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Evaluation of New Pearl Millet Lines to Maiduguri Pathotype of *Sclerospora graminicola*

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ABSTRACT

A field and pot screen was conducted at Maiduguri, in the Sudan Savanna of Nigeria to evaluate 25 lines of pearl millet against Maiduguri pathotype of *Sclerospora graminicola*, the causal pathogen of pearl millet downy mildew. Downy mildew varied from one season to the other in terms of both incidence and severity. Of the 25 lines evaluated, 15 were classified as moderately resistant, eight as moderately susceptible and two lines (Ex-Borno & MBH110) as susceptible. Four lines (J10451, 18292, P310-17, 5121B), which were classified as susceptible were among those that produced higher yields. These materials could be considered tolerant and may be recommended for improvement. Most of the lines that were categorized as moderately resistant did not produce as much yield as the susceptible ones; therefore, any improvement program with these genotypes will have to consider incorporating genes for yield. It is recommended that the search for resistant genotypes should continue utilizing the diverse pearl millet collections in Africa and Asia in order to increase the genetic diversity of the crop for effective resistance to downy mildew. The screening process should combine both the pot and field techniques described here to ensure reliability of results.

Key Words: Pearl millet; Downy mildew; *Sclerospora graminicola;* Pathotypes; Resistance; Susceptible

INTRODUCTION

Pearl millet (*Pennisetum glacum* (L.) R. Br.) provides a major source of food to a large population in the semi-arid regions of Africa and Asia and a high quality fodder to livestock in many parts of the world. Despite its quality as a hardy crop for the drylands, pearl millet has been vulnerable to a number of fungal diseases (Gwary *et al.*, 2001, 2002a, b), most important of which is the downy mildew caused by *Sclerospora graminicola* (Sacc.) Schroat. Downy mildew has been reported to cause crop losses from 10 to 60% (Nene & Singh, 1976) depending on the severity of infection and the crop variety. Such levels of losses are particularly important considering the fact that pearl millet may be the only cereal that can tolerate the semi-arid zones, where they are most currently grown. The control of this disease has been well investigated among many plant pathologists especially at the International Crops Research Institute for the Semi-Arid Tropics with its headquarters in India. However, its control has been difficult, because both pearl millet and *S. graminicola* are highly out crossing and thus genetically highly variable (Michelmore *et al*., 1982; Ball, 1983). Many studies have also shown that even with the introduction of hybrid pearl millet, the pathogen still caused problems (Safeeulla, 1977). The most feasible control now is the use of resistant cultivars. The development of resistant cultivars is a long process, which normally starts with the identification of breeding materials, which may be local or introduced materials. Significant efforts have been made towards identifying resistant sources (Gwary *et al.*, 2002a; Wilson, 2004) but the search is a continuous exercise in view of the abundance of the pearl millet germplasm.

The aim of this study was to continue to evaluate new pearl millet lines in the semi-arid region of Nigeria as they become available through our collaborating institutions nationally or internationally. We report here the results of two years evaluation of 25 lines against the downy mildew pathogen under natural disease pressure, supplemented by initial artificial inoculation as well as pot screens.

MATERIALS AND METHODS

Field screening. The trial was conducted at the Research farm of the Department of Crop Protection University of Maiduguri, Nigeria for two years. The trial was established in a downy mildew "sick plot" where the universally susceptible variety 7042-S as well as Ex-Borno had been cultivated for over five years, which allowed for the build up of the soil inoculum. The field screening technique (Williams *et al.*, 1981) as described earlier (Gwary *et al.*, 2002b), which is routinely used at ICRISAT was used here. Twenty five pearl millet lines obtained from International Crops Research Institute for the Semi Arid Tropics (ICRISAT) India through Lake Chad Research Institute Maiduguri were planted out in a randomized complete block design and each entry was replicated three times. The entry Ex-Borno was included as a local check. Each plot measured 3 x 5 m and inter- and intra row spacing of 50 and 7.5 cm, respectively were adopted giving a plant population of 24. All agronomic practices including fertilizer

application were followed as recommended for the area (BOSADP, 1989).

Pot screening. To take care of disease escape, which is common in field screens and to ensure uniform inoculum pressure on the test lines, a pot screen was also conducted. Plastic pots measuring 30 cm in height and 10 cm diameter were filled with sandy loam soil to which 10 g of oospore-infected plant materials, which was finely ground was incorporated into the top 3 cm soil of each pot. The soil was watered to field capacity and seeds of the pearl millet test lines were sown at the rate of 10 seeds per pot.

Observation and Data Collection

Plant establishment. The total number of seedlings that germinated and grew normally were counted in each plot and expressed as a percentage. This is an important genotype characteristic for evaluation in crop improvement programmes.

Days to 50% flowering. Days to 50% flowering was determined by monitoring the number of days when 50% of the plants in each plot came into flower.

Disease incidence on main stand. The number of main stands in each plot infected with downy mildew was counted at seedling stage, 30 days after sowing (DAS), at vegetative stage (50 DAS) and soft dough stage (70 DAS). This was divided by the total plants in the plot and expressed as a percentage.

Disease incidence on basal tillers. The number of main stands in each plot infected with downy mildew was counted at seedling stage, 30 days after sowing (DAS), at vegetative stage (50 DAS) and soft dough stage (70 DAS). This was divided by the total plants in the plot and expressed as a percentage.

Downy mildew severity on main stands. At 70 DAS the severity of downy mildew infection on main stands were recorded using a rating scale of Ball (1983) as follows:

1 = No disease symptoms.
2 = Disease only on nodal tillers.
3 = Less than 50% of the basal tillers of plants infected.
4 = More than 50% of basal tillers of plants infected.
5 = No productive panicle is produced

Severity was then calculated using the formula:

$$\text{Disease Severity} = \frac{Y(1\text{-}1) + Y(2\text{-}1) + Y(3\text{-}1) + Y(4\text{-}1) + Y(5\text{-}1)}{N \times 4}$$

Where

Y = number of plants in each reaction category and N = total number of plants in the genotype under test.

Grain yield. When matured, the millet heads from the two inner rows in each plot were cut, sun dried, threshed and winnowed. The grains were weighed. The figures were later converted to kilograms per hectare.

Disease rating scale. For classifying the pearl millet lines the rating scale of Ball (1983), which is based on the incidence of downy mildew on the basal tillers, was adopted:

5% disease incidence = Resistant (R).
6-15% disease incidence = Moderately Resistant (MR).
16-30% disease incidence = Moderately Susceptible (MS).

Data analysis. Data collected were subjected to analysis of variance according to the experimental design. Duncan's multiple range test (DMRT) was used to compare the treatment means.

RESULTS AND DISCUSSION

Pearl millet downy mildew is transmitted through seed and soil inocula. After successful infection of the host, the disease develops systemically affecting the both main stands and the tillers. Tillering is a well known characteristic of the pearl millet plants and contributes substantially to yield. Table I shows the development of downy mildew on the entries evaluated. Disease was assessed at the three critical stages of the plant growth during, which yield could be seriously affected. The stages are the seedling stage (30 DAS), which could be attacked by the pathogen causing damping-off depending on the resistance of the line or cultivar, followed by the flush vegetative growth stage (50 DAS) on which secondary infection with resultant chlorotic symptoms occur and then the reproductive stage (70 DAS) on which the "green ear" symptom develop. In Table I disease can be seen to increase progressively from about 2% at 30 DAS to 65% at 70 DAS on the main stands of all the

Table I. Downy mildew incidence on *main stands* of pearl millet lines evaluated in 1999 and 2000 at seedling (30DAS), vegetative (50 DAS) and soft dough stage (70 DAS) in Maiduguri, Nigeria

Pearl millet lines	Disease incidence (%)					
	1999			2000		
	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS
J10451	15	25	43	9.6	14f-h	16e-h
852-B	3.3	24	45	10.0	21c-g	21c-h
18292	2.0	30	34	10.0	17c-h	17e-h
7042R	0.0	27	40	12.0	20c-g	20c-h
P310-17	3.7	25	40	11.0	20c-g	21c-h
Ex-BORNO	10.0	18	36	14.0	32ab	32ab
MBH110	6.3	20	46	16.0	38a	34a
5121B	15.0	35	43	11.0	25b-f	24a-e
700651	19.0	51	51	8.3	7h	10h
SE13	11.0	23	65	9.0	21c-g	21c-h
P7-41	0.0	34	51	7.1	13gh	13e-h
IP-1893	4.0	30	50	6.1	18c-h	18c-h
T1449-2	4.7	37	37	13.0	17c-h	17e-h
PRT1289-33	4.7	21	21	14.0	24c-g	24ag
WSIL-P81	25.0	26	26	12.0	23c-g	23b-g
863-P21	16.0	25	25	17.0	24c-g	24ag
PT7B-P5	20.0	24	24	10.0	17c-h	17e-h
T123D1	13.0	48	42	14.0	18c-h	18c-h
WS04	8.0	18	24	12.0	18c-h	18d-h
KMP451-P6	8.3	31	35	13.0	27a-e	27a-e
4777183-1	16.0	45	26	12.0	19c-h	19c-h
841B-P3	11.0	20	20	11.0	13gh	13gh
KMP-451-P3	14.0	16	26	7.0	16d-h	16e-h
LGD-1	12.0	32	32	17.0	28a-d	28a-d
B10	7.0	21	21	8.0	13gh	13gh
SE (±)	7.4	11.3	10.8	4.4	6.1	11.6
CV (%)	10.9	16.1	15.3	1.1	8.6	16.4

Column means followed by the same letter(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test; DAS = Days after sowing

entries during the two seasons. Although there were no significant differences in the disease incidence between lines in 1999, the result in 2000 shows some significant differences. Of the 25 entries, four lines, MBH110, Ex-Borno, LGD-1 and KMP451-P6 had significantly higher downy mildew incidence (38, 32, 28 & 27%, respectively) than the rest 50 DAS during 2000. There was higher disease in 1999 than in 2000 except in the case of PRT1289-33. This could be due to a combination of many factors such as dew, relative humidity, wind and sunshine (Singh & Williams, 1980).

Table II shows the incidence of downy mildew on the basal tillers of the main stands during 1999 and 2000 seasons. The result shows that there were more tillers infected in 1999 than in 2000 with a few exceptions like P310-17, Ex-Borno, 863-P21, WS04 and KMP-451-P3, which accommodated more disease on basal tillers in 2000 as compared to those in 1999. In 1999, the lowest disease of 12% was recorded on line 5121B and WS04, while the highest measure of disease incidence of 35% was found on line 4777183-1 70 DAS. In 2000 all the lines had a uniform disease on the basal tillers, which ranged between 11% and 19% except for lines KMP-451-P3 and Ex-Borno, which had 26% and 55%, 70 DAS, respectively.

Until the late 1980s, disease incidence was a sufficient measure for the systemic downy mildew in pearl millet. However, following the observation of recovery resistance in some pearl millet cultivars, where some plants out-grow the disease (Singh & King, 1988), the need to supplement disease incidence with disease severity became necessary in pearl millet screening. In Table III, therefore, the plant growth and yield parameters are shown against the severity of the disease. Four lines, PRT1289-33, 841B-P3, B10 and 852-B had the lowest disease severity of between 1.1% and 1.4%. The highest severity of 8.8 was recorded on SE13 followed by 7042R (5.6%), J10451 (4.6%), P7-41 (4.6%), while the rest fell into the same category, which are not significantly different from each other (1.5 - 3.5%). The result of plant establishment, which is pooled mean for two years looks generally low and this could be an important area for improvement. Two lines, however, showed a favorable establishment of 75% (P310 - 17) and 70% (18292). Days to 50% flowering varied from 13 in PT7B-P5 to 51 and 57 in WS04 and LGD-1, respectively. Early flowering is an important plant character in this Sudano-sahelian region of Nigeria due to the erratic nature of the rains. Fig. 1 shows the rainfall pattern and amounts during the two seasons of the trial. Both disease and yield are affected by the rainfall. High and well distributed rainfall across the season leads to good yield but poorly distributed

Table II. Downy mildew incidence at on *basal tillers* of pearl millet lines evaluated in 1999 and 2000 at Maiduguri, Nigeria

Pearl millet lines	Disease incidence (%)					
	1999			2000		
	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS
J10451	13	33a	33a-c	11	15c-f	16
852-B	15	27a-d	27a-e	11	14c-g	14
18292	10	13c-g	16e-h	10	12c-g	13
7042R	13	26a-c	32a-c	13	15c-e	15
P310-17	12	12d-g	14e-h	13	14c-g	14
Ex-BORNO	18	19a-g	22b-h	18	28a	55
MBH110	14	14c-g	16e-h	6	11e-g	11
5121B	11	9g	12gh	8	11e-g	11
700651	9	22a-g	15e-h	9	12c-g	12
SE13	11	25a-d	25d-h	8	11e-g	11
P7-41	10	13c-g	14e-h	8	11e-g	12
IP-1893	8	10g	14e-h	9	11e-g	12
T1449-2	14	17b-g	20c-h	16	16cd	18
PRT1289-33	16	23a-g	26a-e	18	17c	19
WSIL-P81	10	13c-g	15e-h	13	13c-g	13
863-P21	8	11e-h	14e-h	12	13c-g	14
PT7B-P5	9	12c-g	14e-h	9	11e-g	11
T123D1	9	13c-g	14e-h	10	11e-g	11
WS04	11	11e-h	12gh	12	14c-g	14
KMP451-P6	10	14c-g	14e-h	9	14c-g	17
4777183-1	12	32ab	35a	11	11fg	12
841B-P3	13	27a-c	27a-e	10	13c-g	13
KMP-451-P3	12	15c-g	17e-h	14	17b	26
LGD-1	10	13c-g	16e-h	10	12c-g	13
B10	12	14c-g	17e-h	8	10e-g	11
SE (±)	8.9	7.7	4.4	7.4	7.7	4.4
CV (%)	12.5	31.5	6.1	30.1	10.2	6.3

Column means followed by the same letter(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test**;** DAS = Days after sowing.

Table III. Plant establishment, days to 50% flowering, downy mildew severity, ear length and grain yield of twenty five sorghum lines evaluated for resistance to downy mildew in Maiduguri in 1999 and 2000

Pearl millet lines	Plant establishment	Days to 50% flowering	% Disease Severity	Ear length (cm)	Grain yield (kg ha^{-1})
J10451	58	43ab	4.6bc	34	602a
852-B	57	24bc	1.4d	37	420a-c
18292	70	28bc	3.2cd	39	481a-c
7042R	49	28bc	5.6bc	34	429a-c
P310-17	75	17c	4.2bc	28	578ab
Ex-BORNO	68	34a-c	2.1cd	22	451a-c
MBH110	44	33a-c	2.0d	33	405a-c
5121B	48	29bc	4.4bc	27	509ab
700651	65	49ab	3.8cd	42	308c
SE13	48	10cd	8.8a	33	430ac
P7-41	67	36ac	4.6bc	29	485a-c
IP-1893	55	42ab	3.4cd	32	484a-c
T1449-2	52	16a-c	3.5cd	29	403a-c
PRT1289-33	47	37a-c	1.1d	31	375c
WSIL-P81	65	33a-c	1.2cd	43	464ab
863-P21	42	19a-c	1.3cd	32	448a-c
PT7B-P5	56	13c	2.0cd	39	475a-c
T123D1	50	24bc	1.3cd	41	422a-c
WS04	62	51ab	1.6cd	39	450a-c
KMP451-P6	48	26bc	2.4cd	34	416a-c
4777183-1	44	25bc	2.5cd	31	387a-c
841B-P3	60	37a-c	1.1d	32	329a-c
KMP-451-P3	52	47ab	1.5cd	47	329a-c
LGD-1	54	57a	1.7cd	28	469ab
B10	57	37a-c	1.3cd	35	454a-c
SE (±)	3.1	4.1	2.01	4.1	90.2
CV (%)	21.1	22.6	8.23	17.1	16.2

*Values are averages for 1999 and 2000. Column means followed by the same letter(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test

rainfall would generally encourage pests and diseases, while dew formations and high relative humidity would lead to high downy mildew on the crop. Grain yield was low but comparable to our earlier screen (Gwary *et al*., 2002b). In this screen, six lines, J10451 (602 kg), P310 - 17 (578 kg), 5121B (509 kg), P7-41 (485 kg), IP-1893(484 kg) and 18292 (481 kg) have shown relatively better yield per hectare. The yield component is another important character for consideration in any improvement program with these lines.

A screen becomes more reliable when the method ensures that there is no disease escape and the disease pressure across all entries remains uniform. In the pot screen (Table IV), while the plant establishment remains similar to what was obtained under the field conditions the disease incidence and severity are higher. The incidence ranged from 51 to 80% as a result of the intimate contact with the oospores propagules applied to the soil in the pot. Although, there is no significant difference between the entries with regards to disease incidence, those with lower scores include, P7-41 (35%), PT7B-P5 (50%), 7042R (51%) and KMP451-P6 (53%). Disease severity in this table ranges from 22 to 36% a level that can lead to epidemic in field situation.

Table IV. Pot screening of the of twenty five pearl millet lines for reaction to Maiduguri pathotype of *Sclerospora graminicola* conducted in 2000 only but replicated three times

Pearl millet lines	Plant establishment	Disease incidence (%)	Disease severity (%)
J10451	78a	75	25
852-B	63a-c	60	33
18292	34c-e	64	35
7042R	66a-c	51	22
P310-17	51cd	56	26
Ex-BORNO	48cd	80	36
MBH110	62a-c	72	30
5121B	56b-d	72	32
700651	76ab	71	27
SE13	53cd	62	28
P7-41	76ab	35	22
IP-1893	28c	60	23
T1449-2	41c-f	78	35
PRT1289-33	53c-d	57	22
WSIL-P81	56b-d	63	35
863-P21	35c-e	54	30
PT7B-P5	38c-f	50	22
T123D1	43c-f	64	33
WS04	58bc	58	34
KMP451-P6	63a-c	67	25
4777183-1	72ab	78	22
841B-P3	66a-c	62	28
KMP-451-P3	51c-d	53	22
LGD-1	51c-d	67	35
B10	35c-e	62	26
SE (±)	8	12	5.3
CV (%)	31	35	14

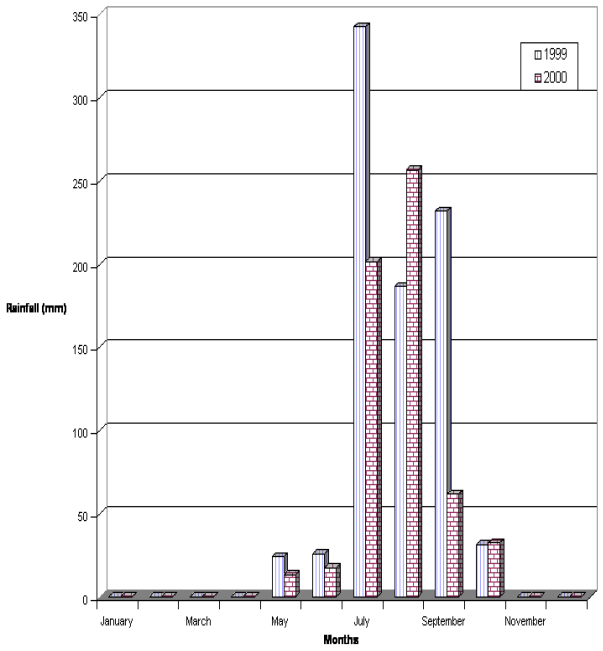
Column means followed by the same letter(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test

Table V. Reaction classification* of twenty five pearl millet lines evaluated in the field and pots during 1999 and 2000 at Maiduguri, Nigeria

Disease Reaction	Pearly millet lines
Resistant (R)	None
Moderately resistant (MR)	P7-41, IP-1893, T1449-2, PRT1289-33, WSIL-P81, 863-P21, PT7B-P5, T123D1, WS04, KMP451-P6, 4777183-1, 841B-P3, KMP-451-P3, LGD-1, B10
Moderately Susceptible (MS)	J10451, 852-B, 18292, 7042R, P310-17, 5121B, 700651, SE13
Susceptible (S)	Ex-BORNO, MBH110

*Resistant = 1-5%; moderately resistant = 6-15%; moderately susceptible = 16-30%; susceptible = >30%

Fig. 1. Rainfall distribution for Maiduguri, Nigeria in 1999 and 2000



In the final analysis of the reactions of both the pot and field evaluation of the twenty five pearl millet lines against the Maiduguri pathotype of *Sclerospora graminicola*, the lines can be classified into three resistant groups (Table V). One of the lines, MBH110 and the local check Ex-Borno were susceptible. The local check had earlier been classified as susceptible (Gwary *et al.*, 2002b) giving credibility to the screening technique. Six lines are categorized as moderately susceptible and 15 are classed as moderately resistant. From Tables III and V, one can observe that four lines (J10451, 18292, P310-17, 5121B) that had been categorized as moderately susceptible to the downy mildew pathogen are among the lines that produced higher yields. Under these circumstances, therefore, these lines should either be considered tolerant or the classification of Ball (1983) should be modified to include yield parameters as well.

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