable progenies were dropped each year, and only the best appearing plants from each ear were selfed for further propagation. In 1920, no successful pollinations were made in certain of the good lines and so the ear remnants of the 1920 planting were planted again in the following year. This is indicated as R in the pure-line number.

In 1923, 41 pure lines of the A strain, and 23 of the B strain were planted. Data on these and their ancestry back to 1919 are given in Table 19. Many more pollinations than are shown in the table were made each year, but only such ears as gave good germination test and superior field performance were continued as new strains. Summarized data on all the A and all the B strains are presented in this table. Yield data were obtained in 1919, 1920, and 1923. The averages of the two groups are very similar in respect to yield. Leaning data were obtained each year. On the average, the B group leaned much more than the A group. Figs. 14 and 15 illustrate the appearance of the plants of some of these strains just prior to harvest time.

CORRELATION OF LEANING AND ROOT ANCHORAGE

Preliminary data on the correlation of leaning plants with the pulling resistance of the roots have been published by Holbert and Koehler.[5] In 1922 and 1923, the plants of a number of the A and B strains were pulled to determine their relative root anchorage. All the

FIG. 14.—PURE-LINE STRAINS SHOW STRIKING CONTRAST IN THEIR ABILITY TO STAND ERECT

On the left, a row of the weak-rooted B strain inbred for six years. On the right, a row of the strong-rooted A strain inbred for the same length of time. See Tables 19, 20, and 22.

pulling tests within each year were made under uniform conditions. The hills were spaced 42 by 21 inches apart and only one plant was grown to a hill. The averages in Table 19 show that the A strains were more firmly rooted than the B strains, the resistance being 227.4 pounds in comparison with 156 pounds in 1922, and 245.5 pounds in comparison with 206.2 pounds in 1923.

It will be noted that pure-line A-1-1-3-R-3 and its progeny stand comparatively erect but have a comparatively low pulling resistance. This probably is due to the smaller size of the plants of this strain; which are smaller in all proportions than any plants of the B strains or of pure-line A-1-1-2-R-3. Consequently, they are well anchored in comparison with their size. If these plants did not have a diminutive habit of growth, the difference in pulling resistance between the A and B strains, as shown above, no doubt would be much greater.

All the B strains that have been propagated up to 1923 are of good height for inbred material, and comparisons may be made between

FIG. 15.—STRONG AND WEAK ROOT ANCHORAGES MAY BE INHERITED
A row of the weak-rooted inbred B strain situated between two rows of the strong-rooted inbred G strain. The B row went down in a rain storm toward the close of the pollination period. Altho the upper half of the stalks had gained somewhat of an upright position when this photograph was taken, the basal half of the stalks remained in this inclining position thruout the remainder of the season. The stalks of the G strain in these rows remained erect thruout the season.

plants of the different pedigrees in regard to percentage of leaning stalks and pulling resistance. Considerable variation occurs in respect to both of these factors. They vary inversely to each other; those with the highest pulling resistance have the lowest percentage of leaning plants. Pulling data were obtained on sixteen strains. The average pulling resistance was 210.7 pounds. If the strains are divided into two groups of the eight highest and eight lowest, the average pulling resistance for the two groups will be 281.5 and 140.0 pounds respectively. Given in the same order, the average percentage of leaning plants for each of the two groups is 46.1 and 76.6 percent. This indicates that the two factors are closely correlated.

In the A strains, pure-lines A-1-1-2-R-3 and A-1-1-3-R-3 must be compared separately, owing to their different habits of growth. When each of these is divided into groups according to pulling resistance, it is also found that the groups with the highest pulling resistance have the lowest percentage of leaning plants.

From these data it seems that a strong root anchorage is the principal factor that holds the stalks in an upright position. It has often been assumed that cornstalks are held erect primarily by the propping function of brace roots. Well-developed brace roots enter the soil several feet deep, and the experience of the writers is that they function much more as anchorage roots than they do as brace roots. At a certain stage of development, of course, the brace roots have barely entered the soil. Most lodging of corn occurs during or after rains. It is quite evident that the bracing function of short brace roots is practically nil when the soil is soft. That is why the percentage of inclining plants correlates very closely with the pulling resistance.

LEANING AND PULLING RESISTANCE AS RELATED TO EXTENT OF ROOT SYSTEMS

On each of the A and B strains, which were of nearly the same size above ground but which differed greatly in regard to lodging and pulling resistance, plants were selected for a special study of the extent of their root systems. A year before the corn was planted, two parallel rows of sugar barrels were placed in a trench. These were filled with well-mixed, screened soil, and the trench was filled in with soil around the barrels so that the soil surface in the barrels was of the same level as that of the surrounding ground. One row of barrels was planted with pure-line A-1-1-R-3-2, the other with pure-line B-1-1-1-R-8-2. They were planted at the rate of two kernels to a barrel, but soon after emergence were thinned to one plant to a barrel.

When the plants were two months old, the soil was taken away from around the barrels (Fig. 16), the hoops were cut, and the staves removed. The soil was then slowly washed away from the roots by a stream of water (Fig. 17). Connections were made with a drain tile, so that the water drained away after it had been used. Altho the plants were barely beginning to show the tassels at this time, a number of plants of the B strain were already leaning considerably (Fig. 18).

Data on the results of this experiment are given in Table 20. As plants 1 and 2 had suffered some damage they were not included in this table. Data on the remaining eleven plants of each pure line are summarized at the bottom of the table. It will be seen that the two groups are similar in height, the A strain averaging 4.5 inches taller. There is a considerable difference between the two groups in circumference of stalks. It is doubtful whether thickness of stalk has much to do with extent of root development. An HY inbred strain has an unusually thick stalk but is very weak-rooted, whereas a tall, slender-stalked pure line of the G strain is strong-rooted.

The great difference between the two groups that accounts for the difference in lodging and pulling resistance is in the number and extent of the roots. This is shown graphically in Fig. 19. In counting the roots, no differentiation was made between brace roots and non-brace roots.

FIG. 16.—PURE-LINE CORN STRAINS GROWN IN BARRELS SO THAT THE ROOT SYSTEM COULD BE STUDIED TO BETTER ADVANTAGE

These barrels were sunk into the ground and filled with well-mixed, screened soil a year before the corn was planted. This photograph shows the soil removed from around the barrels preparatory to opening them and washing the soil away from the roots. Following the excavation they were covered with wet burlap until they were opened. The row of barrels marked A was planted with pure-line A-1-1-2-R-3-2 and the row marked B was planted with pure-line B-1-1-1-R-8-2. A number of plants in the latter group had been leaning, but these were fastened in an upright position before the excavation was made.

It is often very difficult to distinguish between the two. Many roots that have their origin above the soil level penetrate the substratum deeply and apparently have the same function as those that have their origin lower down. Even when plants of the same pure line are examined it is found that roots from similar nodes may appear above ground on one plant and below ground on another.

Plants of the A strain not only had more roots but they branched much more and the branches were longer (Fig. 20). This is shown statistically in the air-dry weights of the roots (Table 20). The average air-dry weights of the roots of the B strain were only 53.0 percent as heavy as those of the A strain (Fig. 19).

Another root study parallel to that above was conducted with strong-rooted and weak-rooted progenies of the G strain. These were

FIG. 17.—REMOVING THE SOIL FROM THE ROOTS

Each barrel was first removed from its original position until it had a clearance of about a foot all around. The hoops were then cut and the staves removed. The stalk was tied in an upright position. Plenty of water was applied, but with little force, at the top of the soil until it was all washed away.

planted at the same time and harvested only a few days later than those of the A and B strains above. In this case, the plants of the two groups averaged very closely not only in plant height but also in number of roots (see Table 21 and Fig. 21); but the roots of G-4-2-1 were profusely branched while those of G-4-4-1 were but slightly branched. This caused a great difference in dry weight of the roots, those of the weak-rooted strain weighing only 43.5 percent as much as those of the strong-rooted strain (Fig. 21).

Further data on the field performance of plants of the strains just discussed is given in Table 22. It shows the respective pulling resistance of the four strains as measured by the average values for fifty plants in

FIG. 18.—BEHAVIOR OF STRONG-ROOTED AND WEAK-ROOTED SELF-FERTILIZED STRAINS

On the left, plant 21 of pure-line A-1-1-2-R-3-2, standing erect. On the right, plant 22 of pure-line B-1-1-1-R-8-2, leaning 40 degrees. Data on both of these plants are given in Table 20. Photographed when plants were 61 days old. Fig. 20-A shows these same plants on the same day after the soil had been removed from the roots.

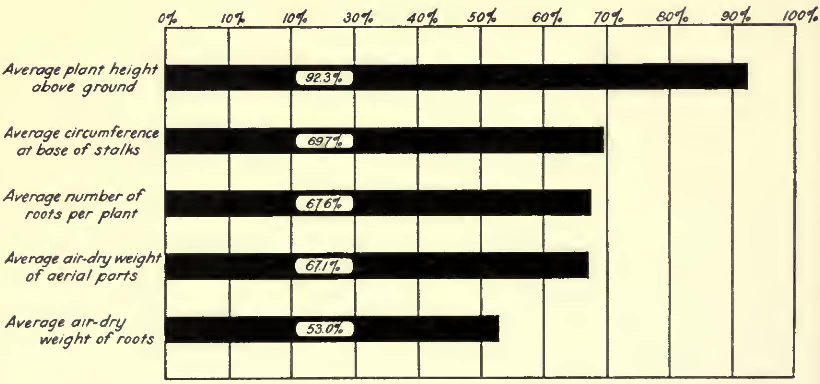

FIG. 19.—CERTAIN CHARACTERISTICS OF STRAIN B-1-1-1-R-8-2 AS COMPARED ON A PERCENTAGE BASIS WITH STRAIN A-1-1-2-R-3-2

Strain A-1-1-2-R-3-2 in each case represents 100 percent. From data shown in Table 20.

FIG. 20.—ROOT SYSTEMS OF STRONG-ROOTED AND WEAK-ROOTED SELF-FERTILIZED STRAINS

A—On the left, pure-line A-1-1-2-R-3-2. On the right, pure-line B-1-1-1-R-8-2, harvested 61 days after planting. The figures on the margin indicate distance in feet. These two plants are shown in their original environment in Fig. 18. Altho the heights of the aerial parts of these two plants were practically the same, the air-dry weights of their roots were 130 and 44 grams, respectively. The latter plant leaned about 40 degrees. This was caused, no doubt, by insufficient root anchorage. The difference is due primarily to genetic factors.

B—Two plants of the same age and same pedigrees as shown in A. One of the plants had been blown down in the young-plant stage, owing no doubt to insufficient root anchorage; later it elbowed back into a vertical position. This condition is often seen in ordinary cornfields. The air-dry weights of the roots were 98 grams for the straight plant and 54 grams for the elbowed plant.

TABLE 20.—MEASUREMENTS AND WEIGHTS OF STALKS AND NUMBER AND WEIGHTS OF ROOTS OF TWO SELF-FERTILIZED STRAINS OF CORN, ONE (A-1-1-2-R-3-2) HAVING A STRONG TENDENCY TO STAND ERECT AND THE OTHER (B-1-1-1-R-8-2) TO LODGE

Planted May 22 and harvested July 19 to 23, at Bloomington, 1923

Pure-line No. A-1-1-2-R-3-2						Pure-line No. B-1-1-1-R-8-2					
Plant No.	Height of plant	Circumference of stalk	Number of roots	Air-dry weight: Aerial parts	Air-dry weight: roots	Plant No.	Height of plant	Circumference of stalk	Number of roots	Air-dry weight: Aerial parts	Air-dry weight: roots
	inches	*inches*		*grams*	*grams*		*inches*	*inches*		*grams*	*grams*
3	45.5	2.6	33	62	40	4	39.8	1.8	28	20	19
5	49.0	3.0	48	84	47	6	39.5	1.5	14	20	9
7	59.5	3.5	48	120	103	8	52.0	2.0	20	42	17
9	50.5	3.4	47	102	100	10	49.8	2.3	24	52	50
11	58.0	3.0	42	98	47	12	54.0	2.0	30	60	32
13	65.0	3.8	62	105	93	14	54.0	2.8	38	56	36
15	59.0	3.3	56	82	72	16	58.0	2.9	39	82	72
17	64.0	3.5	58	92	98	18	66.0	1.8	47	110	85
19	68.0	3.5	45	88	68	20	59.0	2.8	38	86	46
21	71.0	4.0	63	130	110	22	66.0	2.9	47	115	44
23	54.0	3.0	41	88	98	24	56.0	2.6	31	62	54
Average	58.5	3.3	49.4	95.5	79.6		54.0	2.3	32.4	64.1	42.2

each group in 1922, the pulling resistance of an extreme representative of each strain selected for propagation, and the average pulling resistance of the respective progenies of these extreme individuals. It will be noted from the table that each of these four parent plants differed markedly from the average value of the population from which it was chosen.

The four progenies grown in 1923 then represent the offspring of the strongest plant in each of the two strong strains and of the weakest plant in each of the weak strains. As shown in Table 22, by the average values of the progenies, the strong-rooted and weak-rooted strains differed more widely in their average pulling resistance than did the parental population of fifty plants, but they did not differ so widely as

TABLE 21.—MEASUREMENTS AND WEIGHTS OF STALKS AND NUMBER AND WEIGHTS OF ROOTS OF TWO SELF-FERTILIZED STRAINS OF CORN, ONE (G-4-2-1) COMING FROM A FIRMLY ROOTED PLANT AND THE OTHER (G-4-4-1) FROM A PLANT EASILY PULLED UP

Planted May 22 and harvested July 21 to 25, at Bloomington, 1923

Pure-line No. G-4-2-1						Pure-line No. G-4-4-1					
Plant No.	Height of plant	Circumference of stalk	Number of roots	Air-dry weight: Aerial parts	Air-dry weight: roots	Plant No.	Height of plant	Circumference of stalk	Number of roots	Air-dry weight: Aerial parts	Air-dry weight: roots
	inches	*inches*		*grams*	*grams*		*inches*	*inches*		*grams*	*grams*
1	56	2.8	39	108	63	2	58	1.9	50	42	32
3	66	2.8	57	114	122	4	66	2.3	44	82	64
5	60	2.3	35	78	44	6	58	2.0	34	58	42
7	60	2.8	38	82	44	8	62	2.2	37	56	26
9	67	3.0	52	166	152	10	68	2.5	57	108	56
11	73	3.0	48	149	115	12	67	2.5	47	86	32
13	70	2.6	44	106	98	14	70	2.9	52	78	66
15	72	3.1	59	172	127	16	66	2.5	49	68	54
17	63	2.9	53	105	112	18	63	2.4	34	85	40
19	61	3.0	40	115	140	20	57	2.0	53	50	30
Average	64.8	2.8	46.5	119.5	101.7		63.5	2.3	45.7	71.3	44.2

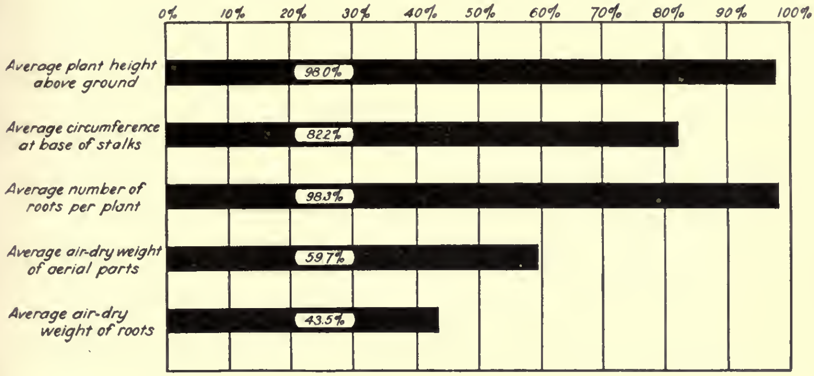

FIG. 21.—CERTAIN CHARACTERISTICS OF STRAIN G-4-4-1 AS COMPARED ON A PERCENTAGE BASIS WITH STRAIN G-4-2-1

Strain G-4-2-1 in each case represents 100 percent. From data shown in Table 21.

their respective parents. This shows that selection still had an effect on this strain and that it was not yet homozygous.

The table also shows clearly that the average dry weight of roots, as well as the average pulling resistance per stalk, correlates indirectly with the average percentage of leaning stalks.

A few first-generation crosses between weak-rooted and strong-rooted strains have been grown. When a cross was made between pure-lines A-1-1-2-R-3 and B-1-1-1-R-8, the result was a stand of very erect plants. In several other cases, little lodging occurred when strong-rooted and weak-rooted strains were crossed. However, when one of the strong-rooted A strains was crossed with one of the weak-rooted HY strains, the resulting plants lodged practically 100 percent

TABLE 22.—PULLING RESISTANCE, DRY WEIGHT OF ROOTS, AND PERCENTAGES OF LEANING PLANTS IN SEVERAL SELF-FERTILIZED STRAINS, SHOWING RELATION OF INHERITED STRONG OR WEAK ROOT ANCHORAGE TO PROPORTION OF LEANING PLANTS

Factors considered	Strong roots	Weak roots	Strong roots	Weak roots
	(A-1-1-2-R-3)	(B-1-1-1-R-8)	(G-4-2)	(G-4-4)
Average pulling resistance of 50 plants in parental population (1922), in pounds	273.0	144.2	340.7	166.5
Pulling resistance of plant chosen as parent (1922), in pounds	460.0	122.0	720.0	40.0
	(A-1-1-2-R-3-2)	(B-1-1-1-R-8-2)	(G-4-2-1)	(G-4-4-1)
Average pulling resistance of progeny of above plant (1923), in pounds	286.0	84.5	400.7	161.2
Average air-dry weight of roots per plant (1923), in grams	79.6	42.2	101.7	44.2
Average percentage of stalks leaning 30° or more (1923)	2.8	90.5	3.6	28.2

(Fig. 22). This indicates that the inheritance of the tendencies to strong and weak roots is not to be explained on the basis of a single genetic factor, but appears to be more complex in nature.

FIG. 22.—FIRST-GENERATION HYBRIDS BETWEEN WEAK-ROOTED AND STRONG-ROOTED SELF-FERTILIZED STRAINS

On the left, a plot of an F_1 generation cross between the weak-rooted B strain and the strong-rooted A strain. This condition resulted in a stand of very erect plants. On the right, a plot of an F_1 generation cross between the weak-rooted HY strain and the strong-rooted A strain. Altho the same strong-rooted parent was used as in the previous case, this corn lodged 100 percent. Evidently the factors for the weak-rooted and strong-rooted characters are not a single pair of allelomorphs.

COMPARISON OF STALK BREAKING IN SELF-FERTILIZED LINES AND FIRST-GENERATION CROSSES

Self-fertilized strains of corn vary greatly in the tendency of stalks to break during the latter part of the growing season and after maturity. Certain strains have been isolated in which there have been no broken stalks up to the first of December during the past three seasons. In other self-fertilized strains, under the same conditions, almost all the stalks were broken within two or three weeks after maturity. The inheritance of the breaking tendency of cornstalks in first-generation crosses between self-fertilized lines, and its effect on the quality of grain are given in Table 23.

TABLE 23.—INHERITANCE IN THE FIRST-GENERATION CROSSES OF THE BREAKING TENDENCY OF CORNSTALKS. BLOOMINGTON, 1924

	Characteristics of inbred parent strains							Field data on first generation crosses of inbred strains						
	Pistillate parent			Pollinating parent										
Group No.	Pure-line No.	Relative resistance to frost injury	Broken stalks	Pure-line No.	Relative resistance to frost injury	Broken stalks	Field stand		Relative resistance to frost injury	Acre yield		Broken stalks	
										Total	Sound	Per plot	Average
			perct.			perct.	No.	perct.		bu.	bu.	perct.	perct.
1	HY901-1-5-5....	Intermediate...	95.1	W10-2-2........	Intermediate...	98.2	149	71.0	Intermediate....	61.0	15.0	63.8	....
	W10-2-2........	Intermediate...	98.2	HY901-1-5-5....	Intermediate...	95.1	183	87.1	Intermediate....	64.2	12.1	78.1	71.0
2	A-1-1-2-R-1-1...	High..........	0.0	W10-2-2........	Intermediate...	98.2	191	93.2	Intermediate....	93.6	92.1	46.6	....
			0.0			98.2	195	95.1		95.5	93.0	26.6	....
			0.0			98.2	190	92.6		96.2	94.1	44.7	....
	A-1-1-2-R-1-1...	High..........	0.0	HY901-1-5-5....	Intermediate...	95.1	175	85.3	Intermediate....	90.4	87.9	37.1	....
			0.0			95.1	167	81.5		92.1	89.2	18.0	....
	A-1-1-2-R-1-2...	High..........	0.0	W10-2-2........	Intermediate...	98.2	187	91.2	Intermediate....	86.0	84.5	27.3	....
			0.0			98.2	185	90.2		80.1	78.1	20.5	....
			0.0			98.2	189	92.2		83.0	81.2	16.4	....
			0.0			98.2	192	93.6		87.0	85.3	8.3	....
	A-1-1-2-R-1-2...	High..........	0.0	HY901-1-5-5....	Intermediate...	95.1	180	87.8	Intermediate....	98.3	96.1	15.0	....
	B-1-1-1-1-7-2....	High..........	0.0	W10-2-2........	Intermediate...	98.2	175	85.4	Intermediate....	79.2	76.1	18.3	....
			0.0			98.2	178	86.8		77.4	74.2	7.9	....
			0.0			98.2	181	88.3		78.3	75.4	11.0	22.9
3	A-1-1-2-R-1-1...	High..........	0.0	B-1-1-1-1-7-2....	High..........	0.0	190	92.6	High..........	101.0	98.2	0.0	....
	A-1-1-2-R-1-2...	High..........	0.0	B-1-1-1-1-7-2....	High..........	0.0	185	90.2	High..........	105.3	101.4	1.6	....
			0.0			0.0	183	89.2		107.0	104.8	3.3	....
			0.0			0.0	186	90.7		98.1	96.3	14.0	....
			0.0			0.0	181	88.3		103.0	101.2	16.0	
	B-1-1-1-1-7-2....	High..........	0.0	A-1-1-2-R-1-2...	High..........	0.0	191	93.2	High..........	110.3	108.1	0.0	....
	A-1-1-2-R-1-2...	High..........	0.0	B-1-1-3-R-7-2...	High..........	0.0	189	92.2	High..........	95.6	93.1	10.0	....
	K4-10-2........	High..........	0.0	B-1-1-3-R-7-2...	High..........	0.0	184	89.8	High..........	96.5	95.1	8.1	6.6
4	K4-3-1.........	Intermediate...	10.3	A-1-1-1-R-4-1...	Low..........	8.2	188	91.6	Low..........	70.8	35.4	58.0	
			10.3			8.2	181	88.3		75.3	25.1	76.2	....
	A-1-1-1-R-4-1...	Low..........	8.2	K4-3-1.........	Intermediate...	10.3	163	79.5	Low..........	63.4	16.4	76.6	70.3
5	G8-8-1.........	High..........	3.1	A-1-1-1-R-4-2...	Low..........	8.9	169	82.5	Low to intermediate........	78.4	65.3	42.6	....
			3.1			8.9	175	85.4		76.3	67.2	40.8	....
			3.1			8.9	170	83.0		74.4	63.1	42.3	41.9
6	HY-901-1-5-5...	Intermediate...	95.1	A-1-1-1-R-4-1...	Low..........	8.2	189	92.2	Low..........	70.3	33.2	65.1	65.1

Three conditions, which are heritable to a large extent, are recognized as being responsible for broken stalks. These are (1) weak morphological structure of the stalks, (2) susceptibility to disease, and (3) susceptibility to frost injury. Under morphological structure one must consider not only the diameter of the stalks but also the toughness

FIG. 23.—BROKEN STALKS IN FIRST-GENERATION CROSSES

All three of these rows are first-generation crosses, the central row being HY901-1-5-5 X W10-2-2 shown in Group 1, Table 23. As most of the ears came in contact with the ground, only a small percentage of them were marketable at harvest. Both parents had a strong tendency to stalk breaking.

of the outer shell, or cortex. Frequently a stalk will stand more strain than another that is a little thicker, due to the toughness of the hard outer tissues.

Infections by diseases may be of two types; systemic and local. Under the former, infection with *Aplanobacter stewarti* or *Cephalosporium acremonium* would no doubt be important. The latter organism was found to cause increases in broken stalks in open-pollinated strains (Table 10). Local infections resulting in increases in the percentages of broken stalks may be caused by smut, Diplodia, Fusarium, Gibberella, and probably other organisms. Some self-fertilized strains are especially susceptible to one or several of the diseases caused by these organisms and the stalks often break over early at the infected nodes. When the breaking does not occur until after maturity, the cause is more often due to the anatomical structure of the stalk.

FIG. 24.—TWO CONTRASTING ROWS OF FIRST-GENERATION CROSSES

On the right, one of the crosses shown in Group 3, and on the left, one of the crosses shown in Group 5, Table 23. The high percentage of broken stalks in Group 5 was due largely to frost injury. The central row was cut out before photographing.

In the case of low resistance to frost injury, the plants die when a light, early frost occurs, while the more hardy strains are not affected. After death, the stalks are generally invaded by saprophytic organisms, and by the time a month has passed the breaking strength of the stalks has been considerably reduced.

In Group 1 (Table 23) both pistillate and pollinating parents contained a very high percentage of broken stalks. The first-generation crosses between these two strains grew vigorously and developed large ears on almost every stalk. However, a high percentage (71.0 percent of the plants) broke very early in the fall (Fig. 23), and as a result the yield of grain was not only greatly reduced but less than 25 percent of the corn was sound. In Group 2, where only one of the parents of the cross exhibited a tendency to stalk breaking, the percentage of broken stalks was much less, being reduced from 71.0 to 22.9 percent.

FIG. 25.—ONE OF THE PARENTS OF THIS FIRST-GENERATION CROSS WAS VERY SUSCEPTIBLE TO FROST INJURY

The central row shows one of the crosses of Group 4, Table 23. An early frost killed this row while the adjoining rows, also first-generation crosses, were but slightly affected. Some weeks later the stalks broke down, as here illustrated.

Furthermore, the relatively low percentage of breaking in Group 2 occurred much later in the season and as a result there was little injury to the quality of grain. In Group 3 both parents were free from the stalk-breaking tendency, and the first-generation cross stood up well, even to the last of November (Fig. 24).

During the fall of 1924 much variation in relative resistance to frost injury was observed among the self-fertilized strains growing in experimental plots near Bloomington. In the cases observed, low resistance to frost injury apparently was dominant to high resistance to frost injury

(Table 23). Plants injured by early frosts were much more easily broken by the strong winds in October and November. In Group 4, where the parents contained only 8.2 and 10.3 percent of broken stalks, but where one of them carried low resistance to frost injury, the stalks in the cross were weakened by the frost injury and broke under the weight of the heavy ears and the force of the strong prairie winds (Fig. 25).

Group 4 contained about as many broken stalks as Group 1—70.3 percent as compared with 71.0 percent. Plants in Group 5 (Fig. 24) were not affected by the early frost which killed those in Group 4, but were killed before those in Group 3. The stalks did not break until they were fairly dry; consequently, there was less damaged corn than in Group 4 (Table 23). Altho only one of the parents in Group 6 exhibited a tendency to high percentage of stalk breaking, the plants were killed by the early frosts and the stalks broke soon thereafter. As a result, this group contained 65.1 percent broken stalks as compared with 22.9 percent in Group 2.

It is evident from the data presented in Table 23 that both resistance to frost injury and resistance to stalk breaking can be controlled to a large extent by careful selections within self-fertilized pure lines and by proper recombinations of these pure lines.

SUMMARY

In the study of lodging in corn two subdivisions of the plants were made: namely, those having "broken" stalks and those having "leaning" stalks. Stalks inclining 30 degrees or more were considered as leaning stalks.

In studying the effect of corn diseases on lodging, experiments were conducted only with seed infections and seed inoculations. While all of these infections and inoculations resulted in decreased vigor and yield, not all of them increased the amount of lodging.

Increases in the percentage of leaning stalks occurred when seed was infected with *Diplodia zeae*, when starchy seed susceptible to scutellum rot was used, or when the seed was naturally infected or artificially inoculated with *Gibberella saubinetii*. On the other hand, no significant increases in the percentage of leaning plants occurred when seed was infected with *Fusarium moniliforme* or *Cephalosporium acremonium*, and increases were doubtful when horny seed susceptible to scutellum rot was used.

Increases in percentage of broken stalks due to seed infection occurred only when seed was infected with *Cephalosporium acremonium* or when starchy seed susceptible to scutellum rot was used.

Commercial strains of corn, even tho practically free from seed infection, vary considerably in respect to lodging.

The time of planting, whether early or late in the season, may have a marked influence on the relative percentage of both leaning and broken stalks.

Corn planted at the rate of two kernels to a hill stood more erect than that planted at the rate of three kernels to a hill.

When corn followed several consecutive corn crops on the same soil, the percentage of leaning plants was much greater than when corn was grown to succeed virgin sod or a leguminous crop. The percentage of broken stalks was not affected thereby.

The application of 4 or more tons of limestone per acre to the soil had a remarkable effect on decreasing the percentage of leaning plants. It did not, however, influence the percentage of broken stalks, nor did it have a marked influence on the yield of grain.

Barren stalks, on the average, leaned to a greater extent than stalks bearing ears.

In a number of self-fertilized strains, great differences in respect to lodging were observed, even tho practically disease-free seed was used thruout. Strains that grew to about the same height, of which one was inclined to lodge and the other to stand erect, were studied, and the erect strain was found to have about twice as great a root system as the former. Plants having a tendency to lodge also were found to have less resistance to a vertical pull.

Self-fertilized strains were also found to vary greatly in the tendency of the stalks to break during the latter part of the growing season and after maturity. Some strains had practically no broken stalks up to the time winter set in, while many others were broken down completely at that time. These differences in behavior indicate that it may not be difficult to develop commercial strains that will have very little tendency toward stalk breaking even under adverse conditions.

It is evident from the foregoing that some of the corn root rot diseases may cause increases in leaning or broken stalks of corn, but these are by no means the only causes, for many other factors such as climate, previous cropping, rate and time of planting, and soil treatment, also influence the amount of lodging.

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