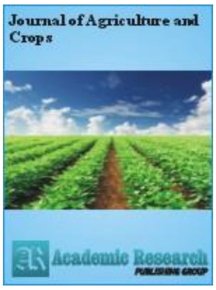

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Evaluation of Heterosis in Pearl Millet *(Pennisetum Glaucum (L.) R. Br)* for Agronomic Traits and Resistance to Downy Mildew (Sclerospora Graminicola)

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Abstract: An experiment was carried out in Bakura and Zaria to evaluate heterosis for downy mildew resistance in some pearl millet using Complete Randomized Block Design. Four resistant varieties (PEO5532, SOSATC88, P1449 and DMR15) and four susceptible varieties (BDP1, MOP1, LCIC9702 and PEO5984 were used as male and female respectively. The resistant varieties were crossed with the susceptible varieties using North Carolina design 11. Sixteen (F1) hybrids obtained were evaluated along with their parents for downy mildew resistance, grain yield and other agronomic traits. The analysis of variance showed highly significant difference among parents and hybrids for all agronomic characters. Location × genotype interaction effects were only significant for grain yield and number of panicles per plot. The study selected the best parents that give high heterosis in terms of yield components, yield and downy mildew resistance. Two hybrids PEO5984 × P1449 and PEO5984 × PEO5532 had significant heterosis for 50% days to flower ng, PEO5984 × P1449, PEO5984 × PEO5532, PEO5984 × DMR15 and PEO5984 × SOSATC88 for yield, the best MP and BP heterosis for downy mildew incidence is PEO5984 × P1449 and MOP1 × p1449 for MP heterosis and BDP1 × P1449 for BP heterosis. Correlation among the characters studied showed that magnitudes of genetic correlation were higher than those of phenotypic correlation in some of the traits considered. The number of panicles / plot and panicle weight / plot showed significant genetic correlations indicate degree of correlation with grain yield. This showed that selection for any of these characters could lead to indirect selection of grain yield.

Keywords: Heterosis; Agronomic traits; Resistance; Pearl millet; Downy mildew; Hybrids.

1. Introduction

Pearl millet [*Pennisetum glaucum* (L.) R.Br.] 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. 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 [1]. Some common local names include Joro, Maiwa, and Ahai. 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 occur. About 2000 years ago the crop was carried to eastern and central Africa and to India, where its excellent tolerance to drought became established in the drier environments [2].

The downy mildew pathogens infecting maize, sorghum, and pearl millet have similar environmental requirements for asexual reproduction. Prior to sporulation the host tissue requires exposure to high light intensity for photosynthetic energy. At 20^{0}C in the dark, a systemically infected sorghum leaf produced 10,800 conidia cm^2 at 100% RH, but only 3600 conidia cm^2 at 85% RH, and none at 80% RH. A minimum of 3h at 25 ^{0}C and 95% RH is essential to initiate sporulation in *S. graminicola* [3]. Production of conidia and sporangia in the field has a marked period of release and has a close relationship with temperature and RH. Most sporulation occurs when temperatures are around 20 ^{0}C and RH >95% [4, 5].

The pearl millet downy mildew pathogen is highly variable, adaptable and has the capacity to develop host-specific pathotypes [6-8]. Using DNA fingerprinting techniques, Sastry, *et al.* [9], confirmed the existence of distinct host genotype-specific virulence in downy mildew pathotypes. The pathogen populations present in different locations of India generally do not differ qualitatively. However, sharp differences in aggressiveness exist between the populations from India and Nigeria. There are also differences between the populations present in different Western African countries, for example, between Nigeria and Senegal as reported by Singh, *et al.* [3] and [10].

1.1. Uses and Nutritive Status of Pearl Millet

Pearl millet is the most drought tolerant warm-season cereal crop predominantly grown as a staple food grain and source of feed and fodder. It provides nutritionally superior and staple food for millions of people living in harsh environments characterized by erratic rainfall and nutrient-poor soil. In fact, pearl millet is the only suitable and efficient crop for arid and semiarid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize [11]. Farmers prefer the crop as low cost, low risk option not only by choice but also by necessity [12]. The relative proportion of germ to endosperm is higher than in sorghum. According to Gerard and Cathryn [13], it is the staple food of millions of world's poorest and most food insecure people particularly in India and Africa. [2].

The grain has high levels of protein with balanced amino acids, CHO and fat which are important in the human diet, and its nutritive value is considered to be comparable to rice and wheat. It is also cultivated as green fodder crop in some parts of the Nigeria. The green fodder is more palatable than sorghum because it does not have HCN content.

1.2. Botany of Pearl Millet

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 rainfalls [14]. Purseglove [15], described it as an erect annual plant with a good tillering ability. According to Andrews, *et al.* [16], 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). The gero types are early maturing and non- photosensitive while the maiwa and dauro are late maturing and photosensitive.

Gero, maiwa and dauro are grown in Nigeria. The gero types are early maturing and non- photosensitive while the maiwa and dauro are late maturing and photosensitive.

1.3. Heterosis for some Agronomic Characters in Pearl Millet

Johnson and Hutchinson [17], defined heterosis quantitatively, as the upward deviation from the mid-parent values. Heterosis may be positive or negative, both of which are useful for crop improvement depending on the breeding objectives. Positive heterosis is desirable for grain yield while negative heterosis is desirable for downy mildew resistance [18]. Nienhaus and Pickett [19], reported that the key for obtaining heterosis otherwise known as hybrid vigour is genetic diversity. When crosses involve geographically diverse and presumably genetically diverse parents, high yielding hybrids are produced. In their study on sorghum, hybrids that involve both exotic and landraces gave a grain yield of 183% above the mid-parent value. In pearl millet, Quendeba, *et al.* [20], reported heterosis of up to 81%, which indicated their genetic potential for hybrid development.

Manga and Dubey [21] in a diallel study, observed good amount of heterosis for productive tillers per plant and ear weight. Sheoran, *et al.* [22] recorded the maximum heterobeltiosis for grain yeild per plantthis character among all the characters studied. Ramamoorthi and Govindrasu [23], observed that hybrid PT3832 x 732B recorded significantly high heterosis for grain yield than all crosses, while Blummel and Rai [24] reported significant positive as well as negative heterosis. Pethani, *et al.* [25] recorded heterosis over mid parent and better parent for various traits, the hybrid MS 2072A x J-2338 expressed the highest heterotic value for grain yield over mid parent (152.92 %) and better parent (121.45%). Manga and Dubey [21] in a diallel study, observed high heterosis (96.2 to 300.7%) for grain yield. Yadav, *et al.* [26] reported heterosis up to 88% for grain yield.

Correlation coefficients provide a measure of genetic association between characters and this helps to identify the more important characters to be considered in breading programmes. The cause of correlation can either be genetic or environmental. Genetic correlation which is the correlation of breeding value is chiefly pleiotropy or through linkage and it is the cause of transient correlation, particularly in populations derived from crosses between divergent strains [27]. The association between two characters that can be directly observed is the correlation of phenotypic value or phenotypic correlation. This is determined from measurement of the two characters in a number of individual of the population.

2. Materials and Method

2.1. Description of Experimental Materials Used in the Study

Pearl millet genotypes used in the study are: BDP1, MOP1, LCIC9702, PEO5984, PEO 5532, SOSATC 88, P1449 and DMRI5. PEO5532, SOSATC88, P1449, DMRI5, LCIC9702 and PEO5984.

2.2. Experimental Design

Crosses were obtained using a factorial mating scheme of North Carolina Design II, where each male was mated to each of the female [28, 29]. The ridges were 10 meters long with 20 plants per ridge and two ridges per plot with inter row spacing of 75cm and intra row spacing of 50cm The evaluation of hybrids and parents on the fields was done using Randomized Complete Block Design (RCBD) with three replications.

2.3. Analysis of Data

The forms of the general analysis of variance was calculated

2.3.1. Estimates of Heterosis

Heterosis was estimated using MPH and BPH. Mid-parent heterosis (MPH) is the performance of a hybrid relative to the average performance of its parents expressed in percentage.

$$H(\%)Mp = \frac{F_1 - Mp}{Mp} \times 100$$

High-parent heterosis (HPH) is the performance of a hybrid relative to the performance of its best parent expressed in percentage. [30]

$$H(\%)Hp = \frac{F_1 - Hp}{Hp} \times 100$$

Where; F_1 = mean of F_1 generation
Mp = mean of mid-parent 1 and 2
Hp = mean of superior performing parent

3. Results and Discussion

Hybrids obtained from the cross of 4 resistant and 4 susceptible of pearl millet varieties were: BDP1 ×PEO5532, BDP1 ×SOSATC88, BDP1 ×P1449, BDP1 ×DMR15, MOP1 ×PEO5532, MOP1 ×SOSATC88, MOP1 ×P1449, MOP1 ×DMR15, LCIC9702 ×PEO5532, LCIC9702 ×SOSATC88, LCIC9702 ×P1449, LCIC9702×DMR15, PEO5984 ×PEO5532,PEO5984 ×SOSATC88, PEO5984 ×P1449 and PEO5984 ×DMR15.

From the analysis of variance (table 1), highly significant mean squares were observed among the genotypes for all agronomic characters except number of tillers per plot and downy mildew severity. 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 Yahaya [31], reported a similar result in pearl millet studies. The non- significant mean squares due to the male x female interaction indicated that hybrids did not differ significantly in their sca effects for all the traits. Highly significant mean squares due to 'parents vs. hybrids' showed presence of heterosis in hybrids for all the traits except number of tillers /plot, panicle diameter and downy mildew severity. Genotype × location was non-significant for all traits except for number of panicles /plot and grain yield /plot. Lack of significant of Genotype × location interaction variance indicates adequate buffering capacity of the two environments of testing. Erikson, *et al.* [32] explained that non-significant Genotype × location is an expectation in population showing little genetic variation however, Miller, *et al.* [33] explained that, it was due to non-random sampling of the genotypes. Erikson, *et al.* [32] explanation is more likely to hold true for this study because the findings in this study confirmed Erikson's explanation.

Table-1. Mean square from 10 characters in pearl millet (Bakura and Zaria combined)

Expected Mean Square

Source of variation	DF	DI	DS	50% DF	PTH (cm)	NT	PANH (cm)	PAND (cm)	NPAN	PANWT (Kg)	GRWT/Ha (Kg)
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**

* = significant at (p ≥ 0.05) ** = highly significant at (P≥0.01)
Where:
DF= degree of freedom
DI=downy mildew incidence
DS= Downy mildew Severity
50% DF =50% Days to flowering
NPAN = Number of Panicle
PTH =Plant height
PANH =Panicle height
PAND =Panicle Diameter
PANWT =Panicle Weight

3.1. Heterosis

It was evident from the tables 2 and 3 that the degree of heterosis varied considerably for grain yield and its components. A critical examination of the heterosis for grain yield/ha indicated that it was mainly the result of heterosis for Panicle weight/plot and Number of panicles / plot. Similar observations were also made by Ugale, *et al.* [34] and Baviskar [35] for the same combinations showing significant heterosis for grain yield. The heterosis for grain yield/ha is in turn contributed by Number of tillers/plot, panicle length, panicle diameter and number of panicle/ plot [1, 24, 25, 36] reported similar findings.

The study on heterosis indicated that highly significant heterotic crosses were generally productive. Negative heterosis observed in downy mildew incidence, downy mildew severity and 50% DF are desirable in breeding for earliness and downy mildew resistance. Also, negative heterosis for earliness indicated the scope of developing high yielding and early maturing hybrids. Heterosis for earliness has also been reported by several workers [37-39].

The negative heterosis observed in characters like Panicle height, Number of tillers, Panicle diameter, Panicle weight and Grain weight/ha (tables 2 and 3) could be due to sample variation, linkage, inadequate statistical and genetic models. Similarly, plant height had very low heterosis. These results revealed that heterosis for grain yield in pearl millet is mainly contributed by the panicle components rather than vegetative traits. Yahaya [31], observed similar result in his research on pearl millet.

Table-2. Mid Parent Heterosis of hybrids over different characters in Pearl millet

	50% DF	PTH	NT	PANH	PAND	NPP	PANWt	GRWT/Ha	DI	DS
BDP1 ×DMR15	-2.01	9.90**	-2.01	-0.03	8.54*	65.81**	126.42**	85.28**	-23.53	-7.91
BDP1 ×P1449	-3.68	10.16**	-3.68	-8.38	6.48*	73.90**	81.60**	56.99**	-16.71	-16.06
BDP1 ×PEO5532	-3.68	6.40*	-3.68	7	-0.41	82.15**	105.65**	38.19*	-20.69	-0.1
BDP1 ×SOSATC88	-6.26	-3.63	-6.26	-9.61	-0.3	36.65*	-10.16	-0.94	8.9	4.36
MOP1 ×DMR15	-1.69	7.37*	-1.69	17.66**	-4.64	74.13**	167.07**	53.23**	-19.32	8.71
MOP1 ×P1449	-0.34	5.73*	-0.34	-0.58	8.84**	26.99*	52.29*	44.70**	-30.11	-17.32
MOP1 ×PEO5532	-1.68	1.37	-1.68	15.66**	-5.53	17.81	25	33.89*	-12.73	-12.63
MOP1 ×SOSATC88	-6.3	-7.52	-6.3	1.43	-0.59	23.74	-15.7	-2.67	25.80**	-17.35
LCIC9702 ×DMR15	1.37	8.83**	1.37	28.42**	3.5	26.88	83.94*	33.70*	-30.48	7.81
LCIC9702 ×P1449	-0.34	9.46**	-0.34	-0.07	6.72*	19.94	56.02*	20.76	-24.08	-5.08
LCIC9702 ×PEO5532	1.02	14.42**	1.02	16.67**	-5.74	5.41	10.24	39.75**	6.33	5.76
LCIC9702×SOSATC88	-5.34	-4	-5.34	-1.46	-3.84	-4.52	-21.86	-16.78	-5.18	0.49
PEO5984 ×DMR15	1.4	16.77**	1.4	38.67**	2.76	57.34**	332.32**	174.84**	-49.28	-4.7
PEO5984 ×P1449	3.85**	12.97**	3.85**	22.04**	12.03**	3.11	133.99**	129.54**	-54.44	-11.81
PEO5984 ×PEO5532	3.50**	19.26**	3.50**	30.91**	-6.4	20.62	109.58**	99.61**	-40.35	-3.65
PEO5984 ×SOSATC88	-3.36	5.5	-3.36	7.17	3.15	39.53**	61.58*	52.13**	-36.37	-7.19

*=significant at 5% (p ≥ 0.05); **=highly significant at 1% (p ≥ 0.01)

Table-3. High-parent heterosis (HPH) of hybrids for different characters in Pearl millet

	50% DF	**PTH**	**NT**	**PANH**	**PAND**	**NPP**	**PANWt**	**GRWT/Ha**	**DI**	**DS**
BDP1 ×DMR15	-2.34	9.25**	-2.34	-6.98	8.09*	54.59**	92.81**	76.12**	-31.2	-18.08
BDP1 ×P1449	-4.32	9.47**	-4.32	-12.42	3.94	38.80**	49.49*	48.71**	-19.19	-21.98
BDP1 ×PEO5532	-4.32	5.46*	-4.32	-3.78	-2.58	56.25**	61.06**	26.51*	-21.26	-10.26
BDP1 ×SOSATC88	-6.73	-5.74	-6.73	-18.95	-3.85	15.32	-31.71	-21.02	-2.17	2.02
MOP1 ×DMR15	-2.68	2.96	-2.68	11.18**	-5.91	40.94**	84.03**	25.60*	-31.17	-1.74
MOP1 ×P1449	-1.66	1.36	-1.66	-3.43	5.3	16.41	39.50*	29.74*	-32.22	-21.85
MOP1 ×PEO5532	-2.99	-1.4	-2.99	5.56	-6.75	17.81	21.85	24.10*	-17.25	-20.23
MOP1 ×SOSATC88	-6.46	-8.84	-6.46	-7.69	-3.28	21.32	-17.07	-10.56	19.61**	-17.75
LCIC9702 ×DMR15	-0.67	7.55*	-0.67	24.53**	-0.96	4.22	36.96	9.53	-37.87	6.24
LCIC9702 ×P1449	-2.66	8.20*	-2.66	-5.71	0.19	8.07	50.51*	8.2	-25.79	-8.2
LCIC9702 ×PEO5532	-1.33	11.44**	-1.33	15.92**	-7.46	3.44	0	29.44*	6.28	5.37
LCIC9702×SOSATC88	-6.46	-7.72	-6.46	-2.41	-4.21	-8.11	-31.71	-23.47	-14.24	-7.54
PEO5984 ×DMR15	-3.34	12.74**	-3.34	24.34**	1.26	18.81	296.30**	149.91**	-52.27	-9.62
PEO5984 ×P1449	-1.33	9.10**	-1.33	6.72	11.42**	2.58	80.81**	90.49**	-62.11	-12.31
PEO5984 ×PEO5532	-1.66	13.52**	-1.66	21.43**	-10.12	10.05	54.87**	60.98**	-49.44	-7.66
PEO5984 ×SOSATC88	-7.14	-0.85	-7.14	-0.29	-2.31	29.64*	16.26	9.43	-50.31	-11.37

*=significant at 5% (p ≥ 0.05); **=highly significant at 1% (p ≥ 0.01)

Table-4. Average heterosis (%) of pearl millet hybrids carrying resistance genes

			Average heterosis (%) (PEO5532, SOSATC88, P1449 and DMR15)
TRAITS	Maximun	Minimum	
Downy mildew Incidence	8.9	-54.44	-20.14
Downy mildew severity	8.71	-17.35	-4.792
Days to 50% flowering	3.85	-6.26	-1.471
Plant length	19.26	-7.52	7.062
Number of tillers	14.91	-11.31	-10.39
Panicle length	38.67	-8.38	10.344
Panicle diameter	12.03	-6.4	1.536
Number of panicle / plot	82.15	-4.52	35.593
Panicle wt / plot	332.32	-21.86	81.124
Yield/ha	174.84	-16.78	52.639

Table-5. Average performance of parents, MP, F1 generation and average MP

Characters	Parental mean				Heterosis (%)
	P1	P2	MP	F1	
Disease Incidence	68.27	63.30	65.79	51.13	-20.14
Disease severity	0.94	0.88	0.91	0.86	-4.79
50% DH	47.83	49.79	48.81	48.08	-1.47
Plant length	166.24	169.51	167.87	179.43	7.06
Number of tillers	7.08	6.97	7.02	7.02	0.06
Panicle length	25.18	24.49	24.84	27.23	10.34
Panicle diameter	8.17	8.17	8.17	8.28	1.54
Number of panicle per plot	51.88	51.46	51.67	68.87	35.59
Panicle wt per plot	1.37	1.58	1.48	2.45	81.12
Yield/ha	7.01	7.54	7.27	10.56	52.64

Table-6. Genotypic (R_g) and Phenotypic Correlation (R_p) Among Yield Related Characters in Millet across Two Locations

Character		50% DF	Plant length	Number of tillers	Panicle length	Panicle Diameter	Number of Panicle	Panicle Weight	Disease Incidence	Grain Yield	Disease severity
50% DF	rg		0.41**	0.51**	-0.33**	0.54**	-0.27*	0.03	-0.76**	-0.37**	-0.65**
	rp		0.29*	-0.32**	0.19	-0.12	-0.15	-0.19	0.00	-0.10	0.05
Plant length	rg			-0.21	-0.43**	0.10	0.35**	-0.06	-0.21	-0.70**	-0.38**
	rp			-0.45**	0.14	-0.26*	-0.02	0.25*	-0.49**	0.20	-0.28
Number of tillers	rg				0.99**	0.15	-0.65**	-0.27*	0.69**	-0.56**	0.34**
	rp				-0.21	0.16	0.18	0.11	0.11	0.11	0.09
Panicle length	rg					0.89**	0.98**	-0.09	0.05	-0.95**	0.82
	rp					0.18	0.17	0.22	-0.04	0.16	0.00
Panicle Diameter	rg						-0.88**	-0.88**	0.05	-0.44**	0.79**
	rp						0.12	-0.14	0.18	-0.15	0.04
Number of Panicle	rg							0.94**	0.05	0.80**	0.44**
	rp							053**	-0.07	0.54**	0.23
Panicle weight	rg								0.96**	0.46**	0.18
	rp								-0.31	0.92**	-0.17
Disease Incidence	rg									0.22	0.29*
	rp									- 0.27*	0.09
Grain Yield	rg										-0.78**
	rp										-0.16
Disease severity	rg										
	rp										

*=significant at 5% (0.235)
**=highly significant at 1% (0.306)
Degree of freedom= N-2= 70

3.2. Average Heterosis (%) of Pearl Millet Hybrids Carrying Resistance Genes

From Table 4, the average heterosis (%) of PEO5532, SOSATC88, P1449 and DMR15 for the traits studied revealed that the direction and magnitude of heterosis was significantly influenced by the male parents. The average heterosis was high for number of panicle per plot, panicle wt per plot and grain yield/ha. The average heterosis was in the desired direction for downy mildew incidence, downy mildew severity, days to 50% flowering and the yield components except number of tillers.

With a view to crystallizing the results, average heterosis was calculated by using parental and F1 generation means. The positive heterotic values were maximum for panicle weight per plot , grain yield/ha, number of panicle per plot and Panicle length in that order.

3.3. Correlation

The magnitudes of genetic correlation coefficient indicate degree of correlation were higher than those of phenotypic correlation coefficients for Plant height, Number of tillers, Panicle diameter, Panicle weight and downy mildew incidence. This is in agreement with Yeye [36]; Phul and Athwal [40]; Rao and Pardhasarathi [41]; Gupta and Dhillon [42] and Diz and Schank [43] who reported higher magnitude of genetic correlations than phenotypic correlations in their studies on pearl millet.

In pearl millet, the most important character of interest to the breeder is the grain yield and disease resistant. Since grain yield is a quantitative character that is influenced by environmental factors, direct selection for yield per se would be difficult. Therefore, to improve the grain yield it is desirable to select for one or more yield related characters e.g panicle length, tiller count and panicle weight. Days to 50% flowering, plant length, number of tillers /plot, panicle weight /plot, panicle diameter and downy mildew severity were found to have negative genetic association with grain yield while number of panicle/plot, panicle weight /plot and downy mildew incidence have positive genotypic correlation with grain yield /ha. This result confirmed the earlier findings of Mahadevappa and Ponnaiya [44] who reported similar findings for 50% days to flowering. This result showed that selection for any of these characters would lead to indirect selection for grain yield. The result was also in agreement with that of Navale and Harinarayana [45] who reported positive genetic correlation between grain yield and total number of tillers, effective tillers and plant height.

The genotypic correlation was higher than the phenotypic correlation indicate correlation between downy mildew incidence and yield indicating that there was a strong inherent relationship between downy mildew incidence and yield. This was in agreement with Johnson and Hutchinson [17]. However, reverse was the case for downy mildew severity and yield indicating that environmental and /or non-additive genetic effect are acting on characters in the same direction.

4. Summary and Conclusion

The study of heterosis was aimed at selecting the best parents that give high heterosis in terms of yield components, yield and downy mildew resistance. From PEO5984 source, two hybrids PEO5984 × P1449 and PEO5984 × PEO5532 had significant heterosis for 50% days to flowering, PEO5984 × P1449, PEO5984 × PEO5532 and PEO5984 × DMR15 for plant height, and panicle height, PEO5984 × P1449 for panicle diameter, PEO5984 × SOSATC88 and PEO5984 × DMR15 for number of panicles per plot and PEO5984 × P1449, PEO5984 × PEO5532, PEO5984 × DMR15 and PEO5984 × SOSATC88 for yield. Hybrids BDP1 × P1449, BDP1 × PEO5532 and BDP1 × DMR15 from BDP1 source have significant heterosis for plant height, BDP1 × P1449 and BDP1 × DMR15 for panicle diameter, BDP1 × P1449, BDP1 × PEO5532, BDP1 × DMR15 and BDP1 × SOSATC88 for number of panicles per plot and BDP1 × P1449, BDP1 × PEO5532 and BDP1 × DMR15 for yield; hybrids MOP1 × P1449 and MOP1 × DMR15 from MOP1 source were significantly heterotic for plant height,MOP1 × PEO5532 for number of tillers per plot, MOP1 × P1449for panicle diameter,MOP1 × P1449 and MOP1 × DMR15 for panicle weight per plot and MOP1 × P1449, MOP1 × DMR15 andMOP1 × PEO5532 for yield; while all the hybrids form LCIC9702 source had significant heterosis for all of the traits except days to 50% flowering, and number of tillers per plot. Considerable heterosis was observed for grain yield and its components. The heterosis for grain yield was largely due to panicle length, panicle girth, panicle weight per plot and number of panicles per plot. The genotypic correlation was higher than the phenotypic correlation between downy mildew incidence and yield indicating that there was a strong inherent relationship between downy mildew incidence and yield. However, the hybrids showed various degrees of downy mildew incidence, they were more tolerant to the disease and have higher yields than their parents.

In conclusion the most productive and most heterotic combination was PEO5984 × DMR15 followed by PEO5984 × P1449 then PEO5984 × PEO5532 and PEO5984 × SOSATC88. The best hybrid as shown by Mid parent and Better parent heterosis for downy mildew incidence was PEO5984 × P1449 while BDP1 × P1449 was the best hybrid Mid parent heterosis for downy mildew severity and the best Better parent heterosis for downy mildew severity was MOP1 × SOSATC88.

References

[1] Lakshmana, D., 2008. *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 Desertation Department Genetics and Plant Breeding*. Dharwad - 580 005: University of Agricultural Sciences.

[2] Angarawai, I. I., 2004. "Inheritance studies of downy mildew resistance. A Ph.D Dissertation submitted to department of crop protection ABU Zaria." p. 120.

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

[4] Payak, M. M., 1975. "Epidemiology of maize downy mildew with special reference to those occurring in Asia." *Tropical Agricultural Resource Series (Tokyo),* vol. 8, pp. 81–91.

[5] Shetty, H. S., 1987. "Biology and epidemiology of downy mildew of pearl millet," In *Proceedings International pearl millet workshop (J.R. Witcombe and S.R. Beckerman, eds). ICRISAT*, Patancheru, India, pp. 147-160.

[6] Singh, S. D. and Singh, G., 1987. "Resistance to downy mildew in pearl millet hybrid NHB 3." *Indian Phytopathology,* vol. 40, pp. 178–180.

[7] R.P., T., Shetty, K. G., and King, S. B., 1992. "Selection for host-specific virulence in asexual populations of Sclerospora graminicola." *Plant Pathology*, vol. 41, pp. 626-632.

[8] Singh, S. D., 1994. "Recycling of pearl millet cultivars for the control of downy mildew." *Indian Journal of Plant Protection,* vol. 22, pp. 164-169.

[9] Sastry, J. G., Ramakrishna, W., Sivaramakrishnan, S., Thakur, R. P., Guphata, V. S., and Ranjekar, P. K., 1995. "DNA fingerprinting detects genetic variability in the pearl millet downy mildew pathogen (Sclerospora graminicola)." *Theoretical and Applied Genetics*, vol. 91, pp. 856-861.

[10] Jones, E. S., Liu, C. J., Gale, M. D., Hash, C. T., and Witcombe, J. R., 1995. "Mapping quantitative trait loci for downy mildew resistance in pearl millet." *Theoretical and Applied Genetics,* vol. 91, pp. 448–456.

[11] Harinarayana, G., Kumar, K. A., and Andrews, D. J., 1999. *Pearl millet in global agriculture. In pearl millet breeding*. New Delhi: Oxford and IBH publishing Co. PVT, Ltd.

[12] Harinarayana, G., 1987. *Pearl millet in Indian agriculture. "Proc. Int. pear millet workshop"*. Andra Pradesh: ICRISAT, Pattencheru.

[13] Gerard, J. G. and Cathryn, T., 2001. "Pearl millet in developing countries. International grain sorghum." *Indian Journal of Genetic and Plant Breeding,* vol. 33, p. 239.
[14] Khairwal, I. S., Rai, K. N., Andrews, D. J., and Harinarayana, G., 1999. *Pearl millet breeding*. New Delhi: Oxford and IBH Publishing Co. PVT. Ltd.
[15] Purseglove, J. W., 1977. *Tropical, Crops:*: Monocotyledous Longman.
[16] Andrews, D. J., Rajewski, J. F., and Kumar, K. A., 1993. *Pearl millet: New feed grain crops. In J. Janick and J.E. Simon (eds.)*. New York: New Crops. Wiley.
[17] Johnson, T. E. and Hutchinson, F. W., 1993. "Absence of strong heterosis for lifespan and other life history traits in Caenorhabditis elegans." *Genetics* vol. 134, pp. 465-474.
[18] Alam, M. F., Khan, M. R., Nurazzaman, M., Parvez, S., Swaraz, A. M., Alam, I., and Ashan, N., 2004. "Genetic bases of heterosis and inbreeding depression in rice." *Journal of Zhejang University of Science,* vol. 5, pp. 406-411.
[19] Nienhaus, M. H. and Pickett, R. C., 1966. "Heterosis and combining ability in diallel crosses in sorghum vulgare Pers." *Crop science,* vol. 6, pp. 33-36.
[20] Quendeba, B., Ejeta, E., Nyquist, W. E., Hanna, W. W., and Kumar, A., 1993. "Heterosis and combining ability among African pearl millet landraces." *Crop Science,* vol. 36, pp. 735-739.
[21] Manga, V. K. and Dubey, L. K., 2004. "Identification of suitable inbreeds on combining ability in pearl millet (Pennisetum glaucum)." *Indian Journal of Agricultural Science,* vol. 74, pp. 98-101.
[22] Sheoran, R. K., Govila, O. P., Balzor-Singh, and Singh, B. B., 2000. "Genetic architecture of yield and yield contributing traits in pearl millet." *Annual Agricural Resource,* vol. 21, pp. 443-445.
[23] Ramamoorthi, N. and Govindrasu, R., 2000. "Heterosis for grain yield and its components in pearl millet." *Madras Agricultural Journal,* vol. 87, pp. 159-161.
[24] Blummel, M. and Rai, K. N., 2003. "Stover quality and grain yield relationship and heterosis in pearl millet." *International. Sorghum and Millet Newsletter,* vol. 44, pp. 141-145.
[25] Pethani, V. K., Afara, S. D., and Monpara, B. A., 2004. "Heterosis and combining ability for plant and seed characters in pearlmillet." *Nation. Journal of Plant Improvement,* vol. 6, pp. 115-118.
[26] Yadav, O. P., Sabharwal, P. S., Beniwal, C. R., and Hanuman, 2000. "Combining ability study for some newly developed male sterile lines for forage attributes in pearl millet." *Forage Resource,* vol. 27, pp. 277-280.
[27] Falconer, D. S., 1981. *Introduction to quantitative genetics,* 2nd ed. New York: The Ronald Press Company.
[28] Comstock, R. E. and Robinson, H. F., 1948. "The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance." *Biometrics,* vol. 4, pp. 254-66.
[29] Hallauer, A. R. and Miranda, J. B., 1981. *Quantitative genetics in maize breeding*, 2nd ed. Ames, IA: Iowa State Univ. Press.
[30] Hallauer, A. R., Russell, W. A., and Lamkey, K. R., 1988. *Corn Breeding. In corn and corn improvement, G. F. Sprague and J. W. Dudley, (eds.),* 3rd ed. Wisconsin, WI: ASA-CSSA-SSSA,Madison.
[31] Yahaya, Y., 2004. "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." pp: 154.
[32] Erikson, L. R., Beversdorf, W. D., and Ball, S. T., 1982. "Genotype × environment intersction for protein in Glycine max × Glycinine soja crosses." *Crop Science,* vol. 22, pp. 1099-1101.
[33] Miller, P. A., Robinson, H. F., and Pope, O. A., 1962. "Cotton Variety Testing. Additional information on variety × environment interactions." *Crop Science,* vol. 2, pp. 349-352.
[34] Ugale, S. D., Hapse, R. S., and Bharati, D. A., 1989. "Heterosis in pearl millet." *Journal of Maharashtra Agricultural University,* vol. 14, pp. 335-337.
[35] Baviskar, A. P., 1990. "Genetic studies on grain yield and its components in pearl millet (Pennisetum americanum(L.) Leeke)," Ph.D.Thesis, M.P.K.V.Rahuri (India).
[36] Yeye, Y. M., 2000. "Variability analysis of three synthetic population of nagerian pearl millet (Pennisetum americanum (L) Leeke) and implications in crop improvement. A Ph.D Dissertation. ABU Zaria." pp: 113.
[37] Kushwah, V. S. and Singh, M., 1992. "Heterosis in diallel crosses of pearl millet." *Journal of Maharashtra Agricultural Universities,* vol. 11, pp. 273-275.
[38] Chavan, A. A. and Nerkar, Y. S., 1994. "Heterosis and combining ability studies for grain yield and its components in pearl millet." *Journal of Maharashtra Agricultural Universities,* vol. 19, pp. 58-61.
[39] Kulkarni, V. M., Arayana, K. J., Navale, P. A., and Harinarayana, G., 1993. "Heterosis and combining ability in white grain pearl millet." *Journal of Maharashtra Agricultural Universities,* vol. 18, pp. 219-222.
[40] Phul, P. S. and Athwal, D. S., 1969. "Inheritance of grain size and grain hardness in pearl millet." *Indian Journl of Genetica And Plant Breeding,* vol. 29, pp. 184-191.
[41] Rao, D. V. N. and Pardhasarathi, A. V., 1968. "Studies on genetic variability in raji: 1. Phenotypic variation, genetypic and environmental correlations between important characters and their implication in selection." *The Madras Agricultural Journal,* vol. 55, pp. 397-400.
[42] Gupta, V. P. and Dhillon, B. S., 1974. "Variation and covariation of some plant and grain traits in pearl millet." *Indian Journal of Agricultural Science,* vol. 44, pp. 213-2216.

[43] Diz, D. A. and Schank, S. C., 1995. "Heritability, genetic parameters and response to selection in pearl millet × Elephant hexaploid hybrids." *Crop Science*, vol. 35, pp. 95-101.

[44] Mahadevappa, M. and Ponnaiya, B. W. X., 1967. "Discriminant function in the selection of pearl millet (Pennisetum typhoides Staff and Hubb) population for grain yield." *The Madras Agricultural Journal*, vol. 54, pp. 211-222.

[45] Navale, P. A. and Harinarayana, G., 1987. "Character correlation, heritability and selection response in population of foxtail millet." *Journal of Maharastra Agricultural University*, vol. 12, pp. 152-155.