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EVALUATION OF CORN GERMPLASM TO FUSARIUM MONILIFORME STALK ROT

by

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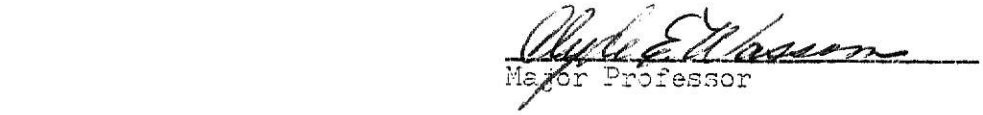

Major Professor

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Stalk rots are disease complexes caused by numerous species of fungi and bacteria and affect a multitude of crops. Stalk rot damage is of variable importance from region to region and season to season and occasionally, epiphytotics occurs over wide areas. Severity of stalk rot varies greatly as temperature, rainfall, soil drainage, soil type, available nutrients and other conditions change and interact. Production practices such as the genotype of seed planted, date of planting, crop sequence, fertilizer treatment and plant population have marked effects on severity of infection. Mechanical injury and insect damage generally enhances stalk rot severity.

In recent years, changes in cultural practices involving high plant populations and the liberal use of fertilizers has come about. These developments have resulted in greater yields and thus greater corn stalk strength is required. Stalks weakened by rot causing losses due to broken stalks and lodging. Therefore stalk rot is an important consideration in any corn improvement program.

In 1914, Pammel (37) described Fusarium disease of corn in Iowa. In many cases stalks were lodged, many were barren, and the pith of diseased corn stalks was soft and essentially destroyed. Tissues were brownish or reddish in color. It was stated that Fusarium disease was likely the most important problem in the corn growing area in Iowa. Today, Fusarium species, particularly Fusarium graminearum schwabe and Fusarium moniliforme (Sheldon), are considered among the most destructive fungi on corn causing stalk rot, seedling blight, root rot and ear rot. Stalk rot

is particularly noticeable as corn matures during September and October. Most frequently the infection progresses upward from the adventitious roots and crown into the stalk causing premature necrosis, chaffy or rotted ears, shank breakage, ear dropping and stalk breakage. This results in yield losses, poor grain quality and problems with harvesting. Losses due to stalk rot in Kansas are variable and were 8%, 13%, 7.5%, and 9% in 1977, 1978, 1979 and 1980, respectively (51).

The primary objective of this study was to ascertain tolerance in genotypes that can be utilized in breeding programs. To achieve this objective a considerable number of genetic sources were collected and screened by inoculating genetic sources with F. moniliforme under field conditions.

LITERATURE REVIEW

Pathogens and Symptoms

As early as 1896 and 1904, Moore (34) and Peters (42) reported on a wide spread disease of cattle and other animals known as the "stalk rot" disease. This disease occurred in the fall and early winter when cattle were grazing on corn stalks. Peters (40) suggested that the disease might have been caused by Fusarium spp. and the organism was described (47) as Fusarium moniliforme sheldon in Nebraska in 1904.

The confirmation of F. moniliforme as one of the major causes of stalk rot and seedling blight began with Valleau's work (57) in 1920. He isolated it from ears of corn showing a pink mold, and described it as "sporodochium, subeffuse, salmon-pink; sporophores, simple or branched, usually opposite microconidia, continuous, oblong - and generally with three septate, 25-40 μ long.

Factors that influence stalk rot development

Moisture and temperature

Stove (54) at Wisconsin studied temperature effects on growth of F. moniliforme in culture and reported that the optimum growth was obtained at 26°C - 33°C. Higher temperatures decreased growth with minimal growth at 37°C. Growth response was slight at 5° - 7°C, optimum at 30°C and slight at 36° - 36.5°C. (13).

Diplodia zea is another fungal irritant of corn stock rot and is most destructive in regions of heavy rainfall in late summer or during the late growing season (8). For stalk rot to develop, other conditions besides abundant precipitation must occur and they include: (a) sufficient

nutrients in the corn plant; (b) rapid growth of tissue; and (c) loosened leaf sheath. Presence of water between the leaf sheaths and the stalks is essential for germination of spores and growth of D. zea.

Although moisture is one of the most important factors, temperature also plays a significant role. Michaelson (32) increased the incidence of stalk rot in corn grown in the green house at a temperature of 30°C more than at 18°C when the plants were inoculated with Diploidia zeae and Giberella zeae.

Additionally, less stalk rot developed in the field in corn stalks inoculated with Diplodia zeae and Gibberella zeae when the plants were growing on wet soil, than on relatively dry soil (32). The plots were flooded with 7 to 10 cms of water about 2 weeks before inoculation. Plants inoculated and growing on non-flooded plots died 2 to 3 weeks after inoculation, whereas, those on wet ground remained green almost as long as the non-inoculated plants.

Soil Fertility

Soil fertility greatly influences the susceptibility of corn to stalk rot. Many workers now agree that stalk rot is more severe when nitrogen is in excess in relation to potassium (39, 34, 25, 26, 1). Accordingly, nitrogen tends to increase stalk rot severity and potassium tends to decrease it. Spencer and McNew (51) found that excess nitrogen and deficient potassium greatly increased bacterial wilt in sweet corn. Low phosphorous levels resulted in necrotic lesions, and at high levels dwarfing and necrosis resulted. Phosphorous has not been reported, in general, as an important factor affecting development of stalk rot. In a green house study, Thayer and Williams (56) found that phosphorous decreased severity of stalk rot

and concluded that high levels of phosphorous would protect corn against the disease. Koehler (27) concluded that potassium chloride fertilizer decreased stalk rot, but this was not true when potassium sulfate or potassium metaphosphate was used. It was suggested that the decrease in disease resulted from applying chloride and not from applying potassium.

Hoffer and Carr (14) found that an accumulation of aluminum and iron in the corn plant rendered the stalks more susceptible to invasion by stalk rot organisms. Lime did not influence the percentage of broken stalks, but did greatly decrease the percentage of leaning stalks (25). Otto and Everett (36) reported differences in stalk rot in corn hybrids growing in fertility plots though it was known that corn hybrids differ in their ability to utilize nutrients (29). The various studies on the influence of soil fertility on stalk rot have been made with naturally occurring stalk rot or with stalk rot resulting from inoculation with different stalk rotting organisms. None of the studies have attempted to show that the response to fertilizer might vary because of the pathogens. However, certain applications of fertilizer resulted in stalk rot being more severe when some corn hybrids were inoculated with one of the pathogens but not when inoculated with the other (5). White et al (59) reported that stalk rot from natural infection and stalk rot following inoculation with Diplodia maydis or Colletotrichum graminicola decreased with increasing nitrogen rates which he contributed to the continuous supply of nitrogen throughout the growing season.

Isolation, Inoculation and Data Collection

Foley (10, 12) reported that Fusarium moniliforme can be isolated from

kernels, roots, leaf sheaths, axillary buds and stalks of corn with the highest frequency of isolates from leaf sheaths. Similar results were reported by Kucharek and Kommedahl (28).

Numerous techniques utilized tolerance. Genotypes determined to be resistant to stalk rot when artificially inoculated may not necessarily maintain the resistance under natural infection. Zuber et al (65) found an inbred line resistant to stalk rot when inoculated with Gibberella zeae, but was susceptible to natural infection in Illinois (27). Others (2, 23, 30, 47, 52) reported progress in breeding for resistance to stalk rot on the basis of artificial stalk inoculation. Data obtained from inoculated genotypes is greatly influenced by the final reading date. Although most workers record stalk rot notes 3 to 4 weeks after inoculation, Koehler (27) and Hooker (17) concluded that final data on stalk rot ratings should not be taken until 3-4 weeks after inoculation.

Resistance

Resistance to stalk rot involves many physiological, morphological, and perhaps functional characteristics, which in turn may be influenced by many factors. No inbred or hybrid of corn has been reported to be immune to stalk rot. Certain hybrid varieties are now grown in the corn belt that appear to be moderately tolerant to stalk rot. Progress has been made on techniques for testing lines and varieties of corn, although there is no general agreement on the method of selecting for resistance. The development of varieties tolerant to stalk rot is the only practical method for controlling the disease (36). Numerous investigators (22, 47, 55) have reported pronounced variation in reactions of inbreds and hybrids.

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Resistance to one or more pathogens has been frequently reported, but there is no evidence that any variety is resistant to all stalk-rotting organisms. Varieties considered resistant to Diplodia stalk rot were reported to be very susceptible to bacterial stalk rot in Egypt (43). Kirmelasvili (24) reported that varieties resistant to F. moniliforme in eastern Georgia were susceptible in western Georgia. Mesterhazy (31) reported a highly significant correlation between root rot and basal stalk rot disease indices, based on natural infection, indicating that selection for resistant roots gives resistant or tolerant stalks. He also concluded that the stalk splitting method was less laborius than artificial inoculation. Sprague (52) stated that reaction of corn to Diplodia zeae provided a measure of resistance to stalk rot in general but Hooker (16) reported that varieties resistant to one pathogen were not necessarily resistant to other pathogens and resistant in one part of a plant does not insure resistance in other tissues. Similar results were reported by others (7, 41, 60, 62).

Open-pollinated corn varieties also differ in susceptibility to stalk rots. Sidorov et al (48) tested 38 inbreds, hybrids and varieties of corn for resistance to Diplodia zeae in Russia and reported marked difference in susceptibility. Flint corns were more resistant than dent corns. Sansom (44) reported that all local varieties in Rhodesia were susceptible to stalk rot, but improvement has been made by hybridization and selection.

According to Sprague (52), there are marked differences in frequency of genes for resistance to stalk rot in different varieties. Smith et al (50) indicated that dominant factors imparted resistance to Diplodia zeae. Jugenheimer (22) studied responses of several inbreds, single crosses and

top crosses of corn and reported that top cross progenies were more resistant than the inbreds involved. He also found some crosses were less resistant than the parental inbred line and concluded that, although resistance to stalk rots was complex and partially dominant, it appeared to be due to many factors. In addition, he reported that some inbreds were more potent in transmitting resistance than others.

Resistance to F. moniliforme appears to be polygenic in inheritance (19). Sarca et al (45) from Romania reported the type of inheritance of resistance to F. moniliforme as additive in nature. Younis et al (64) studied F_1 and F_2 and BC_1 and concluded that the two major gene pairs control reaction to the pathogen with resistance completely dominant over susceptibility and he also reported the heritability estimate for resistance as 0.73. Younis (62) also studied the interaction of "pathogenicity genes" in F. moniliforme and "reaction genes" in Zea mays and reported that the host genotype changes towards increased resistance, the pathogen races differ in different locations with the result that resistant lines in one location are susceptible in another. He further reported a significant host parasite interaction and suggested selecting resistant lines to the prevalent races of the pathogen only.

There are conflicting reports on the anatomical nature of resistance. Durrell (8, 9) indicated that resistant inbred lines contained more liquified tissue than did susceptible inbreds, especially in the lower nodes. Loesch et al (3) concluded that rind thickness was not affected by Diplodia zeae infection, but that the crushing strength of stalks from lodged and susceptible crosses was reduced. Black (3) concluded that standability of corn

was associated with a high number of vascular bundles in the fourth node above the soil. Even when the plants were partly rotted by Gibberella zeae, the number of vascular bundles appeared to give strength to the stalks. Pappelis (29) found that at the end of the growing season, the spongy pith tissue of lodged and stalk rot susceptible varieties was dead, but similar tissue in resistant, non-lodged varieties was alive. Foley (11) reported that cellulose occurred in corn plants whether susceptible and resistant to F. moniliforme.

Determination of Resistance

Various methods of testing to determine resistance of maize to stalk rot have been reported. Zwartz (66) reported that resistance should be determined by correlating the degree of stalk disintegration with average yield loss while Mesterhazy (31) concluded that selection for resistant roots would result in concomitant selection for resistant or tolerant stems.

Numerous investigators have reported that stalk rot is a disease of corn which develops as plants approach maturity (8, 15, 20, 25). Michaelson (32) obtained infection on all dates, but the earlier inoculations were much less effective than the later ones. He also showed that infection could occur long before pollination, and the fungi remain more or less dormant until the silking period. In addition, he suggested that after the plant has reached a certain stage of maturity, the resistance does not change. Sprague (52) and Jugenheimer (22) concluded that more stalk rot developed when inoculations were made at silking than at later dates. Sprague (52) stated that the greatest disease severity occurred when the plants are inoculated at the time of pollination. Hooker (18) made similar tests and

inoculated at the interval of 1 to 4 weeks after silking and obtained similar results. Results indicate that the exact timing of inoculation is not critical, hence one can inoculate a group of hybrid or inbred lines on the same date, even though they differ by as much as 10 days in flowering date. This assumes that the amount of diseased tissue is used as a basis of measuring resistance, and not premature dying of the stalks.

There is considerable evidence that rot severity depends on the internode in which the inoculation is made, but there is no general agreement on the exact internodes to inoculate in order to obtain the most efficient results, though most workers inoculate internodes below the ear. Hooker (18) inoculated four inbreds in the first, second, third, fourth, and fifth elongated internodes. Not all inbreds reacted alike to the inoculations at the different internodes. In the susceptible line, the diseased tissue was equally severe in the five inoculated internodes. In the resistant line, rot was least severe in internodes one and two, but increased progressively in the next three internodes, and in the fifth internode the rot was as severe as in the susceptible inbred. Cappellini (4) in New Jersey obtained progressively greater amount of rot with the distance up the stalk. Koehler (27) obtained the same amount of rot in all the three lower internodes. In another test he obtained more rot in the fourth internode than in the first. Christenson et al (5) reported that rot becomes progressively more severe in the internodes from the bottom to the top of the plant. Differences in susceptiblity among internodes may be due to differences in carbohydrate content. De Turk et al (6) found consistantly in single cross hybrids, less carbohydrates and lower total sugars in the lower part of the

stalk than in the middle part of normal plants.

Splitting the stalk and observing the rot is the most reliable method of determining both the amount of stalk rot and whether or not it resulted from natural infection or inoculation. Koehler (27) and others (21, 58, 4) measured both the extent of discolored pith and the number of rotten internodes. Hooker (18) used a disease scale from 1 to 6. Scores of 1 to 4 denoted rot confined to one internode; 5 indicated rot had spread into adjacent internodes; and 6, plants were killed.

MATERIALS AND METHODS

Field experiments were conducted during the 1979 and 1980 growing seasons at the KSU Agronomy Farm test site No. 1, the KSU Ashland Agronomy farm test site No. 2, Manhattan, Kansas and the CIMMYT[1/] research station at Tlaltizapan, Mexico, test site No. 3. The Kansas State University Agronomy farms are situated at about 39° 11' north latitude at about 310 M elevation with silty loam soils. Tlaltizapan, Mexico is located at 19°N latitude, about 950 M elevation and has a loamy clay soil type with an alkaline reaction. Sources and origin of the entries are presented in the Appendix.

Field Trials, 1979

In 1979, two experiments were conducted at the KSU Agronomy Farm, test site No. 2, under irrigated conditions.

Experiment No. 1

Over seventy genotypes including open pollinated varieties, inbred lines and hybrids were evaluated for tolerance to F. moniliforme with data collected from thirty-three entries. The experimental design was a randomized complete block design with two replications. Single row plots six meters long with seventy-five centimeters between rows and 25 cms between plants were used. Four plants were inoculated in each row at the 50% silking stage. Inoculations were performed at different dates because of the differences in silking time among genetic sources.

Experiment No.2

Twenty-five experimental hybrids were included in this study. Two row plots 3 meters long were planted in a randomized complete block design. The plants were inoculated at the 14-leaf and 50% silking stages of growth.

[1/] CIMMYT - International Corn and Wheat Improvement Center

One row of each plot was used for 14-leaf stage inoculation and the second row was used for 50% silking stage inoculation. Data were, therefore, analyzed as a split-plot design with growth stage comprising the subplot.

Field Trials, 1980

In 1980, experiments were conducted at three test sites. Sufficient seeds of the 1979 experiments No. 1 and 2 sources were not available, therefore, different genotypes were included in the 1980 study.

Experiment No. 3

Twenty-eight maize sources were used in this study, including open pollinated cultivars and experimental hybrids and was planted at Agronomy Farms No. 1 and No. 2 under non-irrigated and irrigated conditions respectively. Serious drought and high temperature climatic conditions were encountered in 1980, therefore plants were exposed to severe stress conditions throughout the growing period. Inoculations were done at the 50% silking stage.

A randomized complete block design with 3 replications and single row plots 5 meters in length were used.

Experiment No. 4

This experiment was conducted at the CIMMYT station at Tlaltizapan in Mexico. Twenty-eight maize germplasms were included in this test comprising most of the composite corn varieties from Nepal. This study utilized a randomized complete block design with two replications. The individual plots were two rows 5 meters long. Plots were irrigated as necessary.

Inoculations were done at 50% silking stage.

Inoculation Method

Fusarium moniliforme was isolated from infected corn stalks. The isolation and purification of the fungus was done by L. E. Claflin in the Dept. of Plant Pathology. The fungus was cultured at room temperature on potato dextrose agar (POA) plates. Mycelia and spores were lifted from the medium and suspended in distilled water. Spore suspension concentration was ascertained with a Hemacytometer and adjusted to 2×10^4 spores per milliliter with distilled water. The inoculum was prepared 30-60 minutes prior to inoculation. A B-D Cornwall leur-lok 10 ml syringe equipped with 16 gauge needle was used for inoculation. The tip of the needle was soldered shut and two holes were drilled in both sides of the needle near the tip. This partially eliminated clogging of the needle with stalk tissue. The syringe was fitted with a continuous pipetting device and 2 ml inoculum was injected into the second elongated internode above the brace roots. Four to 10 plants in each row of each experiment were inoculated.

At Tlaltizapan the inoculation was done by a CIMMYT technician and injections were made into the 4th internode from the base of each plant.

Evaluation

The stalk rot evaluation was done at physiological maturity. The inoculated plants were split lengthwise through the inoculated internode and the length of the infection was measured. Measurements for individual plants were averaged to obtain plot scores and analyzed statistically. Duncan's multiple range test was used for mean separation.

RESULTS AND DISCUSSION

Experiment No. 1

The reaction among entries to Fusarium moniliforme differed significantly as shown by analysis of variance, Table 1, in length of damage in the stalk due to infection. The mean infection lengths for each of the entries are shown in decreasing order in Table 2. Entry means ranged from 10.79 cms to 28.50 cms. Those entries designated by the same letter in Table 2 were not significantly different from each other at .05 probability level. No significant differences were found among entries 1 to 11, 2 to 15, 3 to 17, 4 to 25 and 8 to 33, Table 7. Nepal 103 had highest infection length of 28.50 cms while Fla 73-74:15 x 11 had the lowest infection length of 10.79 cms. The entries denoted by the letter "e" were classified as less susceptible and merit further testing.

Table 1. Analysis of Variance of Infection Lengths, Experiment No. 1.

Source of Variation	D.F.	SS	MSS	F Value
Entries	32	1475.0799	46.4087	2.87**
Replication	1	7.2800	7.2800	1.45
Error	32	517.9243		
TOTAL	65	2010.2842		

** = Statistically significant at the 1% level.

Although entries from serial numbers 8 to 33 do not differ significantly from each other, entries Nepal 104, Nepal 108, Fla 73-14:18 x 11, Gemiza 7421 and Fla 73-14:15 x 11 should be considered for further testing on the basis of

Table 2. Duncan's Multiple Range Test for Mean Infection Lengths, Experiment No. 1.

Entries	Mean Infection Length[1/]
1. Nepal 103	28.50a
2. Nepal 203	26.71 ab
3. Nepal 207	25.25 abc
4. Nepal 304	23.63 abcd
5. Nepal 202	23.27 abcd
6. Nepal 206	22.71 abcd
7. Nepal 105	22.71 abcd
8. Nepal 209	20.25 abcde
9. SJ1072-1x	19.88 abcde
10. Rampur 7433	19.83 abcde
11. Nepal 114	19.14 abcde
12. FLA 73-74:80 x 71	19.08 bcde
13. SJ 109-1 x	17.46 bcde
14. Nepal 210	17.35 bcde
15. FLA 73-74:70 x 61	17.31 bcde
16. Nepal 301	17.12 cde
17. Nepal 211	16.83 cde
18. Nepal 303	15.89 de
19. Amarillo BAJ10	14.87 de
20. FLA 73-74:50 x 41	14.83 de
21. Khumal (1)-7642	14.71 de
22. Amarillo TYFD	14.46 de
23. Nepal 107	14.44 de
24. Pirsabak 7447	14.25 de
25. FLA 73-74:19 x 11	14.13 de
26. Rampur 7434	12.69 e
27. Nepal 305	12.50 e
28. FLA 73-74:69 x 61	12.50 e
29. Nepal 104	12.34 e
30. Nepal 108	11.56 e
31. FLA 73-74:18 x 11	11.23 e
32. Gemiza 7421	10.81 e
33. FLA 73-74:15 x 11	10.79 e

[1/] Means followed by the same letter are not significantly different at the 0.05 level.

relatively lower infection length among the groups. Generally open pollinated cultivars from Nepal were found relatively more susceptible than the US sources and CIMMYT varieties.

Experiment No. 2.

Entries in this experiment were inoculated at two different stages; 50% silking and 14-leaf. The analysis of variances showed a significant difference between the stages (Table 3). The mean infection lengths of both stages of inoculation is presented in Table 4. The incidence of stalk rot was relatively higher at 50% silking stage than 14-leaf stage. A high incidence of stalk rot development was also reported by Jugenheimer (22) and Sprague (52) at 50% silking stage. The interaction between stages and

Table 3. Analysis of Variance of Infection Lengths, Experiment No. 2.

Source of Variation	D.F.	SS	MSS	F Value
Entries	24	1130.1828	47.0909	2.24**
Replication x Ent.	72	1510.5972	20.9805	
Stage	1	269.5842	269.5842	18.29**
Stage x Ent.	24	385.8408	16.0787	1.09
Error (b)	75	1105.6050	14.7414	

** = Statistically significant at the 1% level.

entries was not significant indicating that certain entries were relatively highly susceptible or less susceptible irrespective of the inoculation stages, which can be shown by the mean infection lengths presented in Table 4.

The mean infection lengths of both stages are presented in decreasing order in Table 4. Means ranged from 9.64 cms to 18.10 cms in length. The experimental hybrid No. 3 was found highly susceptible while No. 6 was the least. No significant differences were found among the entries from serial

Table 4. Mean infection-lengths of damage resulting from inoculation at two stages of growth, Experiment No. 2.

Entries	14 Leaf Stage	50% Silking Stage	Mean[1/]
1. Experimental hybrid No. 3	15.50	20.70	18.10a
2. Mo 17 x B68	13.80	22.25	18.03ab
3. Experimental hybrid No. 16	13.87	20.75	17.31abc
4. VA 26 B73	15.55	17.13	16.34abcd
5. Experimental hybrid No. 22	12.47	18.35	15.41abcde
6. Experimental hybrid No. 21	14.38	15.70	15.04abcdef
7. Experimental hybrid No. 8	13.72	15.10	14.41abcdef
8. Experimental hybrid No. 9	12.27	16.43	14.35abcdef
9. Experimental hybrid No. 15	10.75	16.70	13.73abcdef
10. Experimental hybrid No. 19	16.00	10.48	13.24abcdef
11. Experimental hybrid No. 2	11.33	14.00	12.66bcdef
12. Experimental hybrid No. 13	12.05	13.23	12.64bcdef
13. Experimental hybrid No. 12	10.97	13.75	12.36cdef
14. Experimental hybrid No. 7	12.65	12.00	12.33cdef
15. Experimental hybrid No. 10	11.65	12.88	12.26cdef
16. Experimental hybrid No. 5	10.70	13.30	12.00cdef
17. Experimental hybrid No. 16	9.70	14.28	11.99cdef
18. Experimental hybrid No. 4	11.27	12.55	11.91cdef
19. Experimental hybrid No. 18	11.28	12.48	11.88cdef
20. Experimental hybrid No. 1	10.90	12.45	11.68def
21. Experimental hybrid No. 23	11.08	10.75	10.91def
22. Experimental hybrid No. 17	9.85	10.68	10.26ef
23. Experimental hybrid No. 20	9.45	11.08	10.26ef
24. Experimental hybrid No. 11	9.28	11.08	10.18ef
25. Experimental hybrid No. 6	9.40	9.88	9.64f

[1/] Means followed by the same letter are not significantly different at the 0.05 level.

numbers 1 to 10, 2 to 12, 3 to 19, 4 to 21, 5 to 24 and 6 to 25. However entries denoted by letter "f" in Table 4 were classified as less susceptible genotypes and should be considered for further testing. Though a nonsignificant difference was found among entries from serial number 6 to 25, only the entries having the relatively low incidence of stalk rot should be considered relatively a less susceptible one. Thus experimental hybrids No. 17, No. 20, No. 11 and No. 6 can be rated as relatively resistant than other entries among the groups. The check hybrids (Mo 17 x B68) and (Va 26 x B 72) were found relatively more susceptible than other sources tested.

Experiment No. 3.

The incidence of stalk rot was relatively higher under irrigated conditions as compared to the non-irrigated condition at the Agronomy Farm, test site No. 1. This may have been attributable to higher soil moisture and higher humidity in the corn field coupled with high temperatures in the post inoculation period. Twenty-eight entries were grown at both locations but data from only twenty entries were used for the combined analysis. The analysis of variance of combined data is shown in Table 5.

Table 5. Combined Analysis of Variance of Infection Lengths, Experiment No. 3.

Source of Variation	D.F.	SS	MSS	F Value
Location	1	344.5257	344.5257	41.82**
Entries	19	978.7936	51.5155	2.43**
Rep (Loc)	4	32.9504	8.2376	
Entries x Location	19	363.1709	19.1143	0.90
Error (b)	76	1608.4310	21.1636	

** = Statistically significant at the 1% level.

Significant differences in infection lengths were obtained between locations. The entry x location interaction was not significant, which can be seen from means presented in Table 6. The combined means of both locations are presented in decreasing order in Table 7. Means ranged from 10.91 cms to 20.92 cms. O's Gold SX 5500 A was highly susceptible while (OH7B x Hy) x 1522 was the least. No significant difference was found among entries 1 through 7, 2 to 14, 4 to 15 and 5 to 20, Table 7. Thus the entries denoted by "d" were classified at least susceptible and probably should be considered for further testing. Entries from serial number 5-20 do not differ significantly, but entries (K55 x H28) x 1505, (k731 x OH7B) x 1518, (K41 x K731) x 1524, (SD10 x ZAP) x 1505 and (OH7B x Hy) x 1522 were considered less susceptible on the basis of low incidence of stalk rot found in them, Table 7.

The data of individual locations were also analyzed separately. The analysis of variance for the irrigated test is presented in Table 8 and of non-irrigated in Table 9. Entries were found highly significant at both locations. The mean infection lengths under irrigated condition ranged from 11.66 cms to 26.97 cms; P1270093 being the most highly susceptible and the P1270071 the lowest, Table 10. Under non-irrigated condition the mean infection length ranged from 8.67 cms to 21.23 cms; Asgrow Rx 901 was highly susceptible and (SD10 x Zap) x 1505 the least, Table 11.

Experiment No. 4.

Genotypes were found significantly different in infection length at 10% level of significance, Table 12. The mean infection lengths of twenty-eight sources are presented in Table 13 in decreasing order and ranged from 7.5 cms to 15.13 cms. Those genotypes denoted by the same letter do not differ significantly at 10% level of significance. Those falling in the group

Table 6. Mean Infection Lengths of Entries at Two Different Locations in centimeter, Experiment No. 3.

Entries	Irrigated	Non-irrigated
1. O's Gold sx 5500A	22.61	19.24
2. PAG sx 333	24.97	13.73
3. Asgro RX 901	17.04	21.23
4. Acco UC 8951	22.10	15.62
5. (SD10 x 2 AP) x 1527	18.00	14.30
6. Northrup King x Pa-74	16.34	14.43
7. Pioneer Brand 3183	18.37	11.97
8. PI 270076	15.17	14.80
9. PI 270082	14.13	15.18
10. BoJac 923	14.02	14.46
11. Cargil 967	16.05	11.80
12. Prairie V818	16.46	10.61
13. Ring Around-RA 1502	15.23	11.60
14. (K64A x K12) x 1516	17.57	9.23
15. (H28 x K64) x 1511	12.07	13.23
16. (K55 x H28) x 1505	13.90	10.50
17. (K731 x OH7B) x 1518	14.20	9.40
18. (K41 x K731)x 1524	13.53	9.30
19. (SD10 x ZAP) x 1505	13.40	8.67
20. (OH7B x Hy) x 1522	11.87	9.96

Table 7. Duncan's Multiple Range Test for Mean Infection Lergths Combined, Experiment No. 3 [1]

Entries	Mean Infection Length [2]
1. O's Gold SX 5500A	20.92 a [3]
2. PAG SX 333	19.35 ab
3. Asgro R x 901	19.14 ab
4. Acco UC 8951	18.86 abc
5. (SD 10 x 2 AP) x 1527	16.15 abcd
6. Northrup King x Px-74	15.39 abcd
7. Pioneer Brand 3183	15.17 abcd
8. PI 270076	14.98 bcd
9. PI 270082	14.55 bcd
10. BoJac 923	14.24 bcd
11. Cargil 967	13.93 bcd
12. Prairie V818	13.53 bcd
13. Ring Around-RA 1502	13.42 bcd
14. (K64A x K12) x 1516	13.40 bcd
15. (H28 x K64) x 1511	12.65 cd
16. (K55 x H28) x 1505	12.20 d
17. (K731 x OH7B) x 1518	11.80 d
18. (K41 x K731) x 1524	11.42 d
19. (SD10 x ZAP) x 1505	11.03 d
20. (OH7B x Hy) x 1522	10.91 d

[1] Twenty entries which were common at both locations are included in the combined analysis.

[2] Mean of two locations.

[3] Means followed by the same letter are not significantly different at the 0.05 level.

Table 8. Analysis of Variance of Infection Lengths, Irrigated, Experiment No. 3.

Source of Variation	D.F.	SS	MSS	F Value
Replication	2	14.5995	7.2997	0.33
Entries	27	1197.2837	44.3438	1.98**
Error	54	1208.1861	22.3738	
TOTAL	83			

** = Statistically significant at the 1% level.

Table 9. Analysis of Variance of Infection Lengths, Non-irrigated, Experiment No. 3.

Source of Variation	D.F.	SS	MSS	F Value
Replication	2	22.5397	11.2698	0.84
Entries	19	639.1901	33.6416	2.49**
Error	38	512.66796	13.4913	
TOTAL	59	1174.3978		

** = Statistically significant at the 1% level.

designated by the letter "f" were placed in the less susceptible category and require further testing. Although entries 9 through 28 do not differ significantly, only the entries Hetauda composite, Amarillo BAJIO, Suwan S.9, (VPI x SU) x Mal composite, Pirsaba, 7442 and Khumal (1) 7633 were considered relatively less susceptible on the basis of low incidence of stalk rot.

Table 10. Duncan's Multiple Range Test for Mean Infection Lengths, Experiment No. 3, Irrigated.

Entries	Mean Infection Length [1] in Centimeter
1. PI 270093	26.97 a
2. PAG SX 333	24.97 ab
3. O's Gold sx 5500A	22.61 abc
4. Acco UC 8951	22.10 abc
5. Pioneer Brand 3183	18.37 abcd
6. PI 270085	18.33 abcd
7. PI 270075	18.10 abcd
8. (SD10 x AP) x 1527	18 00 abcd
9. PI 270077	17.57 bcd
10. (K64A x K12) x 1516	17.57 bcd
11. Asgro Rx 901	17.04 bcd
12. Prairie V818	16.46 bcd
13. Northrup King x Px-74	16.34 bcd
14. Cargil 967	16.05 bcd
15. K55 x H28	15.67 bcd
16. Ring Around RA 1502	15.23 cd
17. PI 270076	15.17 cd
18. PI 270096	15.16 cd
19. (K731 x OH7B) x 1518	14.20 cd
20. PI 270082	14.15 cd
21. BoJac 923	14.02 cd
22. (K55 x H28 x 1505	13.90 cd
23. (K41 x K737) x 1524	13.53 cd
24. (SD10 x ZAP) x 1505	13.40 cd
25. (H28 x K64) x 1505	12.07 d
26. (OH7B x Hy) x 1522	11.87 d
27. (K55 x H28) x 1511	11.80 d
28. PI 270071	11.66 d

[1] Means followed by the same letter are not significantly different at the 0.05 level.

Table 11. Duncan's Multiple Range Test for Mean Infection Lengths, Experiment No. 3, Non-irrigated.

	Entries	Mean Infection Length[1] in Centimeter
1.	Asgro R x 901	21.23 a
2.	O's Gold sx 5500A	19.24 ab
3.	Acco Uc 8951	15.62 abc
4.	PI 270082	15.18 abc
5.	PI 270076	14.73 abc
6.	BoJac 923	14.46 abc
7.	Northrup King Px-74	14.43 abc
8.	(SD10 x 2 AP) x 1527	14.30 bc
9.	PAG sx 333	13.73 bc
10.	(H28 x K64) x 1511	13.23 c
11.	Pioneer Brand 3183	11.96 c
12.	Cargil 967	11.80 c
13.	Ring Around RA 1502	11.60 c
14.	Prairie V818	11.61 c
15.	(K55 x H28) x 1505	10.50 c
16.	(OH7B x Hy) x 1522	9.96 c
17.	(K731 x OH7B) x 1518	9.40 c
18.	(K41 x K731) x 1524	9.30 c
19.	(K64A x K12) x 1516	9.23 c
20.	(SD10 x ZAP) x 1505	8.67 c

[1] Means followed by the same letter are not significantly different at the 0.05 level.

Table 12. Analysis of Variance of Infection Lengths, Tlaltizapan, Mexico.

Source of Variation	D.F.	SS	MSS	F Value
Replication	1	1.2421	1.2421	0.43
Entries	27	141.2111	5.2300	1.79***
Error	27	78.8386	2.9199	
TOTAL	55	221.2918		

*** = Statistically significant at the 10% level.

It is suggested that a procedure to upgrade resistance among those materials rated least susceptible would be to grow a large number of rows, inoculate at 50% silking stage, and sib pollinate among resistant plants. Considerable improvement in the level of resistance might be expected in one or two cycles. This procedure would also permit retention of the original genotypes without much dilution.

A general occurrence of corn borer larvae tunnels were found in the inoculated internodes. It is suspected that holes punched during inoculation by the needle might have provided easy entry of the larvae to the stalk. Most of the early maturing inbred lines and some of the PI lines were found totally rotten and as a result, no infection lengths were recorded.

In general the inoculated plants were not severely damaged by natural infection of any other corn diseases. Plate I and II of the Appendix illustrate the corn stalk reactions to artificial inoculation under field conditions.

Table 13. Duncan's Multiple Range Test for Mean Infection Lengths, Experiment No. 4.

	Entries	Mean Infection Length[1] in Centimeter
1.	Kakani Yellow (Local)	15.125 a
2.	Rampur Mix	13.040 ab
3.	Kathmandu Yellow (Local)	12.725 abc
4.	Obregon 7443	11.855 bcd
5.	Khumal Yellow	11.725 bcd
6.	Kakani Yellow	11.725 bcd
7.	Ganesh-2	11.375 bcde
8.	PI 175334	11.350 bcde
9.	PI 172333	10.750 bcdef
10.	UNCAC	10.675 bcdef
11.	Rampur Yellow	10.660 bcdef
12.	Sarlahi Seto	10.650 bcdef
13.	Rampur Composite	10.550 bcdef
14.	Mix Composite	10.550 bcdef
15.	Ganesh-2	10.475 bcdef
16.	Suwan-1 S10	10.225 bcdef
17.	CIMMYT Mix	10.100 bcdef
18.	Mankamna	9.950 bcdef
19.	Pirsabak 7447	9.725 bcdef
20.	Janaki	9.450 cdef
21.	Pozarica 7525	9.425 cdef
22.	Amarillo Pakisatan	9.400 cdef
23.	Hetauda Composite	9.050 def
24.	Amarillo BAJ10	8.775 def
25.	Suwan S. 9.	8.750 def
26.	(VPI x SU) x Mat Comp. (11)	8.425 ef
27.	Pirsabak 7442	8.174 ef
28.	Khumal (1) 7633	7.500 f

[1] Means followed by the same letter are not significantly different at the 0.10 level.

SUMMARY AND CONCLUSIONS

1. Several corn germplasm sources including open pollinated varieties, composites, hybrids and inbred lines were tested for resistance to stalk rot Fusarium moniliforme, at Kansas State University, Manhattan, Kansas and Tlaltizapan, (Mexico).

2. Experiments were conducted in a randomized complete block design replicated two and three times depending on the availability of seed. Four to ten plants in each row were inoculated at 2nd internodes from the brace roots at the rate of 20,000 spores per millilitre.

3. Evaluation was done by splitting the stalk and measuring length of infection in centimeters.

4. On the basis of one year's data twenty of the entries were classified as relatively resistant (less susceptible) to F. moniliforme under Manhattan, Kansas and Tlaltizapan, Mexico conditions.

5. Stalk rot development was found to be higher under irrigated conditions than non-irrigated.

6. Comparatively higher infection of stalk tissue was observed when plants were inoculated at 50% silking stage than 14-leaf stage.

7. Further testing of the entries classified as resistant (less susceptible) is needed to confirm their level of resistance, to study the mode of inheritance, and to increase levels of resistance through breeding.

8. Among various Nepalese germplasms, Nepal 104, Nepal 108 and Hetauda composite were found relatively resistant to Fusarium stalk rot.

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APPENDIX

Table 1. Pedigrees, origin and source of seed of entries in experiment No. 1.

ENTRY NO.	PEDIGREE	ORIGIN	SOURCE
1.	NEPAL 103	NEPAL	CIMMYT[1/]
2.	NEPAL 203	"	"
3.	NEPAL 207	"	"
4.	NEPAL 304	"	"
5.	NEPAL 202	"	"
6.	NEPAL 206	"	"
7.	NEPAl 105	"	"
8.	NEPAL 209	"	"
9.	SJ1072-1 x	"	"
10.	RAMPUR 7433	"	"
11.	NEPAL 114	"	"
12.	FLA 73-74 : 80 x 71	KANSAS	KSU MAIZE PROJ.
13.	SJ 109-1	"	"
14.	NEPAL 210	NEPAL	CIMMYT
15.	Fla 73-74 : 70 x 61	KANSAS	KSU MAIZE PROJ.
16.	NEPAL 301	NEPAL	CIMMYT
17.	NEPAL 211	"	"
18.	NEPAL 303	"	"
19.	AMARILLO BAJIO	CIMMYT	"
20.	FLA 73-74 : 50 x 41	KANSAS	KSU MAIZE PROJ.
21.	KHUMAL (7642)	NEPAL	CIMMYT
22.	AMARILLO TYED	CIMMYT	"
23.	NEPAL 107	NEPAL	"
24.	PIRSABAK 7447	CIMMYT	"
25.	FLA 73-74 : 19 x 11	KANSAS	KSU MAIZE PROJ.
26.	RAMPUR 7434	NEPAL	CIMMYT[1/]
27.	NEPAL 305	KANSAS	KSU MAIZE PROJ.
28.	FLA 73-74 : 69 x 61	"	"
29.	NEPAL 104	NEPAL	CIMMYT
30.	NEPAL 108	"	"
31.	FLA 73-74 : 18 x 11	KANSAS	KSU MAIZE PROJ.
32.	FLA 73-74 : 15 x 11	KANSAS	KSU MAIZE PROJ.

[1/] International Maize and Wheat Improvement Centre, Mexico.

Table 2. Sources of seed of experimental hybrid in experiment No. 2.

ENTRY NO.	ENTRIES	SOURCE
1.	Experimental hybrid No. 1	7-9292 x 7-9338 Ear 1
2.	Experimental hybrid No. 2	7-9292 x 7-9338 Ear 2
3.	Experimental hybrid No. 3	7-9292 x 7-9338 Ear 3
4.	Experimental hybrid No. 4	7-9292 x 7-9338 Ear 4
5.	Experimental hybrid No. 5	7-9289 x 7-9290 Bulk
6.	Experimental hybrid No. 6	7-9274 x 7-9247 Bulk
7.	Experimental hybrid No. 7	7-9276 x 7-9247 Ear 1
8.	Experimental hybrid No. 8	7-9208 x 7-9234 Ear 1
9.	Experimental hybrid No. 9	7-9251 x 7-9257 Ear 1
10.	Experimental hybrid No. 10	7-9233 x 7-9236 Ear 1
11.	Experimental hybrid No. 11	7-9233 x 7-0236 Ear 2
12.	Experimental hybrid No. 12	7-9233 x 7-0236 Ear 4
13.	Experimental hybrid No. 13	7-9205 x 7-9207 Ear 2
14.	Experimental hybrid No. 14	7-9205 x 7-9208 Ear 1
15.	Experimental hybrid No. 15	7-9282 x 7-9274 Ear 3
16.	Experimental hybrid No. 16	7-9200 x 7-9203 Ear 1
17.	Experimental hybrid No. 17	7-9200 x 7-9203 Ear 2
18.	Experimental hybrid No. 18	7-9269 x 7-9285 Ear 1
19.	Experimental hybrid No. 19	7-9269 x 7-9285 Ear 2
20.	Experimental hybrid No. 20	7-9269 x 7-9285 Ear 3
21.	Experimental hybrid No. 21	7-9277 x 7-9280 Ear 1
22.	Experimental hybrid No. 22	7-9277 x 7-9280 Ear 2
23.	Experimental hybrid No. 23	7-9285 x 7-9339 Ear 3
24.	VA 26 x B 73	
25.	MO 17 x B 68	

Table 3. Pedigree, origin and sources of seed of entries in experiment no. 3.

Entry No.	Pedigree	Origin
1.	PI 270093	West Pakistan
2.	Pag SX 333	USA
3.	O's Gold SX 5500A	"
4.	Acco UC 8951	"
5.	Pioneer Brand 3183	"
6.	PI 270085	West Pakistan
7.	PI 270075	"
8.	(SD10 x ZAP) x 1527	USA
9.	PI 270077	West Pakistan
10.	(K64A x K12) x 1516	Kansas and Mississippi
11.	AC x 901	USA
12.	Prairie Valley V 818	USA
13.	Northrup-King PX-74	"
14.	Cargill 967	"
15.	K55 x 428	"
16.	Ring a Round RA 1502	"
17.	PI 270076	West Pakistan
18.	PI 270096	"
19.	(K731 x OH7B) x 1518	Mississippi
20.	PI 270082	West Pakistan
21.	Bojac 923	USA
22.	(K55 x H28) x 1505	Mississippi
23.	(K41 x K737 x 1524	Mississippi
24.	(SD10 x 2AP) x 1505	"
25.	(H28 x K64) x 1505	"
26.	OH7B x HY) x 1522	"
27.	(K55 x H28) x 1511	"
28.	PI 270071	West Pakistan

Table 4. Pedigree, origin and sources of seed of entries in experiment No. 4. (Tlaltizapan Mexico, 1980)

Entry No.	Pedigree	Origin	Source
1.	Kakani Yellow (local)	Nepal	Nepal
2.	Rampur Mix	"	"
3.	Kathmandu Local (yellow)	"	"
4.	Obregon 7443	"	"
5.	Khumal Yellow	"	"
6.	Kakani Yellow	"	"
7.	Ganesh-2 (1978)	"	"
8.	PI 175334	Australia	Pi Amex Iowa
9.	PI 172333	"	"
10.	Uncac	Nepal	Nepal
11.	Rampur Yellow	"	"
12.	Sarlahi Seto	"	"
13.	Rampur Composite	"	"
14.	Met. Composite	"	"
15.	Ganesh-2	"	"
16.	Suwan-1 S10	"	Thailand
17.	Cimmyt Mix	"	Nepal
18.	Mankamna	"	"
19.	Pirsabak 7447	Nepal	Cimmyt
20.	Janaki	"	Nepal
21.	Pozarica 7525	Nepal	Cimmyt
22.	Amarillo Pakistan	"	"
23.	Hetauda Composite	"	Nepal
24.	Amarillo Bajio	Nepal	Nepal
25.	Suwan S9	Nepal	Thailand
26.	(VPI x SU) x Mal Comp. (11)	"	Cimmyt
27.	Pirsabak 7442	"	"
28.	Khumal (1) 7633	"	"

THIS BOOK CONTAINS NUMEROUS PAGES THAT WERE BOUND WITHOUT PAGE NUMBERS.

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Plate I: Examples of two genotypes of corn which were heavily damaged following inoculation with Fusarium moniliforme. These were classified as highly susceptible.


#6


NORTHROP KING
PX-74
#15

Plate II: Examples of two genotypes of corn which expressed relatively light damage following inoculation with Fusarium moniliforme. These were classified as resistant (less susceptible).


10x2 APACHE
#21


270076
#4

EVALUATION OF CORN GERMPLASM TO FUSARIUM MONILIFORME STALK ROT

by

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AN ABSTRACT OF A MASTER'S THESIS

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Several corn germplasm sources including open pollinated varieties, composites, hybrids and inbred lines were tested for resistance to stalk rot, Fusarium moniliforme, at Kansas State University, Manhattan, Kansas and Tlaltizapan (Mexico). Experiments were conducted in a randomized complete block design replicated two and three times depending on the availability of seed. Four to ten plants in each row were inoculated at 2nd internode from the brace roots at the rate of 20,000 spores per millilitre. Evaluation was done by splitting the stalk and measuring lengths of infection in centimeters. On the basis of one year's data, twenty of the entries were classified as relatively resistant (less susceptible) to Fusarium moniliforme under Manhattan, Kansas and Tlaltizapan, Mexico conditions.

Plants grown under irrigated conditions had a higher stalk rot development than those grown on non-irrigated land. The mean infection lengths were found to be higher in the plants innoculated at the 50% silking stage than at the 14-leaf stage. Further testing of the entries classified as resistant (less susceptible) is needed to confirm their level of resistance, to study the mode of inheritance, and to attempt to increase levels of resistance.