FUSARIUM MONILIFORME IN RELATION TO DISEASES OF CORN.

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INTRODUCTION.

The fungus, *Fusarium moniliforme* Shel. has been reported by several workers (15) (20) to be the cause of ear, stalk, and root rots of corn. The rotting of the corn plant causes very serious losses to the crop. Other organisms parasitic on corn are known to cause the rotting of ears, stalks, and roots of corn, notably, *Diplodia zeae* (Schw.) Lev. (2) *Gibberella saubinetii* (Mont.) Sacc. (7), *Helminthosporium sp.* (18), and certain bacteria (14). Hoffer and Carr (6) have shown that effects very similar to stalk and root rots are produced by excessive accumlation of iron and aluminum in the roots and stalks of corn.

The consideration of *F. moniliforme*, specifically, as one of the major causes of stalk rot and seedling blight began with Valleau's work (20) in 1920. Since that time some workers have advanced evidence supporting Valleau's findings, others have secured contrary results.

The work reported in this paper was undertaken to ascertain if *F. moniliforme* is capable of causing a serious seedling blight of corn; if *F. moniliforme* causes broken and leaning stalks in the field; to what extent it causes molding of ears; and in what way infection reaches the kernels. Incidentally, the problem of seed treatment was taken up in order to secure disease-free seed for inoculation purposes.

A review of literature follows which shows the present status of these problems.

REVIEW OF LITERATURE.

The fungus known as *F. moniliforme* Shel. was described by Sheldon (15) in Nebraska in 1904. He isolated it from ears of corn showing a pink mold, and described it as follows:

"Sporodochium, subeffuse, salmon-pink; sporophores, simple or branched, usually opposite; microconidia, continuous, oblong-

ovoid, moniliform, 6–10u long; macroconidia, falcate, acute, for the most part three-septate, 25–40μ long".

Sherbakoff (16) states that "among the *Fusaria* answering Sheldon's description of *Moniliforme* are several that differ from each other in important characters and are thus different organisms." On these grounds he set up the section *Moniliform* as follows: "Macroconidia type intermediate between *Roseum* and *Elegans*, thin walls mostly three-septate; microconidia also in chains, chlamydospores none, color of substratum from none to violet."

Manns and Adams (11) identified *F. moniliforme* with *Oospora verticilloides* Sacc. reported from Northern Italy in 1881.

Wineland (21) at Wisconsin reported that perfect perithecia were produced when two distinct strains of *F. moniliforme* were plated together. The perithecia were born at the lines where the two strains came in contact. Ascospores from these perithecia on germination gave pure cultures of *F. moniliforme*. The cultures which produced the perithecia were somewhat different morphologically. The perithecia resembled those of *G. saubinettii*.

Stover (18) at Wisconsin studied the effect of temperature on the growth of *F. moniliforme* in culture. After five days visible growth had occurred at a temperature of 12° C., was considerably greater on plates up to 18° C., then increased more gradually to an optimum from 26° C. to 33° C., after which it decreased markedly at each higher temperature. There was little growth at 37° C. Henry (5) gave its temperature range as follows: "slightly at 5°–7° C., optimum at 30° C., and slightly at 36°–36.5° C. He also reports isolating *F. moniliforme* from the soil.

It is probable that many investigators have worked with *Fusarium moniliforme* in connection with studies of seedling blight of corn. There are many papers on this subject which do not name all the organisms studied. Burrill and Barrett (2), Holbert and Hoffer (8), and Pammel, King, and Seal (13) mention a *Fusarium* in this connection.

Valleau (20) in 1920 was the first to assign to *F. moniliforme* any large part in the production of root and stalk rots. He found that it was almost universally present in Kentucky seed corn. He also secured corn from other states and found infection equally high. On the basis of his work he believed

that *F. moniliforme* was an active parasite, more virulent than *G. saubinettii*, that it was capable of causing root and stalk rots in the field, but that it did not injure germination unless infection were very severe. Manns and Adams (10) in Delaware report that *F. monilforme* is very common in seed corn. Branstetter (1) in Missouri found *F. moniliforme* was present in 68.8% of the ears he tested. He also reported a correlation between badly diseased corn, as shown by the germinator test, and low yields. Melchers and Johnson (12) in Kansas found nearly 95% of the seed corn was infected, but could find no correlation between the results of the germination test and stalk and root rot injury in the field.

Sherbakoff (17) reports that seed effectively treated for *F. monilforme* gave no better yield than untreated seed. He suggests that either it is not pathogenic or that it is always present in the soil. Valleau (20) reported that he could find no effective treatment. Manns and Adams (11) state that the internal nature of the infection makes seed treatment ineffectual. Branstetter (1) states that seed corn can be effectively treated by soaking it in mercuric chloride (Hg Cl 1) 1:1000 for one hour.

The effect of soil temperature on the blighting of corn seedlings inoculated with *F. moniliforme* was investigated by Stover (18). He found that *F. moniliforme* attacked corn through a range of soil temperature from 10° to 36° C. However, at the lower temperatures, infection was rare and was shown only by small brownish-yellow lesions which did not represent a serious injury. At 28° to 36° C. seedlings showed considerable injury and *F. moniliforme* was frequently isolated from the lesions. It was thought that high temperature with consequent drying of the surface soil was at least in part responsible.

F. monilforme has been reported from hosts other than corn. Hartley, Merrill, and Rhoads (4) as early as 1918 found that *F. moniliforme* caused normal damping off of conifer seedlings, but was not responsible for germination injuries except when heavy inoculation was practiced. They concluded that it was less important in damping off of conifer seedlings than *Corticium* and *Pythium*. Henry (5) inoculated *F. moniliforme* into wheat, sweet corn, rye, and oats, all of which it attacked.

Experimental Work

The writer's work with *F. moniliforme* Shel. was undertaken during the summer of 1923 at Ohio State University. A small plot of corn in the Botany Department garden was used for field inoculations. The seedling inoculations and soil temperature experiments were carried on in the department greenhouse and laboratory.

Many strains of *F. moniliforme* were used during the progress of this work. Three strains were secured from Mr. R. A. Dobbins, a graduate student in the Department of Botany. Two were isolated from blighted corn seedlings sent in from Morrow County in June 1923. The others were isolated from kernels of corn. In all thirteen strains were secured. Single spore isolations were made from five of these. All of the strains produced macroconidia in chains. The microconidia were produced abundantly in old cultures which had been kept moist. Three and four septate macroconidia were the most common. Five septate macroconidia were frequent. These latter often measured 50–60μ in length.

From a study of the morphology and physiological reactions of these strains in culture it became apparent that they could be separated into at least two distinct groups. The mycelium of the group most closely answering Sheldon's description had a pink tint, was loosely matted, and grew freely into the air. The substratum was deeply colored, ranging from greenish blue or purple on potato dextrose agar with 2% sugar to a deep plum purple on potato dextrose agar with 5% sugar. The mycelium of the other group was pure white and formed a low, dense mat. The substratum was never more deeply colored than salmon. These differences are in agreement with Sherbakoff's statement that the fusaria producing spores in chains include several distinct organisms.

Field Inoculations.

During the first week in August twenty-five stalks were inoculated just before the tasseling stage to ascertain whether *F. moniliforme* causes stalk rots. A small hole was made in the stalk by puncturing it with a cork borer one-eighth inch in diameter. A fragment of the medium upon which *F. moniliforme* was growing was inserted into the puncture, and the opening was closed with absorbent cotton. The cork borer

and needles used were sterilized in the flame of an alcohol lamp before each operation. Control stalks were prepared in the same way except that no inoculum was placed in the punctures. Inoculations were made at various heights from the ground. The media used were potato dextrose agar and steamed rice.

Two inoculated stalks and two checks were cut and examined after three weeks. Others were cut from time to time until the third week in October. In some stalks it was found that the cork borer had penetrated only the sheaths, the stem not having developed far enough to be encountered. The elongation of the internodes had then pushed the sheaths upward and separated them. The mature plant showed the puncture made by the cork borer in several successive sheaths. These punctures were surrounded by a purplish-black ring of discolored tissue. This is shown in Plate I, a. The check plants did not show this discoloration. In other stalks the cork borer penetrated the internodes. Externally the symptoms were the same as found on the sheaths. When the stalks were split through the wound longitudinally, wide streaks of the pith and vascular bundles were found to be black or brown. These streaks were usually very conspicuous within the internode punctured. This is shown in Plate I, b. In the internodes above and below it they appeared less prominently until in the third or fourth nodes it was confined to the vascular bundles. In one stalk these discolored strands were traced to the sixth node above and to the third node below the inoculation point.

Tissue from the brown strands was taken from six stalks and plated on potato dextrose and corn meal agar. *F. moniliforme* grew out from the tissue in all instances, in one case from tissue taken from a point twenty inches above the puncture. In no case did this discoloration extend into the shank of an ear.

The controls showed a light browning around the wound never extending more than two inches from the injury. No *F. moniliforme* appeared when browned tissue from this source was plated. Several plates showed no fungus growth of any kind. The color of the tissue was probably caused by the death of the cells due to the injury and consequent drying.

Inoculations of leaf sheaths and of stalks made by puncturing these parts with a sterile needle and applying a loop of a spore suspension produced only the local symptoms noted above, purplish-black discolorations confined to the area inoculated.

Five stalks were inoculated by pouring several c.c. of a spore suspension between the sheath and the stalk. No infection could be found when these were examined.

Inoculation on Young Silks.

Valleau (20) suggests that in the ear rot produced by *F. moniliforme* the silks are the path of invasion. To secure data on this point eighty ears were covered with glassine paper bags before the silks appeared. Natural infection of the silks was thus presumably prevented. When the silks were well exposed within the bags, the bags were removed, the silk was pollinated by hand and then sprayed with a suspension of spores of *F. moniliforme*. The bags were then replaced. A large number of control ears were prepared. A severe storm of wind and rain tore or blew off almost all the bags. The purpose of the experiment was defeated by the exposure of the control ears to infection. However, the ears were again covered with a stronger type of bag.

About forty ears each of the inoculated lot and the controls were tested by the modified rag doll method after harvesting. All showed infection. External molding occurred on three or four ear tips to which the corn ear worm had gained access. No other molding was found. This is interesting in view of the heavy inoculation practiced.

Direct Inoculation of Kernels.

The husks of eleven ears were slit with a knife and spores of *F. moniliforme* were sprayed on the kernels. This was done when the kernels were just past the dough stage. In four cases the kernels were wounded, in two they were un-injured by the knife, and in the other cases no attention was paid to this point. Checks sprayed with sterile water were made. In both checks and inoculated ears the slits in the husks were made tangent to the ear in such a manner that the husks would cover the sprayed kernels completely. In ten ears a mold developed, but it was usually confined to from three to six kernels, sometimes scattered. One ear was completely involved. On October fourth nineteen more ears and several checks were prepared in the same way. The corn was nearly ripe and fairly dry. Of these ears only one developed mold.

Inoculation in Cobs of Young Ears.

Seventeen ears were inoculated by puncturing with a cork borer through the husks into the cob of the green ear, then inserting into the cavity a sweet clover stalk or apple twig on which the fungus was growing. These ears were affected much like the preceding. Localized areas where the cavity was near the surface of the cob would show moldy, shrunken kernels. The checks showed no mold. The appearance of this infection is shown in Plate I, c.

Discussion of Results of Field Inoculations.

The results of inoculating the young stalk just before tasseling show that *F. moniliforme* is able to grow parasitically in the stalk tissues and to produce the discolorations characteristic of stalk rot. The absence of broken and leaning stalks seems to indicate that the injury is of a mild character. The slight infection secured in the needle puncture inoculations and the failure of the spore suspension to produce infection when poured under the sheath strengthen this view. As it is possible that other environmental conditions might have changed the results, it would be desirable to repeat these experiments and to make the stalk inoculations earlier in the life of the plant.

F. moniliforme is capable of causing molding of ears but probably requires very moist conditions to cause general molding. It does not attack the husks as freely as *Diplodia zeae* (Schw.) Lev. and *Gibberella saubinetii* (Mont.) Sacc.

Seedling Inoculation.

Inoculation of Seeds at Planting.

Thirty ears were tested for internal infection of *F. moniliforme* by plating pieces of surface sterilized kernels in agar. By this method *F. moniliforme* infected ears and ears apparently free from any fungus were selected. Seed of both kinds was surface sterilized in mercuric chloride ($HgCl_2$) 1:1000 and planted in clean, white sand. Twenty-two apparently disease-free, twenty-three diseased, and twenty-four apparently disease-free inoculated seeds were planted. Each seed was placed in a separate pot and the pots were set closely together in a shallow box. The interspaces were filled with sand to help hold the

moisture. The pots used were made of paper of the type used in making rag doll germinator rolls. Planting each seed in a separate pot prevented the fungi from passing from plant to plant and made it easy to secure the entire root system for examination. The plants were watered with a dilute nutrient solution. They remained thrifty and of good color throughout the experiment.

All of the plants were allowed to grow for four weeks. The soil temperatures ranged between 15.5° and 22° C. At the end of that time the infected and inoculated lots were slightly larger than the apparently disease-free. The difference was thought to be due to temperature as the latter showed a soil temperature 1° to 2° C. lower because of its location farther from the steam pipes. There were nine weak plants from the

TABLE I. COMPARISON OF APPARENTLY DISEASE-FREE, INOCULATED, AND NATURALLY INFECTED SEED GROWN IN SAND FOR ROOT ROT INJURY.

Seed	No. Plants	No. Plants Infected	No. Plants Clean	Percent Clean
Apparently disease-free	22	14	8	36
Inoculated	24	19	5	24.6
Infected*	23	21	2	8.6

diseased seed, four from the inoculated seed, and three from the apparently disease-free seed. The percentage of plants found to have clean roots was 8.6%, 24.6%, and 36% for the infected, inoculated, and apparently disease-free, respectively. Few of the injuries were of an extensive nature. Tissue from the rotted roots and mesocotyls gave *F. moniliforme*, *Gibberella saubinetii*, and other fungi. As the seed used in apparently disease-free and inoculated lots was from the same ears, some infection due to the inoculation is indicated.

This experiment was repeated until in all over four hundred seedlings had been grown. In some of the later lots individual potting was omitted.

This work demonstrated that with the seed used freedom from infection occurred only in individual kernels. No ears were found which were entirely free from *F. moniliforme*. The

*It should be noted that one of the infected ears was of a poor type and not suitable for seed.

percentage of infection was found to vary. Inoculation of ears showing a low percentage of infection increased the amount of infection shown by seedlings grown from such seed. The infections secured under the conditions obtaining in this experiment did not affect the vigor of the plants or cause blighting. It would appear that under these conditions the progress of the infection does not keep pace with the growth of the root system.

Seed Treatment.

The experiments discussed above brought out forcibly the need for disease-free seed or some method of seed disinfection. As no ears had been found to be completely free of fungus infection, several experiments were undertaken in an attempt to find efficient method of seed disinfection.

Hot water treatments proved ineffective. Serious injury occurred at temperatures of 60° C. when maintained for over ten minutes. Seed treated below the point of injury was not disinfected.

Javel water, as used by Duggar and Davis (3) was also tried but did not give complete disinfection.

Mercuric chloride ($HgCl_2$) 1:1000 was also tested. It was found that seed killing began between two and one half and three hours. Some disinfection was obtained when seeds were soaked for one hour and forty-five minutes, but the results were not uniform. Disinfection was then attempted by soaking the seed for ten to fifteen minutes in mercuric chloride at a temperature of 50°–60° C. Several small lots of seed treated by this method and tested were found to be free of *F. moniliforme.* Other lots were then treated by the same method with contradictory results. Incomplete disinfection occurred in some cases; total failure resulted in other cases in which heavily infected seed, as determined by agar plating, was used. These results are perhaps explained when it is remembered that the amount of infection in the different kernels varies widely as is shown by plating and other tests. When infection is light and presumably carried in the more accessible parts of the pericarp, a high percentage of disease-free seeds can be secured by this method.

Soil Temperature Effects on Pathogenicity of F. Moniliforme.

The effects of soil temperature on the parasitism of *F. moniliforme* on corn seedlings were studied by the use of temperature tanks of the Wisconsin type. These tanks are described by Jones (9). These tanks are filled with water, and heated with electric space heaters placed in copper tubes which extend through the tanks near the bottom. The higher temperatures are regulated by electric thermostats. Temperatures below 20° C. are secured by running cold water through the tanks.

The cans were made equal in weight by the addition of pieces of crockery and then filled with equal weights of good soil. The moisture content of the soil was ascertained and corrected to about 24% of the dry weight of the soil. This percentage was maintained by weighing the cans once or twice daily and adding water as was necessary.

The experiment was divided into three parts. One hundred and twenty seeds known to be heavily infected with *F. moniliforme* were inoculated by placing them in a heavy spore suspension, and planted. One hundred and twenty seeds from ears known to be lightly infected were treated by heating in mercuric chloride to 55° C. for ten minutes, followed by thorough rinsing. One half of these disinfected seeds were then inoculated in the way just described, the remainder were planted as a control. By the use of disinfected seed for the control the amount of infection from fungi in the soil would be shown.

The temperatures used were 12°, 16°, 20°, 24°, 26°, 28°, and 32° C. At 32° C. the corn came up in about 2 days and 18 hours, at 28° in 3 days, at 24° in 4 days, at 20° in 5 days, at 16° in 7 days, and at 12° in 15 to 17 days. The disinfected seed germinated 100%, but came up a little more slowly. After the tenth day a tendency to tip burn, and a weakness of the stalks appeared in the inoculated cans at 32° and 28°C. As the experiment progressed, many plants at these temperatures fell over. The check plants were notably stronger and nearly normal in appearance to the end of the experiment. The results of this experiment which was closed after three weeks are presented in Table II.

At 32°C. the control plants were strong and erect, although one plant showed some wilting of the top. The roots or mesocotyls of five plants showed serious rotting; five showed slight

rotting, chiefly of the seminal roots. The old kernel still adhered to the mesocotyls. The disinfected, inoculated plants, of which there were ten, were down badly. The kernels had rotted free of the mesocotyls. Six plants showed serious rotting, while four were only slightly rotted. The twenty infected, inoculated plants were also down quite generally. Two plants were nearly dead and four others were stunted. Fourteen plants had badly rotted roots.

At 28°C. the condition of the plants was much the same as at 32°C. At 24°, 20°, and 16°C. the plants stood up well and appeared to be quite vigorous. The rotting of the roots was not of a serious character except in a few plants. At 12°C.

TABLE II. PERCENTAGES OF PLANTS SHOWING INFECTION WITH F. MONILIFORME AT DIFFERENT SOIL TEMPERATURES.

	No. Kernels	Percentage of Plants With Rots or Lesions on Roots or Mesocotyls					
		32°C.	28°C.	24°C.	20°C.	16°C.	12°C.
Control	20	80	45	40	10	0	30
Treated seed, inoculated	20	85	90	41.5	25	5	10
Naturally infected seed, inoculated	40	87.5	92.5	90	50	10	22.5

infection was confined to small lesions, but a serious killing of the tap-root tips occurred which was more common in the cans in which treated seed was used. The plants in the can which showed the most serious killing of the tap roots were from seed from which *F. moniliforme* could not be isolated when plated. These facts suggest that the killing referred to was chiefly a temperature effect, accentuated by some residual effect of the seed treatment.

This experiment was repeated. In the second series the same type of seed was used in all of the cans. It was seed known to be heavily infected with *F. moniliforme*. Two cans of soil for the 32° C. tank were autoclaved for one hour and thirty minutes at 15 pounds pressure. The treated control seed was planted in one of these and the treated-inoculated seed in the other. In this sterile soil 50% of the plants were killed within two weeks. *F. moniliforme* grew visibly on the plants at the surface of the soil. Of the plants in the unsterile

soil at the same temperature all were alive, although two plants showed some wilting. The seed treatment (hot mercuric chloride) was much less effective with this seed and the infection in the control lot was greater than in the first series. Otherwise the results of the two series checked quite closely. The combined results are given in Tables II and III.

Table II is based on a count of all rotted areas and lesions found on the mesocotyls and the seminal and tap roots. The percentages given do not indicate the seriousness of the injury, but the percentage of plants infected.

Table III is based on a count of the plants which showed rotting areas on the mesocotyls or roots, of an actively pro-

TABLE III. PERCENTAGE OF PLANTS SHOWING ACTIVELY PROGRESSING ROTTING AREAS CAUSED BY F. MONILIFORME AT DIFFERENT SOIL TEMPERATURES.

	No. Kernels	Percentage of Plants Showing Actively Progressing Areas on Roots or Mesocotyle					
		32°C.	28°C.	24°C.	20°C.	16°C.	12°C.
Control	20	45	15	0	0	0	0
Treated seed, inoculated	20	60	35	5	5	0	0
Naturally infected seed, inoculated	40	70	65	30	2.5	0	0

gressing nature. Lesions and very small infected areas were not considered.

These tables show that the rotting caused by *F. moniliforme* occurs chiefly at temperatures above 20°C. Serious injury was confined to the two higher temperatures, 28° and 32° C. Many plants on which rotting areas were found were not inferior in growth or vigor to the unrotted plants. This was particularly true of the plants grown at temperatures below 28° C. In the lots grown at temperatures of 28° and 32° C. plants which showed wilting and tip burn at two-and-one-half to three weeks of age frequently were observed to show improvement at the end of four weeks. When taken up for examination the mesocotyls of these plants were found to be completely rotted off. The recovery of the plants was to be attributed to the appearance of the permanent roots from the lower nodes.

The results reported in Table II agree very well with those secured by Stover (18). But owing to the fact that Stover could not reisolate *F. moniliforme* from the infected tissues in all cases, and that other fungi were almost always present in such tissue, he did not consider the pathogenicity of *F. moniliforme* to be satisfactorily established. In the experiments reported above *F. moniliforme* was reisolated from diseased tissue in nearly all cases when plated. From this evidence there seems to be little doubt that *F. moniliforme* can cause serious injury at temperatures above 28° C. when other conditions are favorable. It also would appear that *F. moniliforme* is more virulent in sterile soil. Whether this is constant and whether it is due to biologic, chemical, or physical factors remains to be determined.

It was strongly suggested that the death or survival of infected plants depends upon the speed of the fungus in destroying or cutting off the temporary root system before the permanent roots begin to function. Referring again to the work of Stover (18) and Henry (5) we find the optimum temperatures for growth of this fungus in culture are given as 26°–33°C. respectively.

In searching for statistics on soil temperatures of the corn belt states it was found that there are few available. Swezey (19) at Lincoln, Nebraska, recorded the soil temperature through a period of twelve years. His tables show that at Lincoln the maximum temperature of the soil at a depth of three inches, during May, exceeded 26° C. only three times in twelve years. The mean temperature lay between 15°–24° C. For June the maximum ranged from 23.3°–40.5° C. and the mean from 19.5°–31° C. These are day temperatures. The night temperatures are lower, often by as much as 5°–8° C. If these statistics are representative of the corn belt, it appears that only on occasional years would soil temperature favor serious corn seedling injury due to *F. moniliforme*.

Conclusions.

It is clearly shown that *F. moniliforme* may grow parasitically within the growing stalk, but no effects, shown by broken and leaning stalks, are produced when infection occurs as late as August. No data as to the effect of earlier inoculation was secured.

The inoculation of ears demonstrates that this organism may grow externally on the kernels when moisture conditions are favorable. The area infected externally is usually very limited. The resistance to external molding of the kernels is greater when they have passed the dough stage.

As the possible cause of a seedling blight of corn its relations are interesting. It is present in a high percentage of Ohio seed corn. It was also isolated from the soil. But that it is an organism producing serious injury to corn seedlings at the normal soil temperatures for May and early June could not be demonstrated. The characteristic lesions produced by *F. moniliforme* on the mesocotyls are small, oval, yellowish areas, with a darker spot in the center in old lesions. On the roots the lesions are usually darker. At temperatures of 24° C. small rotted areas may be produced on the mesocotyl, usually close to the seed. At temperatures above 28° C. serious injury may occur.

Soaking the seed in mercuric chloride for two hours at room temperature or for ten minutes at 55° C. will completely disinfect lightly infected seed. No seed treatment was found which would give perfectly clean seed when infection was heavy.

The hot mercuric chloride treatment of seed retards germination a little, but apparently causes no real injury.

LITERATURE CITED.

1. BRANDSTETTER, B. B.
1922. Fungi internal of Missouri seed corn in 1921. *In* Jour. Amer. Soc. Agron. 14:354-357.
2. BURRILL, T. J., AND BARRETT, JAMES T.
1909. Ear rots of corn. Ill. Agr. Exp. Sta. Bul. 133, 109 p., 11 pl.
3. DUGGAR, B. F., AND DAVIS, A. W.
1919. The use of hypochlorites. *In* Annals Mo. Bot. Gard., v. 6, no. 2, p. 159-170.
4. HARTLEY, CARL, MERRILL, T. C., AND RHOADS, ARTHUR S.
1918. Seedling diseases of conifers. *In* Jour. Agr. Research, v. 15, no. 10, p. 521-558, 1 pl.
5. HENRY, A. W.
1923. The pathogenicity of *Fusarium moniliforme* Shel. on cereals. (Abstract). *In* Phytopathology, v. 23, no. 1, p. 52.
6. HOFFER, G. N., AND CARR, R. H.
1923. Accumulation of aluminum and iron compounds in corn plants and its probable relation to root rots. *In* Jour. Agr. Research, v. 23, no. 10, p. 801-823, 21 pl. Literature cited, p. 822-823.
7. HOFFER, G. N., JOHNSON, A. G., AND ATANASOFF, D.
1918. Corn-root rot and wheat scab. *In* Jour. Agr. Research, v. 24, no. 13, p. 611-612.

8. HOLBERT, J. R., AND HOFFER, G. N.
1920. Control of the root, stalk, and ear rot diseases of corn. U. S. Dept. Agr. Farmers' Bul. 1176, 24 p., 25 fig.

9. JONES, L. R.
1921. Experimental work on the relation of soil temperature to disease in plants. *In* Trans. Wis. Acad. Sci., Arts, and Letters 20: 433-459, illus.

10. MANNS, T. F., AND ADAMS, J. F.
1921. Prevalence and distribution of fungi internal of seed corn. *In* Science N. S., v. 54, no. 1399, p. 385-387.

11. MANNS, T. F., AND ADAMS, J. F.
1923. Parasitic fungi internal of seed corn. *In* Jour. Agr. Research, v. 23, no. 7, p. 495-524, 13 pl. Literature cited.

12. MELCHERS, L. W., AND JOHNSON, C. O.
1923. Corn root, stalk, and ear rot investigations in Kansas. (Abstract). *In* Phytopathology, v. 12, no. 1, p. 52.

13. PAMMEL, L. H., KING, C. M., AND SEAL, J. L.
1916. Studies on a *Fusarium* disease of corn and sorghum. Iowa Agr. Exp. Sta. Research Bul. 33, 136 p., 15 fig.

14. ROSEN, H. R.
1919. A bacterial root-rot of field corn. Ark. Agr. Exp. Sta. Tech. Bul. 162, 7 p., 4 pl. Bibliography, p. 6.

15. SHELDON, JOHN L.
1904. A corn mold. *In* Neb. Agr. Exp. Sta. 17th Ann. Report, p. 23-32, 1 pl.

16. SHERBAKOFF, C. D.
1922. *Fusaria* of wheat and corn. (Abstract). *In* Phytopathology, v. 12, no. 1, p. 45.

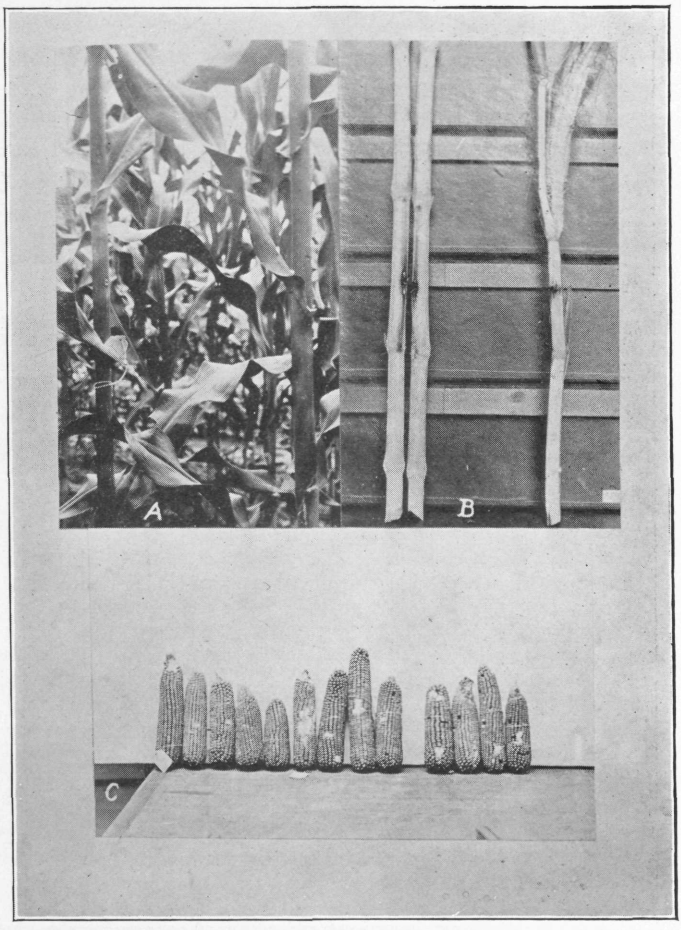
17. SHERBAKOFF, C. D.
1924. Common molds of corn seed in relation to yield. (Abstract). *In* Phytopathology, v. 14, no. 1, p. 46.

18. STOVER, W. G.
Relation of soil temperature to the development of certain fungous seedling blights of corn. Unpublished paper.

19. SWEZEY, G. D.
1903. Soil temperatures at Lincoln, Nebraska. *In* Neb. Agr. Exp. Sta., 16th Ann. Report, p. 95-102.

20. VALLEAU, W. D.
1920. Seed corn infection with *Fusarium moniliforme* and its relation to the root and stalk rots. Ky. Agr. Exp. Sta. Research Bul. 226, 51 p. Literature cited, p. 51.

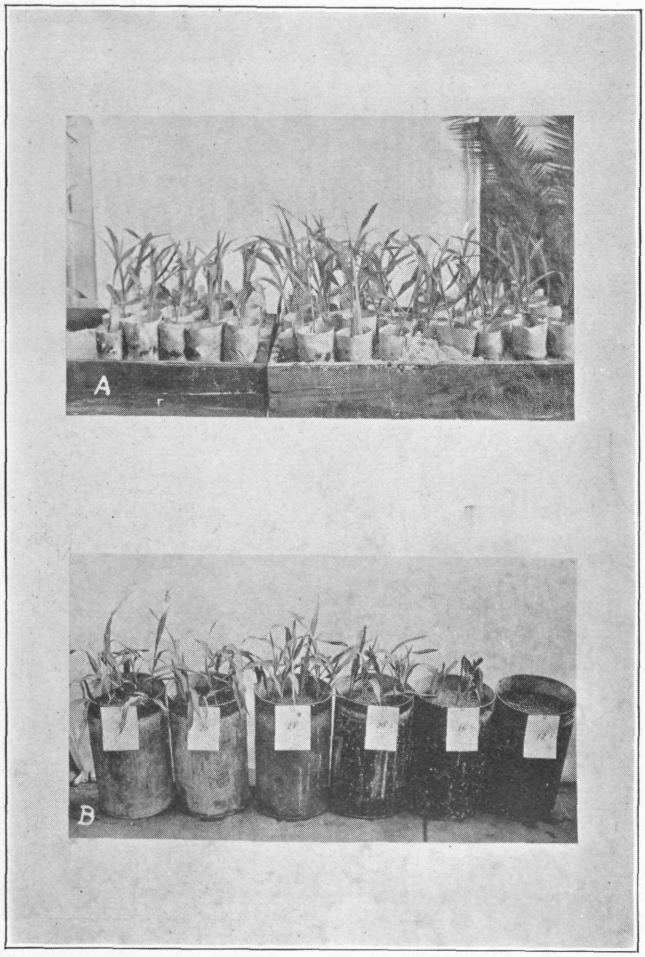
21. WINELAND, GRACE O.
1923. The production in culture of the ascigerous stage of *Fusarium moniliforme*. (Abstract). *In* Phytopathology, v. 13, no. 1, p. 57.



A. General appearance of plants inoculated in the young stalk. Left, inoculated plant. Right, control. Photo taken about two weeks after inoculation.

B. Stalks inoculated in the manner shown in "A" split for examination. Inoculated stalk at the left; check at the right.

C. The nine ears on the left were inoculated by spraying with a spore suspension through a slit in the husks; the four on the right by inserting *F. moniliforme* growing on an apple twig or sweet clover stem into a cavity made in the cob.



A. These plants show method of individual potting described under Seedling Inoculations. Tray at left contains control plants; right tray, the treated inoculated and naturally infected inoculated plants.

B. A series of treated inoculated plants from the soil temperature experiments. Note the weakness of the stalks at temperatures of 28 and 30 degrees C., shown by leaning.