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Field Evaluation of Some Pearl Millet Genotypes for Downy Mildew (Sclerospora graminicola) Resistance and Yield

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Abstract: *Four tested downy mildew resistant pearl millet varieties were crossed to four tested downy mildew susceptible pearl millet varieties using North Carolina design 11 mating design. Sixteen hybrids and their parents (eight) were evaluated for downy mildew incidence, downy mildew severity and yield in two locations. The parents that were tested resistant to downy mildew were found to be susceptible while the susceptible parents maintained their downy mildew status. The aim of the study was to select hybrids with least disease incidence and high yield. Those that were high yielding have high degree of tolerance for downy mildew disease. From the analysis of variance, highly significant mean squares were observed among the genotypes for all the agronomic characters except disease severity and number of tillers per plot. Mean square of the location × genotype was highly significant for yield and significant for number of panicles per plot. Seven hybrids were found to moderately resistant and high yielding indicating their tolerance to the pathogen.*

I. Introduction

Pearl millet is a warm weather crop cultivated annually as a rain-fed crop in the arid and semi-arid tropics of Africa and Indian subcontinent where no other crop can survive due to poor soils and erratic and uncertain rainfalls. Khairwal et al., 1999 Described pearl millet as an erect annual plant with a good tillering ability. According to Andrews et al., (1993), pearl millet is a highly tillering, naturally cross-pollinating tropical cereal species, which is achieved through protogyny, since all the sessile flowers on each head are perfect (i.e. both male and female fertile).

Pearl millet is the most important among a number of unrelated millet species grown for food worldwide (Totok et al., 1997; Rai et al., 1999; Purseglove, 1974). Pearl millet may be considered as a single species but it includes a number of cultivated races. It is almost certainly originated in tropical western Africa, where the greatest number of both wild and cultivated forms occurs. About 2000 years ago the crop was carried to eastern and central Africa and to India, where because of its excellent tolerance to drought it became established in the drier environments.

In general, growth and productivity of pearl millet crop has been hampered by the incidence of diseases and pest. (Lakshmana, 2008). Therefore, there is need for developing hybrids that are both disease resistance and high yielding.

Pearl millet is attacked by about 111 disease induced by fungi, bacteria, viruses and nematodes (Hash et al., 1997). Out of these 111 diseases of pearl millet, fungal diseases are the most serious problem in the production of pearl millet. Fungal diseases of pearl millet include downy mildew (Sclerospora graminicola (Sacc) shoet) (Chahal et al., 1994).

II. Methodology

Four resistant to downy mildew varieties (POE5532, SOSATC88, P1449 and DMR15) were crossed to four susceptible to downy mildew varieties (BDP1, MOP1, LCIC9702 and PEO5984). The experiment was conducted in a randomized complete block design with the 8 lines and their 16 hybrids in three replications. Crosses were obtained using a factorial mating scheme of North Carolina Design II, where each member of a group of males was mated to each member of group of females (Hallauer and Miranda, 1981). The evaluation of hybrids and parents on the fields was done using Complete Randomized block design (CRBD).

Field Evaluation Of Hybrids And Parents

Planting for evaluation was done in Samaru- Zaria (IAR Irrigation Research Farm) and Bakura (IAR Irrigation Research Farm) in Zamfara state. Five meter long ridges with inter row spacing of 75cm and intra row spacing of 50cm was prepared using tractor. Few seeds were sown per hill and the plants were thinned down to two plants per stand two weeks after sowing. Compound fertilizer NPK (15:15:15) was applied two weeks after planting and urea was use as top dress at six weeks after sowing (WAS). All other cultural practice was observed.

The allocation of hybrids to each plot was done with the aid of random number table and each cell represented a plot. Millet variety 7042S was used as infector row. The infectors' rows were between the hybrids such that each hybrid was in contact with the infector row. On each hill in the row, a hole of 3cm was dug and a pinch of the inoculums (Zoospores of downy mildew) was poured after which 4 seeds were planted. The plants were thinned down to 2 plants per hill. This procedure was performed on the hybrids, parents and the infector row (7042S). The infector row was planted 2weeks before the planting of the hybrids and the parents' seeds.
Downy Mildew incidence (number of diseased plants showing downy mildew symptoms expressed as a percentage of total number of plants in a plot) was assessed at 30 and 60 days after sowing (DAS) by scoring for chlorosis of infected plants and at dough stage by scoring for green ears. Downy Mildew incidence (the formula developed by James, 1983), as the number of diseased plants expressed as:

$$\text{DMI} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

At 70 days after sowing (DAS), the severity of downy mildew infection on main stands were recorded using a rating scale as follows: (Ball, 1983)
1 = No disease symptoms.
2 = Disease only on nodal/aerial 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/complete destruction of plant

Severity was then calculated using the formula:

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

Where
Y = number of plants in each reaction category and
N = total number of plants in the genotype under test.
Disease rating scale: For classifying the pearl millet genotypes the rating scale of Ball (1983), which is based on the incidence of downy mildew on the basal tillers, was adopted:
0-5% disease incidence = Highly Resistance (HR)
5-10% disease incidence = Resistance (R)
10-25% disease incidence = Moderately Resistance (MR)
25-50% disease incidence = Moderately Susceptible (MS)
50-80% disease incidence = Susceptible(S)
>80% disease incidence = Highly Susceptible (HS)

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.
Analysis of variance for individual crosses was evaluated based on the differences between the F1 and the parents.

III. Result

Analysis of variance for 10 characters studied is summarized in table 1. Mean squares due to genotypes were highly significant ($(p < 0.01)$ for all the traits across locations except for disease severity and number of tillers per plot. In case of location, all traits indicated highly significant mean square except, panicle weight per plot. In the interaction component, genotype x location yield was highly significant and number of panicles per plot was significant.

Table 1: Analysis of variance (Mean square) in respect of 10 different characters in pearl millet Across Locations

		MS									
Source of variation	DF	DI	DS	50%DH	PtL	NT	PANHT	PAND	NPAN	PANWT	GRWT/Ha
REPLICATION	2										
Location	1	7084.03**	1.31**	4.13**	86652.66**	68.43**	1612.16**	19.75**	12583.75**	0.83	1355.40**
GENOTYPE	23	921.44**	0.04	13.74**	628.93**	0.9	55.58**	0.80*	1056.33**	3.53**	32.07**
Location*Genotype	23	210.7	0.05	2.07	145.31	2.66	9.82	0.32	576.30*	1.06	21.67**
ERROR	96	370.71	0.04	1.5	208.23	1.85	9.33	0.46	334.07	0.81	5.95

Where:

DF= degree of freedom
DI=downy mildew incidence
DS= Downy mildew Severity
50% DF =50% Days to flowering
PtL(cm) =Plant Length
NT= Number of Productive Tillers
P LT =Plant Length
PANL =Panicle length
PAND =Panicle Diameter
PANWT =Panicle Weight
NPAN = Number of Panicle
GRW/ha =Grain Weight/Hectare

Table 2 showed the mean performance of the parents and hybrids for ten characters studied. Duncan multiple grouping test SAS was used to test the significant differences between values obtained in the evaluation of the parents and the hybrids and also to rank performance of the varieties. Also Fisher's protected least significant difference test with the aid of GenStat Fourteenth Edition GenStat Procedure Library Release PL22.0 was used and it was observed that in Bakura variance ratio for Variety were not significant for Disease Severity, Number productive tillers per plot and Panicle diameter. In Zaria, the variance ratio for Variety were not significant for Disease Severity, Number productive tillers per plot, Panicle diameter and plant height.

Table 3 showed the mean performance of Downy mildew incidence and severity rating for pearl millet hybrids and their parents in combined locations.

From the table 2 the mean performance for downy mildew Incidence across locations,

Showed that all the four female parents maintained their status of susceptility with disease incidence ranging from 56.32% (MOP1) to 90.33% (PEO5984). The female parent PEO5984 (90.33%) showed the highest value for disease incidence and the lowest yield (906.7 kg/ ha) among the female parents. MOP1 (1964.4 kg/ ha) gave the highest yield. The male parents' disease incidence ranged from 50.77% (SOSATC88) to 79.70% (DMR15).The male parents were tested as resistant varieties in LCRI Maiduguri but showed some degrees of susceptibility on the fields (Bakura and Zaria farm). Out of the 16 hybrids LCIC9702 ×SOSATC88 (34.23%) had the lowest value of disease incidence with yield of 1826.7kg/ ha followed by BDP1 ×SOSATC88 (43.13) with a yield of 1848.9kg/ ha. Disease Incidence ranged from 34.23% to 67.35% for the hybrids. While for downy mildew severity,

The female parents exhibited disease severity ranging from 0.77 (LCIC9702) to 1.00 (BDP1) and the male parents value of disease severity ranged from 0.67 (PEO5532) to 1.06 (SOSATC88). Among the hybrids the disease severity ranges from 0.77 (MOP1 ×PEO5532) to 0.97 (MOP1 ×SOSATC88).

Table 2: Means Performance of 8 Pearl Millet parents and 16 hybrids of Pearl Millet for ten traits across Locations.

Genotypes	DI	DS	50% DH	P HT	NT	PANHT	PAND	NPAN	PANWT	GRWT/P	GRW/ha
BDP1	63.72bc	1.00ab	49.20abc	171.28bcde	7.02a	30.58abc	8.34abcd	41.00de	1.18ghi	0.9233cdef	1393.3fg
MOP1	56.32bcd	0.95abc	48.83abc	180.72abcd	6.75ab	28.17abcde	8.18abcd	53.33cde	1.98cdefghi	**1.4733ab**	1960.0cdef
LCIC9702	62.75bc	**0.77bc**	47.83c	161.97de	**7.05a**	23.55fgh	**8.72a**	51.33cde	1.53efghi	1.0667bcde	1888.9def
PEO5984	90.33a	0.97ab	**45.17d**	154.42e	**7.50a**	19.88h	7.73bcd	64.67abcd	0.90hi	0.5800f	920.0g
PEO5532	62.80bc	**0.67c**	50.17a	170.85bcde	6.88ab	23.25fgh	8.40abcd	51.33cde	1.88cdefghi	1.0600bcde	1817.8def
SOSATC88	50.77cd	1.06a	49.00abc	175.55abcd	6.97ab	23.10fgh	8.65abc	55.50cde	2.05cdefgh	1.2000abcd	2444.4abcde
P1449	59.92bcd	0.94abc	50.17a	165.77cde	**7.08a**	26.55cdefg	7.65d	64.00abcd	1.65efghi	0.6600ef	1706.7ef
DMR15	79.70ab	0.82abc	49.83ab	165.87cde	6.93ab	25.07efg	7.97abcd	33.00e	0.75i	0.8167def	1255.6fg
BDP1 ×PEO5532	49.68cd	0.88abc	49.50abc	178.38abcd	**7.50a**	**31.22ab**	**8.63abc**	53.50cde	2.10cdefgh	**1.3767abc**	**2473.3abcde**
BDP1 ×SOSATC88	**43.13cd**	0.90abc	48.17bc	**187.00ab**	6.67ab	**31.17ab**	8.07abcd	76.83abc	**3.57ab**	**1.3867abc**	**3146.7a**
BDP1 ×P1449	54.85bcd	0.91abc	48.50abc	**186.07ab**	**7.22a**	**31.32a**	7.70dc	75.17abc	**3.65a**	1.0567bcde	**2460.0abcde**
BDP1 ×DMR15	54.85bcd	0.84abc	48.67abc	**190.40ab**	6.25b	27.08bcdefg	**8.68ab**	59.00bcd	2.05cdefgh	**1.3600abc**	2373.3bcde
MOP1 ×PEO5532	66.77abc	**0.77bc**	49.50abc	**183.38abc**	6.78ab	27.30abcdef	8.07abcd	55.17cde	1.88cdefghi	**1.2633abcd**	2331.1bcde
MOP1 ×SOSATC88	**45.68cd**	0.97ab	49.33abc	**193.95a**	7.25a	**28.23abcde**	7.55d	71.17abc	2.92abcd	**1.6200a**	**2724.4abc**
MOP1 ×P1449	51.98cd	0.87abc	48.67abc	178.18abcd	**7.83a**	**29.73abcd**	7.83abcd	62.83bcd	2.42bcdef	1.2433abcd	**2451.1abcde**
MOP1 ×DMR15	50.17cd	0.85abc	48.00c	180.18abcd	**7.53a**	28.02abcde	8.18abcd	83.33ab	**3.03abc**	0.8333def	2373.3bcde
LCIC9702 ×PEO5532	**46.57cd**	0.84abc	48.83abc	179.37abcd	7.37a	25.03efg	**8.73a**	69.17abc	2.4833abcdef	1.0267bcdef	2306.7bcde
LCIC9702 ×SOSATC88	**34.23d**	0.84abc	49.50abc	180.85abcd	6.47ab	**28.33abcde**	**8.62abc**	66.33abcd	**2.98abc**	**1.3700abc**	**3135.6a**
LCIC9702 ×P1449	**40.62cd**	0.84abc	49.33abc	**183.17abc**	**7.25a**	27.20abcdefg	**8.62abc**	74.50abc	**2.77abcde**	1.0833bcde	**2766.7ab**
LCIC9702×DMR15	51.48cd	0.89abc	48.00c	**183.75abc**	6.98ab	25.50efg	8.35abcd	88.83a	2.47abcdef	0.7967def	2420.0abcde
PEO5984 ×PEO5532	53.82bcd	0.81abc	**45.83d**	162.00de	6.82ab	22.98gh	8.35abcd	51.00cde	1.40fghi	0.6800ef	1728.9def
PEO5984 ×SOSATC88	**44.90cd**	0.87abc	**45.50d**	174.05abcd	6.88ab	23.03gh	**8.45abcd**	83.83ab	2.38bcdef	0.5600f	**2506.7abcd**
PEO5984 ×P1449	67.35abc	0.88abc	**45.83d**	164.73cde	**7.22a**	26.00defg	8.37abcd	67.33abc	1.70defghi	0.9800cdef	1986.7cdef
PEO5984 ×DMR15	62.35bc	0.89abc	**46.17d**	165.47cde	6.32ab	23.60fgh	8.32abcd	64.00abcd	1.40fghi	0.6267ef	1728.9def

DI=Downy mildew Incidence		PANLT =Panicle length	P LT =Plant Length	PANWT =Panicle Weight/plot	
DS=Downy mildew Severity		NPAN = Number of Panicle/plot	NT =Number of Productive Tillers	GRW/ha =Grain Weight/Hectare	
50% DF =Days to flowering		PAND =Panicle Diameter			

Means followed by the same letter(s) are not significantly different using DMRT.

From table 3, the male parents who were tested resistant from the research institutes were susceptible on the field in both locations. Seven hybrids were moderately susceptible while nine were susceptible. The female parents ranged from 56.32% (MOP1) to 90.33% (PEO5984) from downy mildew incidence. Variation for downy mildew incidence among the female parents ranged from 34.23% (LCIC9702 ×SOSATC88) to 66.77% (MOP1 ×PEO5532).LCIC9702 ×SOSATC88 has the lowest downy mildew incidence. The severity study showed different degree of downy mildew severity.

Table 3: Mean performance of Downy mildew incidence and severity rating for pearl millet hybrids and their parents in combined locations. (2011, Bakura and Zaria).

S/No	Genotypes	Downy mildew Incidence % (Mean)	Downy mildew Rating	Downy Severity (Mean)
1	BDP1	63.72bc	S	1.00ab
2	MOP1	56.32bcd	**S**	0.95abc
3	LCIC9702	62.75bc	S	0.77bc
4	PEO5984	90.33a	HS	0.97ab
5	PEO5532	62.80bc	S	0.67c
6	SOSATC88	50.77cd	S	1.06a
7	P1449	59.92bcd	S	0.94abc
8	DMR15	79.70ab	S	0.82abc
9	BDP1 ×PEO5532	**49.68cd**	MS	0.88abc
10	BDP1 ×SOSATC88	**43.13cd**	**MS**	0.90abc
11	BDP1 ×P1449	54.85bcd	S	0.91abc
12	BDP1 ×DMR15	54.85bcd	S	0.84abc
13	MOP1 ×PEO5532	66.77abc	S	0.77bc
14	MOP1 ×SOSATC88	**45.68cd**	MS	0.97ab
15	MOP1 ×P1449	51.98cd	S	0.87abc
16	MOP1 ×DMR15	50.17cd	S	0.85abc
17	LCIC9702 ×PEO5532	**46.57cd**	MS	**0.84abc**
18	LCIC9702 ×SOSATC88	**34.23d**	**MS**	**0.84abc**
19	LCIC9702 ×P1449	**40.62cd**	MS	**0.84abc**
20	LCIC9702×DMR15	51.48cd	S	0.89abc
21	PEO5984 ×PEO5532	53.82bcd	S	**0.81abc**
22	PEO5984 ×SOSATC88	**44.90cd**	**MS**	0.87abc
23	PEO5984 ×P1449	67.35abc	S	0.88abc
24	PEO5984 ×DMR15	62.35bc	S	0.89abc
	Grand mean 56.0	s.e. 16.55		
	l.s.d @ 5% 13.51	cv. 29.5 %		

Downy Mildew Symptoms develop as a result of systemic infection. Downy mildew symptoms generally appear on the second leaf, and once they appear, all subsequent leaves and panicles also develop symptoms; except in the case of recovery resistance where plants outgrow the disease (Singh and King 1988). Symptoms also appeared on the first leaf under conditions that favor severe disease development. Leaf symptoms were first seen as chlorosis (yellowing) at the base of the leaf lamina, and successively younger leaves show a progression of greater leaf area coverage by symptoms (plate 1). Half-leaf symptoms, Characterized by a distinct margin between the diseased (basal portion) and non-diseased area towards the tip. Under conditions of high (>95%) relative humidity (RH) and moderate temperature (20-22 C), massive asexual sporulation were seen on infected chlorotic areas, generally on the abaxial surface of leaves, giving them a downy appearance. Severely infected plants are generally stunted, and do not produce panicles. Green ear symptoms become visible at panicle emergence. Green ears develop because floral parts are transformed into leafy structures, which may vary in shape and size (plate 2); the transformation may be partial or total, depending on when the panicle was colonized by the pathogen. The leafy structures are chlorotic, and sometimes produce sporulation. In latent infections, green ear is the only manifestation of the disease. Very rarely, local lesions are produced on the leaf lamina under certain conditions (Singh et al., 1993). These local lesions vary in shape and size, are chlorotic in the early stages, produce asexual spores, and later become necrotic.

Plate 1. A pearl millet leaf showing the typical half-leaf symptom of downy mildew infection. At IAR Farm S17.

Plate 2: Different manifestations of the disease. At IAR Farm S17 and Bakura Farm

IV. Discussion

From the analysis of variance (table 2), highly significant mean square were observed among the genotypes for all agronomic characters except number of tillers per plot and downy mildew severity. This was an indication of the presence of considerable amount of genetic diversity in the materials which could be used to enhance selection for further population improvement.

The study of the mean performance of the hybrids and their parents (Table 3) hybrids BDP1 ×SOSATC88 (3146.7Kg/ha**)** had the highest yield among all the genotypes studied followed by LCIC9702 ×SOSATC88 (3135.6Kg/ha**)** and downy mildew incidence rating showed that they were moderately susceptible indicating that despite the presence of the disease, the infection has not reach the threshold to affect the physiological development of the plants. That the tested resistant parents were susceptible suggested that the inoculums used were different strain of downy mildew and that the strain was highly virulent. That these

hybrids have high yield also indicated some degree of tolerance for the disease. All the hybrids showed higher yield than most of the parents indicating that the hybrids have some degree of tolerance for the disease and if the yield were high and nine of the hybrids were rated susceptible to downy mildew incidence it shows that if they were inoculated with same inoculums that were used to test the resistant parents they would have higher yield and highly resistant to downy mildew disease.

V. Conclusion

A study on the reaction of hybrids and their parents to downy mildew infestation in the field was aimed at selecting hybrids with least reaction to downy mildew infestation was carried out by involving four downy mildew susceptible line and four downy mildew resistant lines and their hybrids. LCIC9702 ×SOSATC88 had the lowest disease incidence (34.23% moderately susceptible) on field and also recorded the highest yield per hectare (3135.6Kg) the next to it was LCIC9702 ×P1449 though BDP1 ×SOSATC88 had yield that was closed to LCIC9702 ×SOSATC88, it had higher value of downy mildew incidence(43.13%). Also it was moderately susceptible. There was no significant difference downy mildew severity of these hybrids. Thus they are considered to have the best performance and can be selected for pearl millet improvement for disease resistance. However, hybrids LCIC9702 ×P1449, MOP1 ×SOSATC88, PEO5984 ×SOSATC88, BDP1 ×P1449 and, MOP1 ×P1449 performed better in yield than the parent (SOSATC88) with the best mean performance. BDP1 ×PEO5532 and LCIC9702 ×PEO5532 also have high mean performance and were all moderately susceptible to downy mildew infestation and were considered to be tolerance of the disease. That is they were attacked by the pathogens to the same degree as others but they suffered less damage with regard to yield. It was obvious from the performance these hybrids and their parents that they were inoculated with different strain of the pathogen and this downy mildew strain appeared to be more virulent than the strain that the male parent s were tested on. It was observed that the disease have not reach the threshold to have significant effect on the physiology of the plants hence the yield was high for most of the hybrids.

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