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A COMPARISON OF MAIZE DISEASES IN TEMPERATE AND IN TROPICAL ENVIRONMENTS

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A COMPARISON OF MAIZE DISEASES IN TEMPERATE AND IN TROPICAL ENVIRONMENTS[1/]

by
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ABSTRACT

Maize is produced primarily in temperate and warm-temperate zones of the world, but its production is increasing in many tropical regions. Some diseases are common to both of these environmental zones, eventhough their importance may vary greatly. Other diseases are confined to a single zone. The important factors influencing the geographical distribution of maize diseases and some of their vectors are temperature, moisture, cultural practices, and the type and diversity of maize germplasm used. The Sclerospora-incited downy mildew diseases, late wilt, banded leaf and sheath blight, and Rhizoctonia, Botryodiplodia, and gray ear rots occur only in the tropical zone and the warm, temperate areas, while southern rust, Pythium and bacterial stalk rots, Curvularia leaf spot, and ear rot caused by *Dilplodia macrospora* are much more prevalent there, occurring only occassionally beyond 34°north or south latitude. Conversely, bacterial wilt, eye spot, and yellow leaf blight have been found to occur only in the temperate zones. Ergot has been found only in a few locations at high elevation (2500-2700 meters) in Central Mexico. Northern leaf blight, common rust, and stalk and ear rots caused by *Diplodia maydis* and *Gibberella zeae* prevail in the temperate zones and at high elevations and in winter seasons within tropical latitudes.

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1.1 INTRODUCTION

Maize production is largely in temperate areas, but rather recently its culture in tropical as well as subtropical climates has increased markedly (Tables 1 and 2). This increase is due mainly to the development of high-yielding, adapted hybrids and open-pollinated varieties. Some of these are susceptible to certain diseases, and genetic modification of them is underway to incorporate resistance to important diseases that reduce yield and quality.

Improved cultural practices, including increased use of fertilizers, are equally important in boosting maize production in several of the tropical and subtropical countries, and the dissemination of technological information and the training of personnel to coordinate these newer methods and materials have been major forces, also.

1.11 Comparison of Plant Characteristics: Tropical vs Temperate Climates.

By way of orientation, certain general differences in the plant characteristics of maize grown in the tropics should be compared with those grown in the temperate latitudes. Much of the maize in the tropics has a flinty endosperm whereas that grown in the temperate climates has a starchy kernel. However, there are exceptions: Argentina produces flinty, deep, orange-colored maize in its warm-temperate areas. Tropical maize usually possesses a long, tight husk; this affords some protection against insects, but it may also be a partial barrier against invasion by fungi. Maize grown in temperate climates usually has shorter and more open husks which is well adapted to mechanical picking as practiced there. Long tight-husked maize does not "pick clean" with mechanized harvesting equipment.

Lowland, tropical maize varieties are about a meter taller, later in maturity, have a higher leaf number per plant, and are lower yielding under the conditions grown than temperate types. The increased plant height makes management more difficult, mainly because of lodging.

Direct introduction of temperate types to the tropics has not been successful, due largely to high disease and insect susceptibility. Hybridization of the types has been more successful, although the gene dosage of the tropical types must be kept well above 50% to assure adequate resistance. There have been several successful efforts during the past 4 years in shortening plant height of tropical varieties.

The reasons why maize yields less grain in the tropics than in the temperate areas are not fully known, but appear to be due to shorter day length, less intense light, higher night temperatures and, perhaps, plant architecture. Certainly, much higher yields are possible at high elevation and during the dry, higher light-intensity winter seasons, under irrigation in the humid tropics; less disease also occurs in the latter case, and there is better control of insect pests, weeds, and water.

The genetic diversity of maize in the tropics is much greater than in the vast maize-growing areas in temperate climates. Open-pollinated composites, synthetics, and inter-varietal crosses are becoming more popular in the tropics because of their excellent yield records combined with seed production methods well adapted to these areas. In the temperate climates, single-cross hybrids are, by far, in greatest production. This difference of diversity vs uniformity can be an important factor in disease development and spread. An example of the effects of extreme uniformity, in this instance cytoplasmic rather than nuclear, was the rapid spread of the destructive southern corn leaf blight epidemic over the maize crop of the United States in 1970. Here nearly 90% of the crop was of Texas male-sterile cytoplasm which is hyper-susceptible to Race T of *Helminthosporium maydis*.

Cultural practices for maize differ in the two environments: much of the maize in the tropics is produced with hand labor; whereas in the extensive corn belt of the north and in most of the south-temperate areas, maize production is mechanized. Generally, row spacing is narrower in temperate areas and there has been a marked trend toward higher plant populations per unit of land. This practice, coupled with higher applications of fertilizer (especially nitrogen) has influenced certain maize diseases in the temperate maize-growing areas. The continuous cropping of maize throughout the year in some tropical regions permits the maintenance of a high inoculum potential. Where there is an intervening cold season between maize crops (as in the temperate zones), or even a dry period (as in some of the tropics), the inoculum tends to be depleted and then build up again with the onset of the maize-planting season. A practice in some warm-temperate areas of the Southern hemisphere of letting maize stand in the field long after maturity tends to increase losses from ear rots and stalk rots.

2.1 DISTRIBUTION OF SPECIFIC MAIZE DISEASES IN TROPICAL VERSUS TEMPERATE ENVIRONMENTS :

Seedling blights and kernel rots of maize may become prevalent in temperate zones under the stress of cold, wet soil at planting time or soon after. Under such conditions germination is slow and certain fungus pathogens are able to invade the seed or seedling. However, in these temperate areas treatment of seed with a fungicide is a general practice that minimizes these diseases to a point where they are seldom of economic importance. These fungicides protect the seed in the soil, but have little effect on internally-borne infections. Several species of *Pythium* cause seedling blights and seed rots of maize when planted in cold, wet soil. A number of the ear rot pathogens, if established within the seed, are capable of inciting these diseases. The generally high quality of maize seed produced in temperate climates is another factor that has reduced the hazard of seed infection. Conversely, maize is planted in warm soils in the humid tropics, such as India, Thailand and the Philippines, almost always without fungicidal seed treatment. Plants emerge in 2 to 3 days and kernel rot and seedling blight are much less than in the temperate climates. In the humid tropics, some species of *Pythium*, notably *P. aphanidermatum*, may cause seedling blight. The ear rot fungi found in the tropics are often associated with seed rot and seedling blight as a result of using seed infected with these pathogens.

Leaf diseases are among the most economically-important maladies of maize. Northern corn leaf blight (Helminthosporium turcicum), as the name implies, is generally more prevalent in the temperate regions than in the tropics. In the tropics, the disease can become severe at the cooler, higher elevations; and in the winter season in the lowlands, provided moisture is ample. The disease is of little importance in hot, humid environments such as Central India, Thailand and Indonesia.

Southern corn leaf blight (*H. maydis*) is found from the temperate climate of Southern Canada to the hot, humid tropics of Southeast Asia. Both races of the pathogen, Race 0 and Race T, are nearly world-wide in distribution, but tend to be more abundant in the tropics and in the warmer parts of temperate zones. However, these two races have been shown to over-winter in the rigorous, continental climate of the northern Corn Belt of the United States, Race T, characterized by extreme virulence on maize with Texas male-sterile cytoplasm, was first observed in the Philippines. It may be pointed out that Race T appeared to be held in check in 1971 in the Corn Belt of the United States because of unseasonably low temperatures that were common in July and August of that growing season, and in 1972 by the switch to normal cytoplasmic hybrids.

Bacterial wilt or Stewart's disease (Erwinia stewartii) appears to be confined generally to temperate climates. It has not become a serious disease in the tropics, although the vector, the maize flea beetle (Chaetocnema pulicaria), has been observed in some of these regions. In temperate zones, this insect harbors the causal agent over-winter and initiates primary infections through feeding wounds on young maize seedlings. Low winter temperatures decimate the vector populations, whereas more survive in mild winters. Thus, winter temperatures have a marked influence on the prevalence of this disease.

Yellow leaf spot (Phyllosticta maydis) seems to be confined to cool, moist environments in the United States where it has become of some economic importance in recent years when such conditions prevailed in the northern reaches of the Corn Belt. P. maydis, like Race T of H. maydis, is highly virulent on maize with Texas male-sterile cytoplasm, and less so on near-isogenic counterparts with normal cytoplasm.

Eyespot (Kabatiella zeae), first described in the cool, moist environment of Hokkaido, Japan, has caused some minor damage during cool, wet seasons in the northern Corn Belt of the United States. The disease is found also in New Zealand, Austria, and Argentina, but not in the hot, humid tropics.

Tar spot (Phyllachora maydis) is a minor disease of maize in warm climates at both high and low elevations. The disease is rare in temperate regions.

A leaf-shredding disease caused by Pseudomonas rubriliniens is observed occasionally only in hot, humid climates. It has not been found in cool environments.

Curvularia leaf spot is widely distributed in tropical regions and to a limited extent in warm, humid sections of the temperate zones. Several species have been reported as inciting agents, but Curvularia lunata is probably the most frequently encountered of these. The disease does a moderate amount of leaf damage, and in localized areas in the tropics it may become severe.

Zonate leaf spot (Gleocercospora sorghi) is a minor disease on maize and occurs mainly in tropical and sub-tropical countries. It is present, however, in some warm-temperate areas when favorable wheather prevails.

Brown-spot (Physoderma maydis) is widespread in the tropics, but may be observed well into such temperate environments as the central Corn Belt of the United States.

Banded leaf and sheath blight (Hypochnus sasakii) is essentially a tropical disease that is rare in warm-temperate climates. It is of minor importance.

The eight downy mildews of maize are perhaps most typical insofar as geographical distribution is concerned. The important diseases in this group are in the tropics. Sorghum downy mildew, so-called because it was originally described on sorghum and because the latter is more severely attacked than maize, has been found on maize in Texas (USA) within the last 12 years. This is in the temperate zone, but the area where it is most abundant on corn is in the warm, humid, coastal plain of Texas. The pathogen, Sclerospora sorghi, has been identified on Sorghum spp. and recently on maize in South Central United States, well within the temperate zone.

The other downy mildews of maize that are of economic importance have been confined to warm, humid areas in the tropics. Philippine downy mildew (Sclerospora -- philippinensis), sugarcane downy mildew (S. sacchari), Java downy mildew (S. maydis), spontaneum downy mildew (S. spontanea), and brown stripe downy mildew (Sclerophthora rayssiae var. zeae) are among these. Crazy top (Sclerophthora macrospora) is probably widely distributed in both tropical and temperate areas, but it is of minor importance. Graminicola downy mildew (Sclerospora graminicola) has been reported only a few times on maize, and then in cool temperate areas. The pathogen, however, causes "green ear disease" of millets and other grasses in the tropics.

Virus diseases of maize are widespread in tropical regions. Two of these, maize streak in Africa, and maize mosaic in Hawaii and parts of South America, are of economic importance and do not occur in temperate climates. They may be so limited in their geographical distribution because of the specificity of their respective vectors.

Sugarcane mosaic complex, with its several strains, is widespread in the tropics. The breadth of geographical distribution of this complex of strains of the virus may be due to the rather large number of aphid species that act as vectors. Maize dwarf mosaic, considered a strain of sugarcane mosaic by some, became a serious disease in the central and east central Corn Belt of the United States in the 1960's. There is reason to believe it is spread widely in tropical areas, but has not often been specifically identified as such. It is the cause of maize mosaic on the Indian subcontinent and Southeast Asia, though this strain is much less virulent than the MDM strain.

Other virus diseases of maize, some of which are limited to temperate regions, have been of minor importance thus far. Virus-like symptoms are commonly seen on maize in the tropics, but to identify them on the basis of symptoms alone is hazardous because of the influence of environment and host genotype - 2 factors that may modify symptom expression. The abundance of insects, which may act as vectors, in hot, humid climates could account for the apparent prevalence of these diseases in such areas There is need to examine these diseases in greater detail and to positively identify them by means of the newer and more reliable methods. A clear, yet simple, system of naming the virus disorders of maize is highly desirable to correct some of the confusion that now exists within this group of disease.

Corn stunt, once considered to be of viral etiology, is now presumed to be caused by a mycoplasma-like entity. It has been most severe in tropical and warm-temperate environments such as Central America and Mexico, where the populations of its 5 leaf-hopper vectors is high. Like the virus diseases that are not sap-transmissible, and have one or a few specific vectors, the geographical range of corn stunt coincides closely with that of its vector(s).

Maize is susceptible to two smut diseases: common or boil smut (Ustilago maydis) and head smut (Sphacelotheca reiliana). Common smut is widespread in temperate climates and exceedingly sparse in hot, humid areas of the tropics. However, in tropical regions it may be more prevalent at high altitudes where temperature is lower.

Head smut occurs in both tropical and temperate regions where maize is grown under irrigation and the atmospheric humidity is low. It is prevalent in some of the northern inter-mountain irrigated regions of the United States, but not in the Corn Belt of the central part of that country. It may become abundant at times in some of the high, dry plateaus of Mexico where irrigation is practiced. Irrigation with raw sewage or effulent appears to predispose plants to infection.

False smut, as the name indicates, is not a smut disease, and is caused by Ustilaginoidea virens. The disease is restricted to maize tassels where hard, dark, greenish-black galls are formed. It is found in tropical environments and apparently not in temperate climates though it does occur widely on rice. It is of negligible economic importance.

There are three rusts of maize:

Tropical maize rust (Physopella zeae) is restricted to the American tropics; it has not been identified in the other tropical lands, or in temperate regions. It appears to be of little economic importance.

Southern maize rust (Puccinia polysora) is mainly tropical or subtropical in distribution, but it has been observed in the central and north central parts of the Corn Belt of the United States. Originally it appeared to be confined to the western hemisphere, but about 20-25 years ago it was recognized in West Africa where it caused considerable economic loss to the maize crops in several countries. It moved in an easterly direction across Africa onward to Southeast Asia and some of the Pacific Islands. While it has been seen in temperate, as well as other tropical regions, it does not seem to have caused great economic losses other than in West Africa. It is found at low and moderate elevations. At high elevations (1 200m +) in tropical areas it rapidly diminishes in prevalence. A re-identification is needed in those lowland tropical areas reporting common rust as the most prevalent.

Common maize rust (P. sorghi) is world-wide in distribution, but in tropical latitudes it is found at higher elevations (particularly at 1 200 m +). In temperate climates it is widespread and variable in prevalence from year to year and from one location to another, depending on environment. Cool, moist conditions appear to favor it. In the Corn Belt of the United States, this rust is rarely of economic importance since most often it appears after flowering and causes little or no yield reduction.

Stalk rots in temperate zones are caused mostly by fungi. The pathogens of diplodia stalk rot (D. maydis), gibberella stalk rot (G. zeae), fusarium stalk rot (F. moniliforme), and charcoal rot (Macrophomina phaseoli) become more agressive as the host matures. These are diseases of senescence. Increasing nitrogen nutrition beyond optimum levels or a deficiency of potassium has been shown to favor development of these diseases, as does the density of plants per unit area of land. These are situations which are perhaps more apt to occur in temperate areas than in the tropics.

Pythium stalk rot (P. aphanidermatum) is not a disease of old age and is not, as those mentioned above, favored by the stress of senescence. It occurs at any stage of host development and frequently does so before flowering. In temperate climates it becomes prevalent in localized areas after a period of 10-14 days when the temperature is abnormally high (34-38° C) and rainfall excessive. This disease is somewhat more prevalent in the tropics because the environment favoring it occurs there with greater frequency.

Bacterial stalk rots (Erwinia cheysanthemi and Pseudomonas lapsa) occur more frequently in hot, humid tropical climates than in temperate zones. The higher temperatures and humidities are prime factors in their distribution. Irrigation with sewage, a practice often found in the tropics, is known to increase the incidence of bacterial stalk rots.

Late wilt (Cephalosporium maydis), essentially a vascular disease of maize stalks, occurs in the tropics but not in temperate climates. It is an important disease in UAR-Egypt, and India - the only countries where it is reported. It, and the important stalk rot caused by Colletotrichum graminicolum in Thailand are probably much wider spread in the tropics.

The stalk rots caused by Cephalosporium acremonium and by Fusarium moniliforme appear to be somewhat more important in the tropics than in temperate zones. In the latter areas fusarium stalk rot tends to be disease of senescence; and that caused by C. acremonium has not generally been of economic consequence.

Ear rots of maize in temperate climates are most often characterized by a discrete infection of one of the several species of fungi that are pathogenic on maize ears. In the humid tropics multiple infections are common, and the distinctive symptoms that are characteristic of infection by a single fungus species are often obscured.

Gibberella ear rot (G. zeae) is found generally in the cooler parts of the temperate maize-growing countries and seldom in tropical zones except at high elevations such as on Java.

Diplodia ear rot (D. maydis) is a common, but seldom serious, disease in temperate climates. A similar ear rot and a leaf spot of minor importance, caused by Diplodia macrospora, occurs occasionally in warm-temperate or subtropical zones, but not in cool environments such as the central and northern parts of the Corn Belt of the United States.

Rhizoctonia ear rot (R. zeae), Botrydiplodia ear rot (B. zeae), and gray ear rot (Physalospora zeae) are typically tropical, but may be found sparingly in sub-tropical or warm-temperate zones.

Nigrospora cob rot is caused by a weak pathogen, Nigrospora oryzae, that usually attacks ears when the plant is stressed by drought, cold or leaf and stalk diseases. It, like the kernel rot caused by Fusarium moniliforme, is encountered in both hot and cool climates, although a warm, dry environment seems to favor it.

Ergot of maize (Claviceps gigantea) is unique in that it is found only in a few very limited locations in central Mexico. Although these are in a tropical latitude, they are relatively high (2500-2700 M) where moisture is abundant and moderate temperatures prevail. Only in these restricted areas, which are essentially temperate, has maize ergot attained some economic importance. Fortunately, the sclerotia of the pathogen do not contain alkaloids known to be toxic to animals or humans

It should be emphasized that the maize ear is a veritable moist chamber and hence highly vulnerable to invasion. Parasitic, weakly parasitic and saprophytic fungi are able to penetrate the ear by different routes and become established on or within kernels.

Nematode diseases have not been important in the relatively cool maize growing areas of the world. In some sub-tropical and warm-temperate regions various types including root knot nematodes have caused damage where conditions, in addition to warm soils, have been favorable. Studies on the effects of nematocides on growth and yield of maize in tropical areas, where these organisms are prevalent, should be pursued.

Maize is subject to a phanerogamic disease, caused by Striga asiatica. With one exception this disease has been confined to tropical countries. In the 1950's it was discovered in southeastern United States where mild temperatures prevail. A concerted eradication and quarantine campaign appears to have confined it to North Carolina and South Carolina.

3.1 SUMMARY

In this paper we have attempted to contrast the diseases of maize as they occur in temperate and tropical environments. It has been pointed out that some diseases of maize are common to both climates, others are confined mainly to temperate areas, while some are strictly tropical in distribution. Within tropical zones maize diseases may segregate into humid environments, others are favored by dryer, upland climatic conditions. Elevation within the tropics, as this influences temperature, is a factor in distribution of maize diseases.

We have attempted to show also how, in addition to climatic conditions, cultural practices in these 2 major environments may have a bearing on the severity and prevalence of some diseases of maize

Finally differences in the degree of diversity of germplasm and in the type of maize in temperate and in tropical regions have been related to the pathology of this crop.

Table 1 : Approximate maize area and production in tropical* and temperate zones.

	Zone		
Area (M. Ha.)	Temperate	Tropical	% Temperate
1948-52 Av.	69	19	78
1970	77	34	69
20 yr. increase	11%	81%	
Production (M. Tons)			
1948-52 Av.	123	16	88
1970	222	39	85
20 yr. increase	70%	141%	

* within 23.5° latitude.

Table 2 : Approximate maize area and production in tropical and sub-tropical* compared to temperate zones.

	Zone		
Area (M. Ha.)	Temperate	Subtropical	% Temperate
1948-52 Av.	51	37	58
1970	49	61	45
20 yr. increase	(-) 3%	64%	
Production (M. Tons)			
1948-52 Av.	102	38	73
1970	179	83	68
20 yr. increase	75%	119%	

* within 34° latitude.

Table 3 : The relative Prevalence [1/] and Importance [2/] of Maize Diseases of the world.

Disease	Temperate (outside 34° lat.)	Sub-tropical (within 34° lat)	Tropical (within 23.5 lat.) Highland 1000+ M	Lowland Winter 1000(-)M	Lowland Summer 1000(-)M
I. Foliar diseases					
1. Northern leaf blight	+++ 3	++ 1	+++ 3	++	+1
2. Southern leaf blight	+++ 3	+++ 3	+ 1	++ 2	+++ 3
3. Helminthosporium leaf spot (H. carbonum)	++ 1	+ 1	++ 1	+ 1	+ 1
4. Bacterial wilt	++ 1	+ 1	- 0	- 0	+ 1
5. Yellow leaf blight	++ 2	- 0	- 0	- 0	- 0
6. Eyespot	++ 1	- 0	- 0	- 0	- 0
7. Tarspot	+ 0	+ 1	+ 1	- 0	+ 1
8. Leaf shredding	- 0	+ 1	- 0	- 0	++ 1
9. Curvularia leaf spot	- 0	++ 1	++ 1	+ 1	+++ 3
10. Brown spot	+ 1	++ 2	+ 1	+ 1	++ 1
11. Banded leaf and sheath blight	- 0	+ 1	- 0	- 0	++ 1
12. Zonate leaf spot	- 0	+ 1	- 0	- 0	+ 1
II. Smuts and rusts					
13. Head smut	+ 1	++ 2	++ 1	+ 1	++ 1
14. Common smut	+++ 1	++ 1	++ 1	+ 1	+ 1
15. False smut	- 0	+ 1	+ 1	- 0	+ 1
16. Common rust	+++ 2	++ 2	+++ 2	++ 1	+ 1
17. Southern rust	- 0	++ 2	+ 1	+ 1	+++ 3
18. Tropical rust	- 0	+ 1	- 0	+ 1	+ 1
III. Downy Mildews					
19. Sorghum (S. sorghi)	+ 1	++ 2	- 0	+++ 3	+++ 3
20. Java (S. maydis)	- 0	- 0	- 0	+++ 3	+++ 3
21. Philippine (S. philippinensis)	- 0	++ 2	- 0	+++ 3	+++ 3
22. Sugarcane (S. sacchari)	- 0	++ 2	- 0	+++ 3	+++ 3
23. Graminicola (S. graminicola)	+ 1	- 0	- 0	- 0	- 0
24. Spontanea (S. spontanea)	- 0	- 0	- 0	+ 1	++ 2
25. Crazy top (S. macrospora)	+ 1	+ 1	- 0	- 0	+ 1
26. Brown stripe (S. rayssiae)	- 0	+++ 3	- 0	- 0	++ 2
IV. Virus and Mycoplasma - like entities					
27. Maize streak	- 0	++ 2	+ 1	++ 2	+++ 3
28. Sugarcane and Maize dwarf mosaic	+++ 3	+++ 3	+ 1	++ 2	++ 2
29. Wheat streak mosaic	+ 1	- 0	- 0	- 0	- 0
30. Maize leaf fleck	+ 1	- 0	- 0	- 0	- 0
31. Bromegrass mosaic	+ 1	- 0	- 0	- 0	- 0
32. Cucumber mosaic	+ 1	+ 1	- 0	- 0	- 0

Table 3 : Continued.

Disease	Temperate (outside 34° lat.)	Sub-tropical (within 34° lat)	Tropical (within 23.15 lat.) Highland 1000 + M	Lowland Winter 1000(-)M	Lowland Summer 1000(-)M
33. Corn stripe	- 0	+ 1	- 0	+ 1	+ 1
34. Maize rough dwarf	++ 2	++ 2	- 0	- 0	- 0
35. Corn Stunt	+ 1	+++ 3	+ 1	+++ 3	+++ 3
V. Stalk rots					
36. Diplodia	+++ 3	+++ 3	+ 1	- 0	- 0
37. Gibberella	+++ 3	++ 2	+ 1	- 0	- 0
38. Fusarium	+++ 2	+++ 2	++ 1	++ 1	+++ 2
39. Charcoal rot	++ 1	++ 1	+++ 2	+++ 2	+++ 2
40. Black bundle	++ 1	+++ 2	+ 1	++ 1	++ 2
41. Late wilt	- 0	+++ 3	- 0	+++ 3	+++ 3
42. Pythium	++ 1	+++ 3	- 0	+ 1	+++ 3
43. Bacterial	+ 1	+++ 3	+ 1	+ 1	+++ 3
44. Anthracnose	- 0	+ 1	- 0	++ 1	+++ 3
VI. Ear and Kernel Diseases					
45. Diplodia	++ 2	+++ 2	+ 1	- 0	- 0
46. Gibberella	+++ 2	++ 1	+ 1	- 0	- 0
47. Diplodia macrospora	- 0	++ 1	- 0	- 0	+ 1
48. Rhizoctonia	- 0	+ 1	- 0	- 0	++ 1
49. Botryodiplodia	- 0	+ 1	- 0	- 0	+++ 2
50. Gray ear rot	- 0	+ 1	- 0	- 0	++ 1
51. Nigrospora	++ 1	++ 1	+ 1	+ 1	+ 1
52. Fusarium	+++ 2	+++ 2	+++ 2	++ 2	++ 2
53. Ergot	- 0	- 0	++ 1	- 0	- 0
VII. Seedling blights (Mainly species of Pythium, Fusarium, Cephalosporium, Rhizoctonia, Diplodia, Nigrospora, Penicillium, Helminthosporium, and Curvularia).	++ 2	+ 1	++ 2	+ 1	+ 1
VIII. Nematodes (Mainly species of Pratylenchus, Helicotylenchus, Tylenchorhynchus, Trichodorus, Heterodera, and Belonolaimus).	+ 1	++ 2	+ 1	+ 1	+ 1
IX. Striga (S. asiatica).	- 0	+ 1	- 0	++ 1	++ 1

1/ Prevalence	
+++ =	Abundantly present
++ =	Commonly present
+ =	Occasionally present
- =	Not present

2/ Importance	
3 =	Major importance
2 =	Moderate importance
1 =	Minor importance
0 =	Absent or rarely found.