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A Comparism of the Response of Some Pearl Millest *(Pennisetum glaucum* (L.) R. BR) Hybrids and Their Parents to Downy Mildew *(Sclerospora graminicola)* Infestation in Bakura and Zaria (North-western Nigeria)

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ABSTRACT

Downy mildew *(Sclerospora graminicola* (Sacc) Schroet.) of pearl millet [*Pennisetum glaucum* (L.) R.Br.] is a devastating disease that has greatly led to *grain yield loss in Nigeria*. A field experiment was carried out in 2010 at Bakura (Zamfara State) and Zaria (Kaduna State) in North West Nigeria. The objective of this paper was to evaluate downy mildew resistance in some pearl millet using Complete Randomized Block Design. Four resistant male varieties (PEO5532, SOSATC88, P1449 and DMR15) and four susceptible female varieties (BDP1, MOP1, LCIC9702 and PEO5984 were used in this study. The resistant varieties were crossed with the susceptible varieties using North Carolina design 11 for the mating to form sixteen (F1) hybrids. The F1 hybrids were further evaluated along with their parents for downy mildew resistance, grain yield and other agronomic traits (such as: Plant height, panicle height, number of tillers per plant, panicle diameter and number panicles per plot). The resistant male parents were found to be susceptible while none of the hybrids was resistant to downy mildew. However, the degree of incidence and severity of downy mildew disease defer in the two locations. The hybrids exhibited tolerance to downy mildew disease and their yields were higher than their parents. The analysis of variance (one tale ANOVA or which one?) showed highly significant difference among parents and hybrids for all agronomic characters except disease severity and number of tillers per plant. Location × genotype interaction effects were only significant for grain yield and number of panicles per plot.

***Keywords*:** downy mildew, hybrids, obligate biotrophs, resistant, tolerance

1. INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is a collective term referring to a number of small-seeded annual grasses that are cultivated as grain crops, primarily on marginal land in dry areas in temperate, sub-tropical and tropical regions [1]. Millet are widely grown around the world for food and fodder. Pearl millet belongs to the family Poaceae (Graminae) and genus Pennisetum. It is a highly cross-pollinated crop with protogynous flowering and wind borne pollination mechanism, which fulfils one of the essential biological requirements for hybrid development [2]. Pearl millet is diploid (2x = 14) in nature and is commonly known as bajra, cat tail millet, and bulrush millet in different parts of the world [2]. Pearl millet [*Pennisetum glaucum* (L.) R. Br.], is one of the most important staple cereals for over 40 million subsistence farmers living in the most marginal agricultural lands of Northern Nigeria, due to its high tolerance to drought, high temperatures, saline and marginal soils, and high capacity to buffer variable environmental conditions [3]. Improving production of pearl millet while maintaining its production stability is crucial for food security for poor African smallholder farmers cropping under rain-fed farming systems [4]. The exploitation of diverse germ plasm resources of the crop for breeding improved varieties would therefore always be necessary [5].

Downy mildew of pearl millet (*Pennisetum glaucum*), sometimes referred to as ‘green ear’ disease, is caused by an obligate biotrophic pathogenic fungi *Sclerospora graminicola* (Sacc.) Schroet. [6-8]). Downy mildews are obligate biotrophs, i.e. they are host-dependent. Coevolution with plant hosts over a long period has led to divergent forms of pathogen adapted to deferent host taxa. Reproduction is usually both by sexual and asexual means. During the sexual phase oospores are formed. Oospores are thick-walled and long-lived which enable the pathogens to survive crop-free and adverse periods [9-11]). Oospores are the primary inoculum source. When there is conducive weather conditions asexual phase occurs. In Nigeria, several yield loss estimates have been reported ranging from 6-73% depending on variety [12-18]). [19] explained that this disease can assume alarming levels when a single genetically uniform pearl millet cultivar is repeatedly and extensively grown in a region where the downy mildew pathogen is present. Such alarming levels have been reported in India from regions where one single-cross hybrid was widely cultivated for several years [20]. Hence, disease resistance is a major concern in pearl millet improvement and has been the subject of several reviews [21-28]).

This study seeks to identify and select the varieties that performed better in each location and recommend the varieties that perform best for further improvement program.

2. MATERIALS AND METHOD

Study Area

Bakura is located in the northern part of Zamfara state. It is located between 04° to 13° East of the Greenwich meridian and between 10° to 13° North of the Equator. It is located on the Hausa High planes at 450 meters above Sea Level. Bakura enjoys a typical Tropical Continental climate with marked distinct seasonal regimes oscillating between cool to dry and humid to wet seasons that are controlled by the apparent movement of the Intertropical Discontinuity Divide(ITD). The average rainfall is about 942mm. The daily mean temperature is about 27 °C to a mean maximum of 38 °C and is high for most part of the year [29].

Zaria is located at the northern part of Kaduna state in Northern Nigeria on about 11°28'N and about 7°48'E longitude. Zaria is 613 meters above sea level. The climate of Zaria described is a Tropical Continental Climate type comprising of the wet and dry season. The climate is characterized by strong seasonality in rain fall and relatively high temperatures. The mean annual rainfall is 1029.52 mm falling from May to October. The mean annual temperature is 26 °C to a mean maximum of 37 °C ([30], Samaru Map- Satellite Image of Samaru (Map landia. Comp) 22/02/13; 9.51 am.

Description of Experimental Materials Used in the Study.

Pearl millet genotypes PEO5532. According to the LCRI, DMRI5, PEO5532, SOSATC88, and P1449 are resistant to Downy mildew disease; whereas LCIC9702 and PEO5984 are susceptible. Additional two susceptible varieties, i.e. BDP1 and MOP1, were acquired from Institute National de Recherche Agronimiques De Niger Cerra de Maradi (INRAN), Maradi in the Republic of Niger.

Experimental Design

The experimental designs were the same for the two locations. Crosses were obtained using a factorial mating scheme of North Carolina Design II, where each males was mated to each of the females ([31,32]). The evaluation of hybrids and parents on the fields was done using Complete Randomized block design (CRBD).

Evaluation of Hybrids and Parents

Sowing for evaluation was done in Samaru-Zaria,(Kaduna State) and Bakura (Zamfara state).The ridges were five meter long with inter row spacing of 75 cm and intra row spacing of 50 cm. The cultural practices were within the range of the guidelines given for Crop Management by Agriculture Environmental Renewal Canada Inc. and that of Alternative Field Crop Manual from University of Wisconsin Extension. Four seeds were sown per hill and the plants were later thinned to two plants per stand two weeks after sowing (WAS) Compound fertilizer NPK (15:15:15) was applied two weeks after sowing and urea was use as top dress at six weeks after sowing (WAS).

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 3 cm was dug and a pinch of the inoculum (Zoospores of downy mildew) was poured after which 4 seeds were planted per hill. The plants were thinned down to 2 plants per hill. This procedure was performed on the hybrids, parents and the infector rows (7042S). The infector rows were planted 2 weeks before the planting of the hybrids and the parents' seeds.

Statistical Analysis of Data

The forms of the general analysis of variance and the genetic component of variances for each location was performed using SPSS. Duncan Multiple Range Test was used to compare treatment means of the parents and the hybrids and also to rank performances of the varieties.

3. RESULTS AND DISCUSSION

Outcome of the statistical analysis of Data

From the analysis of variance, for Bakura (Table 1.) highly significant mean squares were observed among the genotypes in Zaria for days to 50% flowering, Plant Height, Panicle Height, Panicle weight /plot And Grain weight/Ha. Table 2 shows the results of single tail ANOVA for Zaria. There was significant mean squares for Days to 50% flowering, Panicle Height, Number of panicles per plant, Panicle weight per plot And Grain weight/Ha. This is 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. [33], reported a similar result in pearl millet studies. The non- significant mean squares see table 2 due to the male x female interaction in both locations indicated that hybrids did not differ significantly in their specific combining ability effects for all the traits. Significant mean square see table 2 was observed among females for Disease Incidence, Days to 50% flowering, Number of panicles per plant Panicle Height and Grain weight/Ha in Bakura but in Zaria, non- significant mean squares was observed for all the traits. Among the males highly significant mean square (see table 2) were observed for Days to 50% flowering, Plant height, Panicle Height and Panicle weight per plot in Bakura. Also in Zaria, significant mean square for Days to 50% flowering Plant Height, Panicle Height, Panicle weight per plot and Grain weight/Ha among the males. The non- significant mean squares might be due to error in both location.

Table 1. Mean squares from 10 characters in pearl millet for Bakura

Sources of Variation	DF	MS									
		DI	DS	50%DF	PTH	NT	NPP	PANH	PAND	PANWT	GRWT/Ha
Replication	2	5005.80**	0.04	1.72	2423.87**	5.73**	175.72	95.11**	1.2	0.92	17.06
Genotype	23	429.64	0.04	9.13**	421.40**	1.11	321.03	42.92**	0.43	1.41**	43.32**
Female	3	636.23*	0.03	5.24*	244.83	1.12	18.98*	635.47*	0.45	1.71**	57.70*
Male	3	674.90*	0.05	31.02**	1065.93**	2.04	135.28**	156.19	1.06*	0.98*	5.3
Female x Male	9	189.28	0.03	1.68	140.28	0.49	4.35	146.91	0.25	0.23	10.64
Error	46	269.66	0.03	1.42	106.51	0.70	175.59	6.58	0.46	0.22	6.77

*Significant at ($p \geq 0.05$) ** = highly significant at (0.01)

Table 2. Mean squares from 10 characters in pearl millet for Zaria

Source of Variation	DF	DI	DS	50%DF	PTH	NT	PANH	NPP	PAND	PAN WT	GRWT/Ha
Replication	2	193.76	0.02	1.35	115.63	29.63**	17.87	1488.76	0.89	1.33	4.97
Genotype	23	702.49**	0.04	6.93**	350.39	2.41	20.58**	1408.26**	0.75	3.27**	10.48**
Female	3	352.09	0.01	1.69	160.34	3.25	12.06	997.58	0.57	3.41	7.72
Male	3	275.56	0.02	24.91**	952.99**	7.47*	48.89*	513.41	1.04	8.17*	29.99*
Female x Male	9	142.83	0.02	2.21	70.42	1.60	7.74	853.97	0.5	1.93	5.16
Error	46	277.93	0.05	1.56	214.34	1.61	8.76	444.81	0.43	1.37	4.59

* Significant at ($p \geq 0.05$) ** = highly significant at (0.01)

Where:

DF = degree of freedom	PTH = Plant height
DI = downy mildew incidence	PANH = Panicle height
DS = Downy mildew Severity	PAND = Panicle Diameter
50% DF = Days to 50% flowering	PANWT = Panicle Weight/PLOT
NPAN = Number of Panicle/PLOT	

Mean performance for millet hybrids and their parents in both locations.

Table 3 and 4 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 the means of the parents and the hybrids and also to rank performance of the varieties. Fisher's protected least significant difference test was used. The results of the Duncan multiple grouping test SAS indicates that the genotypes performed better in Bakura for plant height, panicle length, panicle diameter, grain weight and yield, while for number of tillers per plant and number of panicles per plot the genotypes performed better in Zaria. The genotypes performances in the two locations were similar for days to 50% flowering and panicle weight per plot. This may be due to the differences in the soil, climatic conditions and environmental conditions of the two locations.

The male parents that were resistant lines became susceptible under field evaluation. This indicated the possibility of breakdown of resistance to downy mildew by the material collected from the research institute or there could be virulence change in the *S. graminicola*. Moreover, virulence change has been reported in *S. graminicola* and more virulent pathotypes have evolved in the recent past [34,36]).

According to [37] the major change in disease incidence (%) of a pearl millet line over time at the same location was a reflection of virulence shift in the pathogen population. This is based on the basic assumptions that variables, such as environmental factors and inoculum load, were optimal for disease development and that the seed of each pearl millet line was genuine at the time of testing. The work of [37] showed that most of the accessions used in the study have lost their resistance to the new virulence(s). The study also indicated the importance of regular monitoring of virulence shift in the pathogen populations and identifying stable resistance for an effective downy mildew resistance breeding in pearl millet.

For resistance breeding programmes to be effective, it require close monitoring of virulence change in the pathogen and identification of new resistance sources to the new virulent strains. Furthermore, virulence change in *S. graminicola* populations was monitored through a collaborative pearl millet downy mildew nursery, on-farm surveys for downy mildew incidence and by characterizing pathogen isolates collected from highly susceptible cultivars in the farmers' fields on a set of putative differential hosts [38,39]). On-farm surveys in the hybrid-intensive states of India during the past several years have indicated increased susceptibility of a hybrid when grown in the same field for more than three consecutive crop seasons suggesting emergence/selection of new virulence traits over time at the same location [40,41]).

The mean performance for Bakura (Table 3), among the hybrids, the disease severity ranged from 0.62 in PEO5984 × P1449 to 0.88 in BDP1 × P1449. While in Zaria (Table 4) the range of downy mildew severity among the hybrids was 0.82 (BDP1 × SOSATC88) to 1.08 (BDP1 × P1449) [42] attributed the differences in the downy mildew manifestation in different location to environmental conditions such as high rainfall, greater number of humid months and lower temperatures are conducive for disease development..

In both locations hybrid BDP1 × P1449 had the highest downy mildew severity indicating that hybrid BDP1 × P1449 reacted similarly to downy mildew infection in both locations. While for downy mildew incidence in both locations hybrid LCIC9702 × SOSATC88 had the lowest downy mildew incidence though the hybrid exhibited more tolerance to the disease in Zaria having 31% than in Bakura where it have 37% [42] reported similar result in their work on pearl millet downy mildew incidence in different locations. .

Days to 50 per cent flowering, PEO5984 was the earliest among the parents in both location (45 days) the rest were about 50 days. Hybrids PEO5984 × P1449 was the earliest exhibited 45 days to 50 per cent flowering in Bakura. While hybrids PEO5984 × DMR15 and LCIC9702 × DMR15 have 50 days in Zaria. The parents and hybrids showed a wide range of variation in plant height.

The shortest parents have height of 169.60 cm (PEO5984) and the tallest was 206.53 cm (MOP1) in Bakura. In Zaria, the shortest parent exhibited 129.70cm (LCIC9702) and the tallest parent was SOSATC88 (157.17cm). In Bakura the hybrids (225.80 cm) had the tallest plant height, while PEO5984 ×DMR15 (184.63 cm) was the shortest. In Zaria, the tallest hybrid was BDP1 ×P1449 (169.30cm) and the shortest was PEO5984 × DMR15 (136.27cm). Both parents and hybrids were taller in Bakura.

For number of tillers per plot, the parents have number of tiller per plot ranging from 5 tillers to 7 tillers per plot. Among the hybrids, the number of tillers per plot ranged from 5 tillers (BDP1 × SOSATC88 to 7 tillers (PEO5984 × P1449) tillers per plot in Bakura. While in Zaria the number of tillers per plot, the parents have number of tiller per plot ranging from 7(DMR15) tillers to 8 tillers per plot. Among the hybrids, the number of tillers per plot ranged from 5 tillers (BDP1 × DMR15 and PEO5984 × DMR15 to 9 tillers BDP1 ×P1449, MOP1 × SOSATC88 and MOP1 ×P1449) tillers per plot.

In Bakura, the parent with the longest panicle have 31.97 cm (MOP1) while the parent with shortest panicle length have 23.07 cm (PEO5984). Also, among the hybrids, the hybrid with the shortest panicle length was PEO5984 × PEO5532 (25.23 cm) while the hybrid with the longest panicle length was BDP1 × P1449 (36.57 cm). In Zaria, the parent with the longest panicle length had 22.83cm (DMR15) and the parent with the shortest panicle length had 16.70 cm (PEO5984). Also among the hybrids, the hybrid with the longest panicle length was 27.73 cm (BDP1 × PEO5532) and the hybrid with the shortest panicle length was 19.93 cm (PEO5984 × SOSATC88). In both locations, PEO5984 had the shortest panicle length.

In Bakura, Panicle diameter among the parents ranged from 8.30cm (PEO5984) to 9.27 cm (LCIC9702). Among the hybrids, panicle diameter ranged from 7.77cm (MOP1 × SOSATC88) to 9.17cm (LCIC9702 × PEO5532).While in Zaria, panicle diameter among the parents ranged from 6.97cm (P1449) to 8.37cm (PEO5532). Among the hybrids, panicle diameter ranged from 7.20cm (MOP1 × P1449) to 8.77cm (BDP1 × PEO5532).

In Bakura, number of panicles per plot among the parents ranged from 44 (DMR15) to 58 panicles (P1449) per plot. Hybrid BDP1 × SOSATC88 had the highest number of panicles per plot (70) while PEO5984 × PEO5532 had the lowest number of panicles per plot (40). In Zaria, the number of panicles per plot among the parents ranged from 22.00 (DMR15) to 94.67 panicles (PEO5984). Hybrid LCIC9702 × DMR15 (108) had the highest number of panicles per plot while PEO5984 × DMR14 (60.00) had the lowest number of panicles per plot. DMR15 have the lowest number of panicles per plot in both locations. Though DMR15 performed better in Bakura than Zaria.

The panicle weight per plot for the parents in Bakura ranged from 0.80 Kg (PEO5984) to 2.47Kg (SOSATC88). The lowest panicle weight per plot among the hybrids was 1.90Kg (PEO5984 × PEO5532) while the highest was 3.33Kg (BDP1 × SOSATC88 and LCIC9702 × SOSATC88). In Zaria, the panicle weight per plot for the parents ranged from 0.43Kg (DMR15) to 2.50 Kg (MOP1). The lowest panicle weight per plot among the hybrids was 0.83 Kg (PEO5984 × DMR15) while the highest was 4.67Kg (BDP1 × P1449).

For Bakura, the parent with the lowest yield had 1066.70(PEO5984**)** and the parent with highest yield had 3288.90Kg (SOSATC88). Grain yield in the hybrids ranged from 2533.30 Kg (PEO5984 × PEO5532) to 4444.40 Kg (LCIC9702 × SOSATC88 and BDP1 × SOSATC88). While in Zaria, the parent with the lowest yield had 773.30 Kg (PEO5984**)** and the parent with highest yield had 1964.40Kg (MOP1). Grain yield in the hybrids ranged from 746.70Kg (PEO5984 × SOSATC88) to 1848.90 Kg (BDP1 × SOSATC88).

Table 3. Means Performance of 8 parents and 16 hybrids of Pearl Millet for ten traits in Bakura

Genotypes	DI	DS	50% DF	P TH	NT	PANH	NPAN	PAND	PANWT	GRW/ha
BDP1	71.57abc	0.92abc	48.67a-d	191.13cde	6.03abc	30.93b-e	43.00a-d	8.90ab	1.17hij	1555.60hij
MOP1	67.73a-d	1.01ab	48.67a-d	206.53a-d	5.17c	31.97a-d	38.33bcd	8.70ab	1.47g-j	1955.60g-j
LCIC9702	65.33a-d	0.77abc	48.33a-d	195.23cde	5.77abc	23.93gh	50.67abc	9.27a	1.77e-i	2355.60e-i
PEO5984	80.67ab	0.66c	44.67f	169.60f	6.67abc	23.07h	35.00bcd	8.30ab	0.80j	1066.70j
PEO5532	65.70a-d	0.80abc	50.67a	201.60cde	5.43bc	24.60fgh	44.67a-d	8.43ab	1.67f-i	2222.20fghi
SOSATC88	71.80abc	0.62c	48.33a-d	193.93cde	6.27abc	25.77fgh	63.67ab	**9.13a**	2.47a-f	3288.90a-f
P1449	72.23abc	0.79abc	50.33a	194.33cde	6.83abc	31.63a-d	57.67abc	8.40ab	1.90e-i	2533.30e-i
DMR15	85.00a	0.62c	50.00ab	189.40cde	7.20a	27.30d-h	44.33a-d	8.47ab	1.07ij	1422.20ij
BDP1 ×PEO5532	53.13a-d	0.82abc	49.67abc	201.63cde	6.67abc	34.70ab	44.67a-d	8.50ab	2.33a-f	3111.10b-g
BDP1 ×SOSATC88	51.00bcd	0.80abc	47.00de	208.93abc	5.33bc	35.50ab	70.00a	8.30ab	3.33a	4444.40a
BDP1 ×P1449	66.67a-d	0.88abc	48.33a-d	202.83cde	5.77abc	36.57a	58.00abc	8.03ab	2.63a-e	3511.10a-e
BDP1 ×DMR15	65.57a-d	0.82abc	47.67b-e	205.53bcd	6.50abc	31.43bcd	54.33abc	8.93ab	2.20c-g	2933.30c-g
MOP1 ×PEO5532	75.97ab	0.84abc	50.33a	225.80a	5.90abc	31.93a-d	48.00a-d	8.40ab	2.23c-g	2977.80c-g
MOP1 ×SOSATC88	48.73bcd	0.70bc	49.00a-d	223.40ab	5.50bc	32.10a-d	52.67abc	7.77b	2.47a-f	3288.90a-f
MOP1 ×P1449	55.60a-d	75abc	49.33a-d	201.77cde	.33abc	33.90abc	50.33abc	8.47ab	2.43a-f	3244.40a-f
MOP1 ×DMR15	56.13a-d	0.85abc	47.33cde	203.50cde	6.73abc	31.83a-d	61.00ab	8.40ab	2.43a-f	3244.40a-f

LCIC9702 ×PEO5532	58.00a-d	0.74abc	49.33a-d	206.90abc	6.40abc	28.63d-g	55.00abc	9.17a	2.43a-f	3244.40a-f
LCIC9702 ×SOSATC88	37.03d	0.71bc	49.33a-d	207.53abc	6.27abc	32.00a-d	56.00abc	8.50ab	3.33a	4444.40a
LCIC9702 ×P1449	41.23cd	0.68bc	48.33a-d	207.43abc	6.83abc	31.80a-d	65.00ab	9.23a	3.07abc	4088.90abc
LCIC9702×DMR15	57.37a-d	0.65c	49.00a-d	203.57cde	6.63abc	28.93c-f	61.00ab	8.77ab	2.83a-d	3777.80a-d
PEO5984 ×PEO5532	69.53a-d	0.82abc	46.00ef	186.17def	6.97ab	25.23fgh	40.00a-d	8.70ab	1.90e-i	2533.30e-i
PEO5984 ×SOSATC88	54.13a-d	0.82abc	44.67f	198.70cde	6.77abc	26.13efgh	63.00ab	8.73ab	3.20ab	4266.70ab
PEO5984 ×P1449	74.80ab	0.62c	45.67ef	184.63ef	7.43a	28.07d-g	65.00ab	8.60ab	2.00d-h	2666.70d-h
PEO5984 ×DMR15	68.13a-d	1.05a	45.67ef	194.67cde	6.63abc	27.27d-h	68.00ab	8.97ab	1.97d-h	2622.20d-h
Mean	63.04	0.78	47.9	203.94	6.42	31	57.56	8.59	2.55	5790.28
SE	0.71	0.05	0.34	2.98	0.24	0.74	0.2	3.83	0.13	0.75

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

Where
PTH = Plant height
DI = downy mildew incidence
DS = Downy mildew Severity
50% DF = 50% Days to flowering
NPAN = Number of Panicle
GRW/ha = Grain Weight/Hectare
PANH = Panicle Height
PAND = Panicle Diameter
PANWT = Panicle Weight
NT = Number of Productive Tillers per plant

Table 4. Means Performance of 8 parents and 16 hybrids of Pearl Millet for ten traits in Zaria.

Genotypes	DI	DS	50% DH	P TH	NT	PANH	NPAN	PAND	PANWT	GRW/ha
BDP1	55.87bc	1.15ab	50.33a	144.57abc	8.00bac	27.30ab	33.33fg	7.17bc	0.97e	1231.10b-e
MOP1	44.9bc	0.99ab	49.00b-d	154.90abc	8.33abc	24.37a-d	68.33a-f	7.67bac	2.50a-e	1964.40ab
LCIC9702	60.17bc	0.89b	47.33b-f	128.70c	8.33abc	23.17a-d	52.00d-g	8.17abc	1.30de	1422.20a-e
PEO5984	100.00a	1.13ba	45.67f	139.23bc	8.33abc	16.70e	94.33abc	7.17bc	1.00e	773.30de
PEO5532	59.9bc	0.85b	49.67ab	140.10abc	8.33abc	21.90a-e	62.00c-f	8.37ab	2.10b-e	1413.30a-e
SOSATC88	29.73c	1.36a	49.67ab	157.17abc	7.67abc	20.43cde	47.33fg	8.17abc	1.63-e	1600.00a-e
P1449	47.6bc	0.98ba	50.00a	137.20bc	7.33abc	21.47c-f	70.33a-f	6.97c	1.40cde	880.00de
DMR15	74.4ba	0.99ba	49.67ab	142.33abc	6.67bc	22.83a-d	21.67g	7.47abc	0.43e	1088.90b-e
BDP1 ×PEO5532	46.23bc	0.94ba	49.33abc	155.13abc	8.33abc	27.73a	62.33c-f	8.77a	1.87b-e	1835.60ab

BDP1 ×SOSATC88	35.27c	0.82b	49.33abc	165.07ab	8.00.abc	26.83ab	83.67a-e	7.83abc	3.80ab	1848.90ab
BDP1 ×P1449	43.03bc	1.08ab	48.67a-e	169.30a	8.67ba	26.07abc	92.33a-d	7.37bc	4.67a	1408.90a-e
BDP1 ×DMR15	44.13bc	0.87b	49.67a	161.23ab	6.00c	22.73a-d	63.67c-f	8.43ab	1.90b-e	1813.30abc
MOP1 ×PEO5532	57.57bc	0.91ab	48.67a-e	155.00abc	7.67abc	22.67a-d	62.33c-f	7.73abc	1.53b-e	1684.40a-d
MOP1 ×SOSATC88	42.63bc	0.96ab	49.667ba	164.50ba	9.00ba	24.37a-d	89.67a-d	7.33bc	3.37a-d	2160.00a
MOP1 ×P1449	48.37bc	0.83b	49.00b-c	154.60abc	9.33a	25.57a-d	75.33a-e	7.20bc	2.40b-e	1657.80a-e
MOP1 ×DMR15	44.2bc	1.01ab	48.67a-e	156.87abc	8.33abc	24.20a-d	105.67a	7.97abc	3.63abc	1111.10b-e
LCIC9702 ×PEO5532	35.13c	0.89b	48.33a-e	151.83abc	8.33abc	21.43b-e	83.33a-e	8.30ab	2.53a-e	1368.90a-e
LCIC9702 ×SOSATC88	31.43c	0.86b	49.67ba	154.17abc	6.67bc	24.67abcd	76.67a-e	8.73a	2.63a-e	1826.70abc
LCIC9702 ×P1449	40.00c	0.87b	50.33a	158.90ba	7.67abc	22.60a-d	84.00a-e	8.00abc	2.47a-e	1444.40a-e
LCIC9702×DMR15	45.60bc	0.97ab	47.00c-f	163.93ab	7.33abc	22.07a-e	107.67a	7.93abc	2.10b-e	1062.20b-e
PEO5984 ×PEO5532	38.10c	1.01ab	45.67f	137.83bc	6.67bc	20.73cde	62.00c-f	8.00abc	0.90e	906.70cde
PEO5984 ×SOSATC88	35.67c	0.93ab	46.33f	149.40abc	7.00abc	19.93de	104.67ba	8.17abc	1.57b-e	746.70e
PEO5984 ×P1449	59.90bc	1.01ab	46.00f	144.83abc	7.00abc	23.93a-d	69.67a-f	8.13abc	1.40cde	1306.70a-e
PEO5984 ×DMR15	56.57bc	1.05ab	46.67def	136.27bc	6.00c	19.93de	60.00c-g	7.67abc	0.83e	835.60de
Mean	66.09	0.97	48.31	154.93	7.63	23.47	80.19	7.97	2.35	3596.53
SE	4.81	0.06	0.36	4.23	0.37	0.85	6.09	0.19	0.33	0.63

The means followed by the same letter(s) are not significantly different using DMRT

4. CONCLUSION AND RECOMMENDATIONS

The parent with highest yield had 3288.90Kg (SOSATC88).The most productive hybrids in terms of grain yield based on the mean performance in both locations were LCIC9702 × SOSATC88 and BDP1 × SOSATC88 (4444.40 Kg/Ha for Bakura and 3135.6Kg for Zaria). For downy mildew incidence in both locations hybrid LCIC9702 × SOSATC88 had the lowest downy mildew incidence though the hybrid exhibited more tolerance to the disease in Zaria having 31% than in Bakura where it have 37%. 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 had high mean performance and were all moderately susceptible to downy mildew infestation and were considered to be tolerant to the disease. In other words, although, they were attacked by the pathogens to the same degree as others, they suffered less damage with regards to grain yield. It was obvious from the performance of these hybrids and their parents that they were inoculated with different strains of the pathogen which appeared to be more virulent than the strain that the male parent s were tested on.

Parent PEO5984 was the earliest among the parents in both location while Hybrids PEO5984 × P1449 was the earliest exhibited 45 days in Bakura and PEO5984 × SOSATC88 in Zaria. PEO5984 sources are the earliest among the hybrids in both location. Thus PEO5984 can be selected for earliness.

In conclusion, hybridsLCIC9702 × SOSATC88 and BDP1 × SOSATC88are considered to have the best performance and can be selected for pearl millet improvement for yield. Hybrid LCIC9702 × SOSATC88 had the lowest disease resistance thus they are considered to have the best performance and can be selected for pearl millet improvement for disease resistance. Also, PEO5984 × P1449 and PEO5984 × SOSATC88 were considered for earliness.

Reference

[1] FAO and ICRISAT. The world Sorghum and Millet economies- facts, trends and outlook. (Italy: Rome) (1996) 68.

[2] Lakshmana D. Genetic diversity, heterosis and combining ability studies involving diverse sources of cytoplasmic genetic male sterility in pearl millet [*Pennisetum glaucum* (L.) R.Br.] Ph.D. Dissertation Department Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad - 580 005 (2008) 168.

[3] Angarawai, I. I, Aladele S., Dawud M. A. , Turaki Z G S. & Yakub Y. Genetic Diversity among Nigeria 'Maiwa Type' of Pearl Millet Germplasm. Global Journal of Science Frontier Research (D) Volume XVI Issue I II Version I (2016) 15-19.

[4] Pucher Anna, Ousmane Sy, Ignatius I. Angarawai, Jada Gondah, Roger Zangre, Mahamadi Ouedraogo, Moussa D. Sanogo, S. Boureima, C. Tom Hash, Bettina I.G. Haussmann. Agro-morphological Characterization of West and Central African Pearl Millet Accessions. Crop Sci. 55 (2015) 737–748. doi: 10.2135/cropsci 2014.06.0450 c Crop Science Society of America | 5585 Guilford Rd., Madison, WI 53711 USA.

[5] Akromah, R., Afribeh, D. And Abdulai M.S. Genetic variation and trait correlations in a bird resistant pearl millet landrace population. African Journal of Biotechnology Vol. 7 (12) (2008) 1847-1850, 17 June, 2008. ISSN 1684–5315 © 2008 Academic Journals

[6] Singh, S.D., S.B. King and J. Werder. Downy mildew disease of pearl millet. Information Bulletin No. 37 (1993). International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India.

[7] Jeger, M. J., Gilijamse, E., Bock, C. H. and Frinking, H. D. The epidemiology, Variability and control of the downy mildews of pearl millet and sorghum with particular reference to Africa. Plant Pathology 47 (1998) 544-569.

[8] Zarafi, A.B., Emechebe, A.M., Akpa, A.D and O. Alabi. Pathogenic variability Among Sclerospora graminicola isolates in Northern Nigeria. Nigerian Journal of Tropical Agriculture 4 (2002) 1-11

[9] Payak, M.M. Epidemiology of maize downy mildew with special reference to those occurring in Asia. Tropical. Agricultural Resource. Series (Tokyo) 8 (1975) 81-91.

[10] Ramalingam, A., Rajasab, A.H. Epidemiology of sorghum downy mildew. VI. Relative importance of oospores and conidia in epidemics of systemic infection. Proc. Indian Nat. Sci. Acad, Part B 47 (1981) 625-630.

[11] Singh. S.D. Downy mildew of pearl millet. Plant Diseases 79 (1995) 545-550

[12] Selveraj, J. C. Research on pearl millet diseases in Nigeria. Samaru Conference Paper 28 (1979) 20.

[13] Harris E. Diseases of Millet. Samaru Technical Notes, Volume 11A 1.2, Samaru. (1962) 6.

[14] King, S. B. World review of pearl millet diseases: knowledge and future research needs. In Sorghum and millets Diseases: A Second World Review (W.A.J. de Milliano, R.A. Frederikesn and G.D. Bengstoneds). ICRISAT, Patacheru, India. (1972) 95-108.

[15] Zarafi, A.B., Emechebe, A.M., Akpa, A.D and O. Alabi. The incidence of pearl millet downy mildew, Sclerospora graminicola (Sacc.) in Samaru, Nigeria. Nigerian journal of tropical Agriculture 3: (2001) 14-22.

[16] Anaso, A. B. Pearl millet downy mildew in Maiduguri, Nigeria. Disease incidence and loss estimates. Nigerian journal of Plant Protection 16 (1996) 82-92.

[17] Turaki, Z.G.S. Crop loss assessment and Evaluation of pearl millet cultivars for resistance to downy mildew, Sclerosporagraminicola, (Sacc. Schroet.) in Northern Nigeria. A Ph.D Thesis submitted to Crop Protection Department, University of Maiduguri, Nigeria (unpublished) (2004).

[18] Andrews, D.J. Breeding Pearl millet grain Hybrid. In FAO/DANIDA Regional Seminar on Breeding and Producing Hybrid Varieties. (W.P. Feistritzer and A.F. Kelly, eds.) FA, Rome, Italy (1987) Pp 83-109.

[19] Singh, S.D. and G. Singh, Resistance to downy mildew in pearl millet hybrid NHB 3. Indian Phytopathology 40 (1987) 178-180.

[20] Singh, S.D. Recycling of pearl millet cultivars for the control of downy mildew. Indian journal of plant protection 22 (1994) 164-169.

[21] Louvel, D. Breeding Millet (Pennisetum glaucum) for disease resistance. Center National de Recharches Agronomiques, Bambey, Senegal. (1982).

[22] Williams, R.J. and D.J. Andrews. Breeding for disease and pest resistance in pearl millet. FAO plant protection Bulletin 31 (1983) 136-158.

[23] Williams, R.J. Disease resistance in pearl millet. Rev. Tropical Plant Pathology.1 (1984) 245-296.

[24] Andrews, D.J., S.B. King, J.R. Witcombe, S.D. Singh, K.N. Rai, R.P. Thakur, B.S. Talukdar, S.B. Chavan, and P. Singh, Breeding for disease resistance and yield in pearl millet. Field Crops Research. 11 (1985) 241-258.

[25] Rai, K.N. and N.B. Singh. Breeding pearl millet male-sterile lines. In Proceedings International Pearl Millet Workshop. (J.R. Witcombe and S.R. Backerman, Eds). ICRISAT, Patancheru, India. (1987) 127-137.

[26] King, S. B. World review of pearl millet diseases: knowledge and future research needs. In Sorghum and millets Diseases: A Second World Review (W.A.J. de Milliano, R.A. Frederikesn and G.D. Bengston eds). ICRISAT, Patacheru, India. (1972) 95-108.

[27] Talukdar, B.S., S.D. Singh and C.T. Hash. Breeding for resistance to diseases in pearl millet. In Crop Breeding in India. (H.G. Singh S. N. Mishra T.B. Singh, HariHar Rant and D.F Sing eds). International Book Distributing Company, Lucknow, India. (1994) 176-185.

[28] Rai, K.N. and K.A. Kumar. Pearl millet Improvement at ICRISAT – An update. International Sorghum and millet Newsletter 35 (1994) 1-29

[29] Zamfara State Agricultural Development Authority. Planning, Monitoring Evaluation (PME) Department and the Agricultural Development Planning (ADP) Department (2008).

[30] Ati, O.F. Place of weather and climate in the preservation of scholarly and literary traditions and manuscripts heritage. Presented at International Conference on Preserving Nigeria's Scholarly and Literary Traditions and Arabic Manuscripts Heritage organized by Arewa House, Ahmadu Bello University, Zaria in Collaboration with the United States Embassy, Abuja, held at Arewa House, Kaduna, Nigeria. 7th – 8th March 2007. Pp 6

[31] Comstock, R.E., and H.F. Robinson. The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. Biometrics 4 (1948) 254-66.

[32] Hallauer, A.R., and J.B. Miranda. Quantitative genetics in maize breeding. 2nd ed. Iowa State Univ. Press, Ames, IA. (1981).

[33] Yahaya, Y. Studies of Combining Ability and Heterosis of Male Sterile Lines and their Restorers in Pearl Millet (Pennisetum glaucum (L) R. Br.). A Ph.D. Dissertation. ABU Zaria. (2004) 154.

[34] Thakur, R.P., Shetty, K.G. Variation in pathogenicity amongsingle-oospore isolates of Sclerospora graminicola, the causalorganism of downy mildew in pearl millet.Plant pathology. 42 (1993) 715-721.

[35] Thakur, R.P., Rao, V.P. Variation in virulence and aggressiveness among Pathotypes of Sclerospora graminicola on pearl millet. Indian Phytopathology.50 (1997) 41-47.

[36] Thakur R.P., Rao V.P. and Sharma R. Evidence for temporal virulence change in the pearl millet downy mildew pathogen, Sclerospora graminicola in India. Journal of SAT Agricultural Research 3 (2007) (www.icrisat.org/journal/index.htm)

[37] Thakur, R.P.; Rao, V.P. and Sharma, R. Temporal Virulence Change and Identification of Resistance in Pearl Millet Germplasm to Diverse Pathotypes of Sclerospora Graminicola. Journal of Plant Pathology 91 (3) (2009) 629-636.

[38] Sivaramakrishnan S., Thakur R.P., Kannan S., Rao V.P. Pathogenic and genetic diversity among Indian isolates of Sclerospora graminicola from pearl millet. Indian Phytopathology 56 (2003) 392-397.

[39] Sharma R., Rao V.P., Varshney R.K., Prasanth V.P., Kannan S., Thakur R.P. Characterization of pathogenic and molecular diversity in Sclerospora graminicola, the causal agent of pearl millet downy mildew. Archives of Phytopathology and Plant Protection (in press) (2008).

[40] Thakur R.P. Downy mildew prevents realization of high yield potential of pearl millet hybrids in Maharshtra. Downy mildew of pearl millet in Maharshtra. Short communications (2003) 5.

[41] Thakur R.P., Shetty H.S., Khairwal I.S. Pearl millet downy mildew research in India: progress and perspectives. International Sorghum and Millets Newsletter 47 (2006) 125-130.

[42] Zarafi B. A. and Alphonsus E. M. Incidence of Pearl Millet Downy Mildew [Sclerospora graminicola (Sacc.)] in Nigeria. Journal of Plant Protection Research. Vol. 45 (3) (2005) 154-162.

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