GENETIC VARIABILITY AND CHARACTER ASSOCIATION IN PEARL MILLET
[***Pennisetum americanum*** **L.**]

BY

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B. Sc.(Agri.)

DISSERTATION

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IN

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DEPARTMENT OF GENETICS AND PLANT BREEDING
MARATHWADA AGRICULTURAL UNIVERSITY
PARBHANI, 431 402 (Maharashtra) INDIA
1999

CANDIDATE'S DECLARATION

I hereby declare that this dissertation or part thereof

has not been previously submitted by me

for a degree of any other

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CERTIFICATE - I

This is to certify that **Shri Sunil Marotirao Umate** has satisfactorily prosecuted his course of research work for a period not less than six semesters and that the dissertation entitled **"GENETIC VARIABILITY AND CHARACTER ASSOCIATION IN PEARL MILLET (*Pennisetum americanum* L.)"** submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination for award of degree of **MASTER OF SCIENCE** in the subject of **GENETICS AND PLANT BREEDING**. I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any University.

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CERTIFICATE - II

This is to certify that the dissertation entitled **"GENETIC VARIABILITY AND CHARACTER ASSOCIATION IN PEARL MILLET (*Pennisetum americanum* L.)"** Submitted by Shri **Sunil Marotirao Umate** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **GENETICS AND PLANT BREEDING** has been approved by the Student's Advisory Committee after oral examination in collaboration with the External Examiner.

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Introduction

I. INTRODUCTION

Pearl millet [*Pennisetum americanum* (L.) Leeke] is the most important drought tolerant cereal in areas of erratic rainfall in the semi-arid tropics (SAT) of the world. Pearl millet forms the staple food for millions of people and provides good quality fodder for cattle. It covers an area of more than 20 million hectares in the world. Traditionally a component of dryland cropping system in the semi-arid regions receiving 200-250 mm annual precipitation, it is usually grown on soils with depleted fertility. Pearl millet yields are reasonably well on poor sandy soils on which most crops fail(Arnon 1972).

Pearl millet grain contains about 8.6 to 17.1 per cent proteins, 61.5 to 89.1 per cent carbohydrates, 1.5 to 5.8 per cent lipids, 1.4 to 7.3 per cent fibre and 1.6 to 3.6 per cent ash(Hulse, 1980).

In India, pearl millet is grown on an area of 93.82 lakh hectares with the production of 53.92 lakh tonnes and productivity of 575 kg/ha. In Maharashtra, it covers an area of 1765.8 thousand hectares and the production and productivity are 113.3 thousand tonnes and 630 kg/ha, respectively (Anonymous, 1997).

Major constraints in the production of pearl millet are slow spread of improved varieties, poor plant establishment, lack of fertilizer use and susceptibility to diseases. Some suggested remedial measures to increase production include diversification of male sterile lines, improvement of restorers and breeding heterogenous and heterozygous single and multicross hybrids having better drought resistance, higher water use efficiency, efficient nitrogen utilization and tolerance to salt and diseases.

Several high yielding cultivars including single cross hybrids and open pollinated varieties have been released for cultivation. Considerable progress has also been made in identifying germplasm accessions with stable resistance to various diseases and their utilization in breeding programmes. However, the question of breeding pearl millet for improved tolerance of abiotic stresses such as drought and high temperature still continued to be a major area of research.

Selection is the basis of crop improvement. The efficiency of selection depends on identification of genetic variability by the phenotypic expression of the characters.

Further, it is also necessary to know which of the yield components are responsible for influencing seed yield directly and indirectly, so that their potentiality can be fully exploited to achieve higher production. Correlation and path analysis provides an exact picture of the importance of component characters.

The present study was conducted to isolate suitable genotype from the existing variability of the population PAMS 1B for utilization as maintainer line and in population development programme.

The objectives of the present study are as follows.

1. To study the extent of genetic variability in the segregating population of PAMS 1B.
2. To study the genetic advance and heritability for yield contributing characters.
3. To study the correlation coefficient and path coefficient analysis.

Review of Literature

II. REVIEW OF LITERATURE

Pearl millet (*Pennisetum americanum*) forms the staple food for millions of people and provides good quality fodder for cattle in the arid regions. Several high yielding single cross hybrids and open pollinated varieties have been released for cultivation. Considerable progress has also been made in identifying germplasm accessions with stable resistance to various diseases and in their utilization, for improvement to abiotic stresses.

Use of local land races to improve adaptation to stress is suggested and the future direction of research is indicated by several workers , (Reddy and Sharma, 1982; & Vyas 1986). Interspecific hybridization and newly developed biotechnological tools such as Restriction Fragmented Length Polymorphism (RFLP) and Random Amplified Polymorphic DNA (RAPD) could play an important part in improving the effectiveness of conventional breeding programme(Yadav , 1986).

Bhamre and Harinaryana (1994)studied the changes in population structure of 7 composites and 4 synthetics in 3 types of diallels. Crosses involving a synthetic as both or one of the parents produced consistently superior heterotic effect. Synthetics x Synthetics crosses were superior to Composites x Composites, crosses indicating that diversity of combining ability is effective for producing heterosis. Therefore, crosses among sibbed synthetics seemed better for interpopulation improvement in synthetics, but crossing among sibbed synthetics as one parent and sibbed composites as the other parent were better for population improvement in composites.

2.1 Genetic variability

Singh *et al.* (1979) reported wide range of variation for yield per plant, number of fertile tillers, tillers per plant and ear length.

Reddy and Sharma (1982) reported wide range of variation for plant height, tillers per plant and yield per plot.

Kunjir and Patil (1986) reported high genotypic and phenotypic variability for ear length and tiller number.

Vyas and Srikant (1986) reported mean, range, phenotypic and genotypic coefficient of variation, heritability and genetic advance for grain yield per plant and 11 agronomic morphological traits in 122 land races of *Pennisetum americanum*. All traits showed significant variation among land races.

Hepziba *et al.* (1993) reported wide range of variation for yield and six component traits under study.

AL-Shurai *et al.* (1995) reported wide variability for panical length, tillering, thousand seed weight and panical yield.

Tomar *et al.* (1995) studied yield and 12 yield components in 21 *Pennisetum typhoides* and observed wide variation for all characters except spike circumference.

Rao *et al.* (1996) reported wide range of variation for days to 50 per cent flowering and plant height.

2.2 Genotypic coefficient of variation

Phul *et al.* (1980) reported data on grain yield and five yield related traits from two populations of the synthetic variety PSB-3 (derived by intercrossing 45 single crosses for three generations).The genetic variance , heritability and expected genetic advance have been reported. It is concluded that improvement of PSB 3 can be achieved by selection in the S_1 and S_2 of the base population followed by intercrossing of superior lines.

Prakash (1983) reported that out of 34 *Pennisetum typhoides* strains 7111, 7009, 7003 and 7018 (All ICRISAT, India accessions) were superior for plant height, leaf number per plant, leaf length, leaf breadth and ear circumference. Plant height, forage yield per plant and dry matter per plant had high coefficient of variation.

Vyas and Srikant (1986) reported wide range of variation for yield and related characters.

Abraham *et al.* (1989) in 20 diverse genotypes of fingermillet (*Elusine coracana*) showed that phenotypic and genotypic coefficients of variation were high for effective tillers per plant, grain yield per plant. 1000 grain weight and fingers per ear.

Hepziba *et al.* (1993) studied genetic variation for yield and six component traits in 108 diverse *Pennisetum glaucum* genotypes. A wide range of variation was observed for all of the characters measured with the highest coefficient of variation for grain yield per plant followed by ear length, productive tillers and total tillers.

Das (1994) studied 15 genotypes of *Pennisetum americanum*, five of *Pennisetum purpureum* and their 15 hybrids obtained by random crossing were evaluated for quality based on crude protein, calcium, phosphorus and oxalic acid contents. Analysis of variance showed significant differences between genotypes and hybrids for all four traits in *Pennisetum americanum*.

2.3 Heritability and genetic advance

Singh *et al.* (1979) reported that the selection should be based on yield per plant, number of fertile tiller and tillers per plant and ear length, all of which showed comparatively high heritability and high genetic advance.

Sandhu *et al.* (1980) reported moderate to high narrow sense heritability for grain yield, ear length, days to 50 per cent flowering and plant height in pearl millet.

Reddy and Sharma (1982) for the character for percentage of protein content in grains, yield and nine other yield components reported high broad sense heritability with and high genetic advance.

Sandhu and Phul (1984) reported 15 per cent and 20 per cent heritability for yield under wide and normal spacing, respectively. The heritability estimates were high for ear length, days to 50 per cent flowering and plant height in both the environments. Response to selection was greater under half-sib than under full-sib selection.

Shinde *et al.* (1984) also reported high heritability estimates for all the characters. Expected genetic advance was moderate to high for plant height,ear length and ear weight and grain yield per plant.

Ramma Das *et al.* (1986) reported high heritability for ear length and moderate expected genetic advance. It was judged to be the most valuable indirect selection for higher yields in pearl millet.

Kunjir and Patil (1986) reported high heritability and genetic advance for plant height indicating additive gene action for this character .

Vyas and Srikant (1986) reported high estimates of heritability and genetic advance for tiller number, grain yield and ear length.

Abrahm *et al.* (1989) reported high broad sense heritability for days to maturity (99.5 %), days to 50 per cent flowering (97.7 %) and finger per ear.

Ahuja *et al.* (1989) reported moderate heritability for harvest index and effective tillers per plant, while grain yield and biological yield showed poor heritability. The parents 78/705, 78/735 and 36/346 were the best general combiners for yield and harvest index.

2.4 Correlation coefficient analysis

Reddy and Sharma (1982) analyzed the data and reported that yield per plant and yield per plot were positively correlated with plant height, tillers per plant, ear per plant, ear length and test weight.

Ibrahim *et al.* (1986) reported positive and significant correlation of yield with grain number per head, grain size and number of leaves on the main stem. Selection criteria for drought tolerance has been developed with these studies.

Abraham *et al.* (1989) in 20 diverse genotypes of finger millet (*Elusine coracana*) showed that grain yield was significantly and positively correlated with days to 50 per cent flowering, days to maturity, effective tillers per plant and 1000 grain weight.

Bhambre and Harinarayana (1992) reported that grain yield was dependent to varying and effective number of tillers. Genetic correlation were generally greater after sibbing.

Hepziba *et al.* (1993) studied yield correlations for yield and six component traits in 108 diverse *Pennisetum glaucum*. They reported that grain yield was positively and significantly correlated with ear thickness and ear thickness was significantly correlated with plant height, days to maturity and ear length.

Jadhav *et al.* (1994) reported that grain yield had a highly significant positive association with all the growth and yield contributing characters suggesting that all these characters had inherent relationship with grain yield.

Balakrishnan and Das (1995) reported negative correlation of grain yield with 50 per cent, flowering and positive with plant height, leaf area, leaf number, node number and spike thickness.

Navale *et al.* (1995) reported significant and positive association between days to 50 per cent flowering and grain number per cm^2 in all the groups independently. However, the correlation between days to 50 per cent flowering and test weight and grain yield was significantly negative indicating that simultaneous selections for earliness and high grain yield may not be possible. Similarly the studies on correlation suggested that simultaneous selection for ear girth, ear length and fodder yield will be useful in improving grain yield. The same characters have also recorded high magnitude of direct effects with grain yield, indicating close and perfect relationship between these characters. These studies revealed that ear length, ear girth and fodder yield should be considered in pearl millet improvement.

Tomar *et al.* (1995) correlation and path coefficients derived in 21 elite pearl millet (*Pennisetum typhoides*) reported that plant girth, length of first internode, effective tillers per plant, panical girth and length and 1000 seed weight exhibited significant and positive correlations with seed yield both at the phenotypic and genotypic level.

2.5 Path coefficient analysis

Reddy and Sharma (1982) reported that yield improvement in pearl millet could be achieved by selection for plant height, tillers per plant and yield per plot.

Jindal and Gill (1984) in their studies reported that ear height was the most important character affecting yield.

Raveendran and Appaduri (1984) through path anal showed that five yield components particularly, grains per unit length of panicle, panicle length and productive tillers per plant contributed positively and directly to grain yield.

Ramma Das *et al.* (1986) reported the greatest direct and indirect contributions to yield from ear girth, while grain density, ear length and (inversely) days to flowering made significant indirect contributions acting mainly through ear girth.

Khairwal *et al.* (1990) reported that in sowing date experiment 1) biological yield contributed directly towards grain yield 2) plant height had only indirect positive contribution via biological yield and 3) smut severity had negative and days to 50 per cent heading had very poor effects on grain yield. These findings indicated that tall and early hybrids with high biological yield and resistance to smut would be suitable for high grain yield in pearl millet. Hybrids 81A x SRICMPS-101-1 and S10A x H77/181-4 were suggested to fulfill these requirements.

Patil and Jadhav (1992) reported that length of tiller and length and breadth of leaves made the greatest direct contribution to green forage yield and may possibly be used as selection criteria.

Hepziba *et al.* (1993) reported that productive tillers had the greatest direct effect on grain yield. Since, days to maturity had a negative effect on grain yield, tall early maturing genotypes with high productive tillers are the most suitable for increasing grain yield.

Das and Balakrishnan (1994) reported importance of productive tiller number with greatest effect. The remaining seven components out of 11 had negative direct effects. The greatest negative effect was shown by protein content.

Thirumeni and Das (1994) suggested that rapid improvement in green fodder yield could be achieved by selection of dry matter yield in pearl millet and napier grass and number of tillers per clump in the hybrids.

Jadhav *et al.* (1994) showed that dry matter production per plant had the maximum positive direct effect on the grain yield per plant followed by length of ear head, number of tillers and leaves per plant. The study suggested that dry matter production, length of ear head, number of tillers and leaves per plant should be given due emphasis in selection programme of genotypes for substantial grain yield improvement of pearl millet.

Poongodi and Palanisamy (1995) also reported maximum contribution of productive tillers (direct effect) on grain yield.

Materials and Methods

III. MATERIALS AND METHODS

3.1 Experimental material

The hybrid PAHB-3 having the parents PAMS 1A and ZIM-1 was found promising in the yield evaluation trials. The maintainer line PAMS 1B was found to have some variation for yield and yield contributing characters. Therefore, selections were made for different characters and were subsequently sibmated to bring the uniformity in the lines.

The present material for the study comprised 19 uniform selections made from the variable population of PAMS 1B and one original (purified) PAMS 1B. These selections were studied for variability for yield and yield contributing characters, correlations and path coefficient analysis.

3.2 Experimental methods

The experiment was conducted at the experimental farm of the Department of Genetics and Plant Breeding. The experimental details are as follows :

Design	:	Randomized Block Design
No. of Replications	:	Three
No. of Treatments	:	19 Selections + 1 PAMS 1B
Plot size	:	0.90 m x 3.0 m
		2 rows of 3.0 m length of each selection. One guard row was planted around the block to avoid the border effect.

Spacing	:	
Row to Row	:	45 cm
Plant to plant	:	15 cm
Fertilizer dose	:	50 kg N, 25 kg P_2O_5 and 25 kg K_2O/ha
Date of sowing	:	9^{th} July, 1998
Date of harvesting	:	11^{th} October, 1998

3.3 Observations recorded

Five plants were selected randomly from each treatment for recording observations. Average value of each character was determined from these observational plants.

Observations were recorded on following biometrical characters.

1. Plant height (cm)

Plant height was measured from plant base to the tip of the panicle on main tiller.

2. Number of effective tillers per plant

The number of tillers bearing productive panicles were counted.

3. Panicle length (cm)

The length of panicle on the main tiller was measured from the panicle base to its tip.

4. Panicle girth (cm)

Panicle girth was measured in centimetersat the middle of the panicle by using a thread.

5. Grain yield (g/plant)

Panicles of all tillers of selected plants were harvested and threshed together. The grains were dried thoroughly in sun and weighed. Average grain yield per plant was recorded in grams.

6. 1000 seed weight (g)

1000 grains of each selection from each replication were counted by electric counting machine and weighed in grams with the help of electrical automatic balance.

7. Days to 50 per cent flowering

Number of days from planting to the flowering of 50 per cent plants in a plot were recorded.

8. Days to maturity

Number of days required from sowing to maturity of grains were recorded.

3.4 Statistical methods

3.4.1 Analysis of variance

The averaged data of each character was analysed as per the ANOVA given below. The analysis was done as per the procedure suggested by Panse and Sukhatme (1985).

Sr.No.	Source	DF	MSS	Cal. F	Table F
1.	Replication	r-1			
2.	Treatment	t-1			
3.	Error	r-1Xt-1			

For comparision of means critical difference was calculeted as below.

i) Standard error (SE) = $\sqrt{\text{(EMSS / Number of replications)}}$

ii) Critical difference (CD) = SE x 1.414 x t value at 5 per cent level of error degrees of freedom.

3.4.2 Genetic variability

Various parameters of genetic variability were calculated by using the following formula.

i) Genotypic variance ($\sigma^2 g$) = $\dfrac{\text{Treatment MSS - Error MSS}}{\text{Number of replications}}$

ii) Phenotypic variance ($\sigma^2 p$)=Genotypic variance + Error variance

The genotypic and phenotypic coefficients of variability (GCV and PCV) were calculated as per (Burton, 1952).

iii) Genotypic coefficient of variation (GCV) = $\dfrac{\sqrt{\sigma^2 G}}{\bar{X}} \times 100$

iv) Phenotypic coefficient of variation (PCV) = $\dfrac{\sqrt{\sigma^2 P}}{\bar{X}} \times 100$

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

$\bar{X}$ = general mean of characters

3.4.3 Heritability and genetic advance

Heritability (broad sense) was calculated according to the method suggested by Allard *et al.* (1960)

i) $$\text{Heritability } (h^2) \text{ B.S.} = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

The genetic advance at 5 per cent selection intensity was calculated for each character using the formula suggested by Johnson *et al.* (1955a).

ii) Genetic advance (GA) = $K.\sigma p.h^2$

Where,

K = Selection differential at 5 per cent level i.e. 2.06

σp = Phenotypic standard deviation

h^2 = Heritability

The expected genetic advance in percentage of mean was calculated as :

iii) $EGA = \frac{GA}{\bar{X}} \times 100$

Where,

EGA = Expected genetic advance

GA = Genetic advance

$\bar{X}$ = General mean of character

3.4.4 Correlation

Covariances were calculated for all the characters to find out correlation among the characters.

The inter-relationship of different yield contributing characters was worked out according to Johnson *et al.* (1955b)

$$r = \frac{Cov.\ (X.Y)}{(\sigma^2 X.\ \sigma^2 Y)^{1/2}}$$

r = Correlation of coefficient (genotypic/phenotypic) between the characters X and Y.

3.4.5 Path coefficient analysis

Path coefficient analysis was carried out according to Dewey and Lu (1959). The direct and indirect path coefficients were calculated by using the following set of 'P' simultaneous equations by the abbreviated Doolittle technique.

$$Po1 + Po2\ r12 + \ldots\ldots\ Pop\ r1p = ro1$$

$$Po1\ r12 + Po2 + \ldots\ldots\ Pop\ r2p = ro2$$

$$Po1\ r10 + Po2 + r2P + \ldots\ldots\ Pop = roP$$

Where,

Po1, Po2, ... Pop are the path effects of 1, 2 ... P variables, on `0' variable.

r12, r13 .... r1P .... rP(P-1) are the positive correlation coefficients between various independent variables with dependent variables. The different effects of `$i^{th}$' variable via `j^{th}' variable was worked out as (Poj x Pij).

Results

IV. RESULTS

The observations collected on different genotypes for different characters were analysed for genetic components of variation using the standard procedures. The results are presented in following major headings.

1. Analysis of variance
2. Mean performance
3. Genetic variability
4. Correlation and
5. Path coefficient analysis for yield and yield contributing characters

4.1 Analysis of variance

The analysis of variance presented in Table 1 showed significant differences among the genotypes for all the characters studied, indicating presence of substantial variability for these characters among the genotypes.

4.2 Mean performance

The mean performance of the genotypes for different characters is given in Table 2.

4.2.1 Plant height (cm)

Maximum plant height was recorded by selection No. 11 (264.3 cm), followed by selection No.9 (259.40 cm) and selection

Table 1 : Analysis of variance for yield contributing characters

Source of variation	d.f.	Mean sum of squares							
		Plant height (cm)	No. of tillers	Panicle length (cm)	Panicle girth (cm)	Days to 50% flowering	Days to maturity	Test weight (g)	Grain yield / plant (g)
Replication	2	9.309	0.131	13.77	0.146	0.317	2.217	0.317	9.626
Treatment	19	6354.8 **	0.285 **	76.128 **	2.135 **	38.225 **	65.189 **	10.477 **	51826 **
Error	38	11.529	0.027	3.188	0.381	0.685	1.024	0.79	37.04

** = Significant at 1 per cent level.

Table 2 : Mean performance of yield contributing characters.

Selection No.	Plant height (cm)	No. of tillers / plant	Panicle length (cm)	Panicle girth (cm)	Days to 50% flowering	Days to maturity	Test weight (g)	Grain yield / paint (g)
1	207.33	1.86	30.36	8.70	49.00	89.00	11.33	114.60
2	224.83	2.53	32.00	8.96	55.00	95.00	11.33	350.13
3	210.47	2.53	33.20	9.66	53.66	93.66	11.33	349.53
4	223.53	2.40	32.86	9.20	53.00	93.00	10.33	282.00
5	222.20	2.40	27.26	9.06	52.00	92.00	10.33	259.73
6	213.67	2.33	31.60	8.46	52.00	92.00	10.66	266.27
7	253.27	2.40	33.26	9.40	53.00	93.00	13.33	206.40
8	230.07	2.20	32.86	8.96	54.00	94.00	10.66	250.00
9	259.40	1.46	30.46	9.16	54.00	94.00	11.00	215.40
10	208.77	2.73	30.13	9.80	47.00	87.00	12.00	244.67
11	264.33	2.40	35.06	9.60	46.00	86.00	10.33	309.87
12	230.80	2.40	32.26	10.33	50.00	90.00	12.00	279.87
13	247.87	2.66	32.20	9.73	46.00	84.00	13.00	215.60
14	250.80	2.46	32.23	9.63	49.00	89.00	13.33	278.53
15	221.37	2.53	30.76	9.90	53.00	93.00	10.33	253.07
16	161.73	2.86	19.93	6.93	45.00	85.00	10.33	163.27
17	138.40	2.40	19.73	7.90	42.00	77.00	11.00	86.26
18	237.60	2.06	29.36	9.33	51.00	93.00	8.66	135.40
19	109.37	2.40	16.40	7.73	50.00	92.00	14.33	194.53
PAMS-B	209.73	2.60	28.90	9.83	48.00	85.66	14.00	184.93
GM	216.28	2.38	29.54	9.11	50.13	89.86	11.48	231.98
SE ±	1.96	0.09	1.03	0.34	0.47	0.58	0.50	3.56
CD	5.42	0.26	2.85	0.94	1.32	1.61	1.38	9.85

No. 14 (250.80 cm). Lowest plant height was recorded by selection No. 19 (109.42 cm) followed by selection No. 17 (138.40 cm). Majority of the selections were taller than PAMS-B.

4.2.2 Number of tillers per plant

Significantly more number of tillers per plant were recorded by selection No. 16 (2.86). However, the selection No. 10 (2.73)) and selection No. 13 (2.66) were also promising. The lowest number of tillers per plant were recorded by selection No. 9 (1.46) followed by selection No. 1 (1.86) and selection No. 18 (2.06).

4.2.3 Panicle length (cm)

Among the selections, selection No. 11 recorded the maximum and significantly more length of panicle (35.06 cm) closely followed by selection No. 7 (33.26 cm) and selection No. 3 (33.20 cm). Other fourteen selections recorded significantly more panicle length than the check. Selection No. 19 (16.40 cm) recorded minimum length of panicle followed by selection No. 17 (19.73) and selection No. 16 (19.93).

4.2.4 Panicle girth (cm)

Among all the selections, selection No. 12 recorded the maximum panicle girth (10.33 cm), followed by selection No. 15 (9.90 cm). The selection No. 16 recorded the minimum panicle girth (6.93 cm) followed by selection No. 19 (7.73 cm) and selection No. 17 (7.90 cm).

4.2.5 Days to 50 per cent flowering

Significantly early flowering than the check was observed in selection No. 17 (42 days) followed by selection No. 16 (45 days) and selection No. 13 (46 days). Late flowering was observed in selection No. 2 (55 days) followed by selection No. 8 and selection No. 9 (54 days).

4.2.6 Days to maturity

As regards to days to maturity, the selection No. 17 recorded significantly early maturity (77 days) than the check, followed by selection No. 13 (84 days) and selection No. 16 (85 days). The selection No. 2 required maximum days to maturity (95 days) followed by selection No. 8 and selection No. 9 (94 days).

4.2.7 Test weight (g)

Among all the selections, selection No. 19 recorded the highest test weight (14.33 g) followed by the check (14.0 g). In general, majority of the selections recorded low test weight.

4.2.8 Grain yield per plant (g)

Significantly highest grain yield per plant was recorded by selection No. 2 (350.13 g) followed by selection No. 3 (349.53 g) and selection No. 11 (309.87 g). The lowest grain yield per plant was recorded by selection No. 17 (86.26 g) followed by selection No. 1 (114.60 g). Total fourteen selections recorded significantly higher yield than the check line.

4.3 Genetic parameters

The characters under investigation were analyzed for genotypic variance ($\sigma^2 g$), phenotypic variance ($\sigma^2 p$), genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), heritability (broad sense) and expected genetic advance. The results are presented in Table 3.

4.3.1 Plant height (cm)

A wide range of variation was observed from 109.4 cm to 264.4 cm with a general mean of 216.28 cm. The genotypic variance was 2114.42 and phenotypic variance was 2125.97. The values of genotypic and phenotypic coefficient of variability were 21.76 and 21.82 per cent, respectively. High heritability estimates (99.46 %), with high expected genetic advance (44.50) was observed for plant height.

4.3.2 Number of tillers per plant

The range of variation for number of tillers per plant was from 1.46 to 2.8. The general mean was 2.6. Majority of the selections had mean around the general mean. The genotypic and phenotypic variances were 0.09 and 0.018, respectively. The genotypic and phenotypic coefficient of variation values were 12.60 and 17.82 per cent, respectively. The heritability estimate was 50 per cent. The expected genetic advance was 18.49 per cent.

Table 3 : Mean, range, coefficient of variability, heritability and expected genetic advance for different characters in pearlmillet.

Character	Range	Mean	Genotypic variance	Phenotypic variance	Genotypic coefficient of variability	Phenotypic coefficient of variability	Heritability (%)	Expected genetic advance
Plant height (cm)	109.40-264.30	216.28	2114.42	2125.95	21.76	21.82	99.46	44.50
No. of tillers	1.46-2.80	2.38	0.09	0.18	12.60	17.82	50.00	18.49
Panicle length (cm)	16.40-35.00	29.54	24.31	27.49	16.69	17.74	88.43	32.33
Panicle girth (cm)	6.90-10.33	9.11	0.59	0.97	8.43	10.81	60.82	13.39
Days to 50 % flowering	42.00-55.00	50.13	12.51	13.19	7.05	7.24	94.84	14.02
Days to maturity	77.00-95.00	89.86	20.39	21.41	5.02	5.14	95.23	10.07
Test weight (g)	8.66-14.33	11.48	3.23	4.02	16.00	17.85	90.35	29.38
Grain yield /plant (g)	86.26-350.13	231.98	17262.99	17300.03	48.30	48.35	99.78	11.64

4.3.3 Panicle length (cm)

The character panicle length showed a wide range of variation from 16.40 cm to 35 cm. The general mean for this character was 29.54 cm. The genotypic variance was 24.31, while phenotypic variance was 27.49. The genotypic and phenotypic coefficient of variation were 16.69 per cent and 17.74 per cent, respectively. High heritability (88.43 %) was associated with high expected genetic advance (32.33 %).

4.3.4 Panicle girth (cm)

The character was ranged from 6.90cm to 10.33 cm, with a general mean 9.11 cm. The genotypic variance was low (0.59) than the phenotypic variance (0.97). The genotypic and phenotypic coefficient of variation were 8.43 and 10.81 per cent, respectively. The heritability (60.82 %) estimate was moderate. The expected genetic advance was 13.39 per cent.

4.3.5 Days to flowering

The character showed a wide range of variability from 42 days to 55 days. The general mean was 50.13 days. The genotypic variance was 12.51, while phenotypic variance was 13.19. The genotypic and phenotypic coefficients of variation were 7.05 and 7.24 per cent, respectively. High heritability, 94.84 per cent was recorded, with moderate expected genetic advance (14.02 %) was observed.

4.3.6 Days to maturity

The character showed a wide range of variability from 77 days to 95 days with a general mean of 90 days. The genotypic variance was 20.39 and phenotypic variance was 21.41. The genotypic and phenotypic coefficients of variation were 5.02 and 5.14 per cent, respectively. High heritability (92.23 %) estmate was high. The expected genetic advance was (10.07 %).

4.3.7 Test weight (g)

A wide range of variation was observed from 8.66 g to 14.33 g. The general mean was 11.43 g. The genotypic variance was 3.23, while phenotypic variance was 4.02. The estimates of genotypic and phenotypic coefficients of variation were 16.00 and 17.85 per cent, respectively. High heritability (80.35 %) with high genetic advance 29.38 per cent was observed.

4.3.8 Grain yield per plant (g)

A very wide range of variation i.e. from 86.26 g to 350.13 g was recorded for grain yield per plant. The general mean for grain yield per plant was 231.98 g per plant. The genotypic variance was 17262.99, while phenotypic variance was 17300.03. The estimates of genotypic and phenotypic coefficients of variations were 48.30 and 48.35 per cent, respectively. High heritability (99.78 %) coupled with low expected genetic advance (11.64 %) was observed.

4.4 Correlation

Genotypic and phenotypic correlations were calculated among the eight characters including grain yield per plant and presented in Table 4 and depicted in Fig. 1 and 2.

The results revealed that, the character plant height was positively correlated with grain yield at both genotypic and phenotypic levels. The plant height was also positively correlated with panicle length and panicle girth at both genotypic and phenotypic levels.

The character panicle length was positively correlated with grain yield per plant at both genotypic and phenotypic levels. It was also positively correlated with panicle girth, days to 50 per cent flowering and test weight at both genotypic and phenotypic levels.

The character panicle girth was also positively correlated with grain yield per plant at genotypic level only. It was also positively correlated with test weight at both the genotypic and phenotypic levels.

The days to 50 per cent flowering was directly correlated with days to maturity at both genotypic and phenotypic levels. However, days to 50 per cent flowering and days to maturity and test weight showed positive but non-significant correlation with grain yield per plant. The number of tillers per plant showed positive correlation with grain yield per plant.

Table 4 : Correlation coefficient for yield and yield contributing characters

Characters		No. of tillers	Panicle length (cm)	Panicle girth (cm)	Days to 50% flowering	Days to maturity	Test weight (g)	Grain yield / plant (g)
Plant height (cm)	G	-0.329	0.803 **	0.589 **	0.395	0.406	0.244	0.642 **
	P	-0.288	0.754 **	0.455 **	0.388	0.396	0.222	0.639 **
No. of tillers	G		-0.143	-0.007	-0.387	-0.379	-0.079	0.273
	P		-0.176	-0.043	-0.342	-0.319	-0.117	0.240
Panicle length (cm)	G			0.863 **	0.468 *	0.414	0.599 **	0.697 **
	P			0.680 **	0.442 *	0.381	0.502 **	0.656 **
Panicle girth (cm)	G				0.303	0.255	0.833 **	0.561 **
	P				0.192	0.155	0.609 **	0.434
Days to 50 % flowering	G					0.979 **	0.098	0.242
	P					0.934 **	0.089	0.237
Days to maturity	G						-0.026	0.230
	P						-0.023	0.224
Test weight (g)	G							0.191
	P							0.170

G = Genotypic, P = Phenotypic *, ** = Singnificant at 5 % and 1 % level.

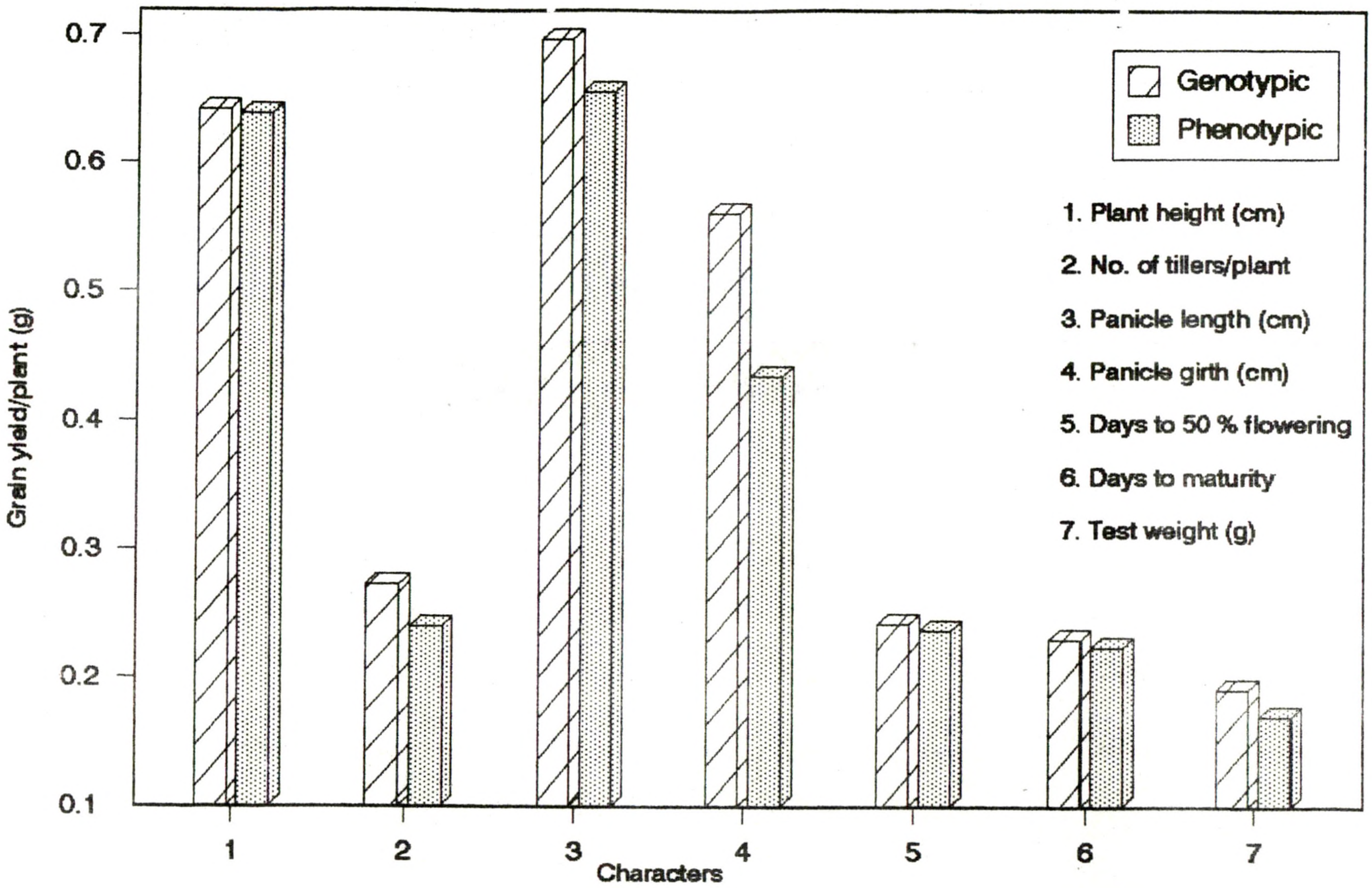
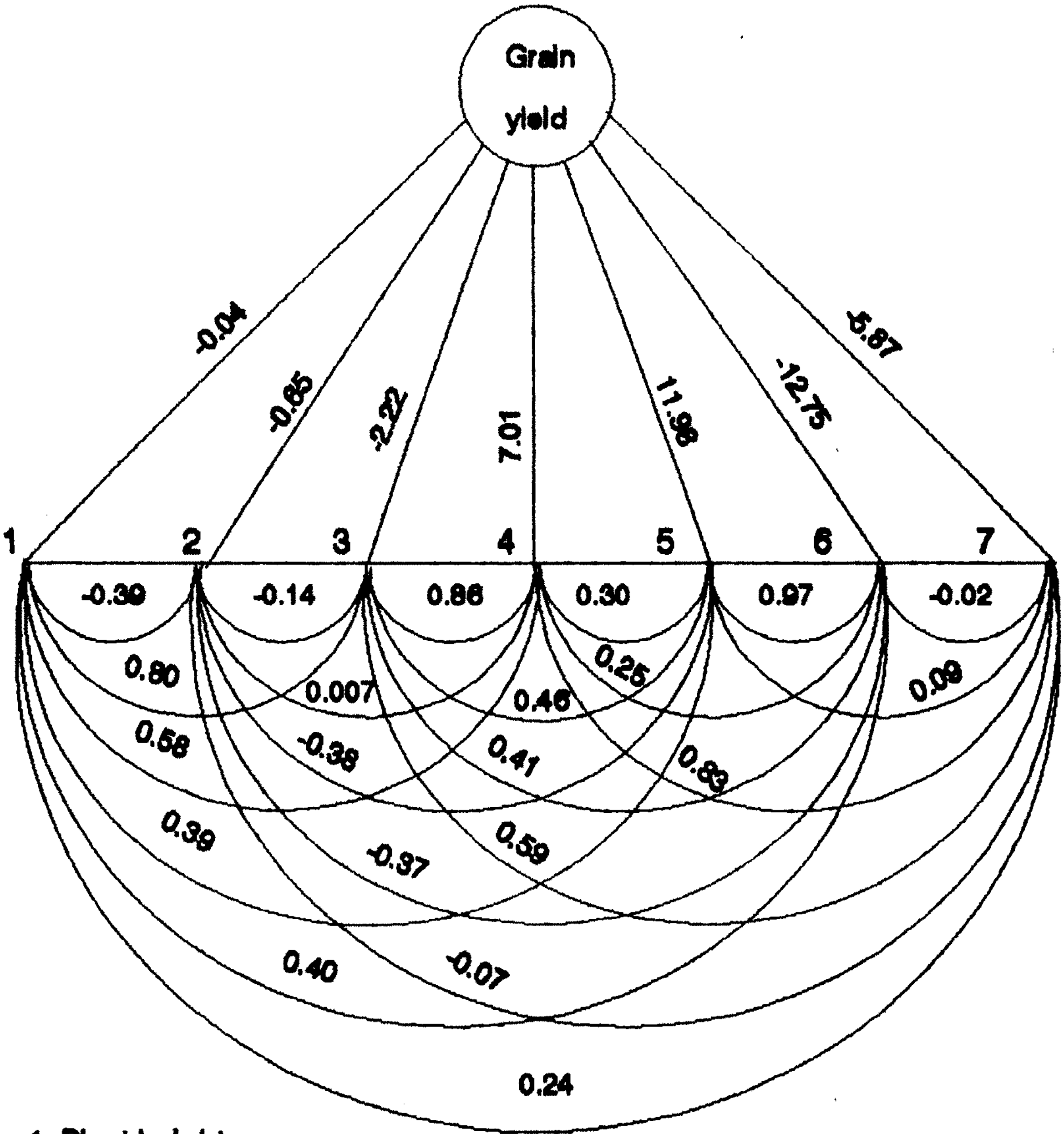


Fig. 1 : Correlation coefficient for yield and yield contributing characters.



1. Plant height
2. No. of tillers/plant
3. Panicle length
4. Panicle girth
5. Days to 50 % flowering
6. Days to maturity
7. Test weight

Fig. 2 : Correlation coefficient showing yield and yield contributing characters

4.5 Path analysis

Genotypic and phenotypic path analysis between yield and yield contributing characters were carried out by using genotypic and phenotypic correlation coefficients and are presented in Table 5.

The results of path coefficient analysis revealed highest positive direct effect of days to 50 per cent flowering on seed yield at genotypic level followed by the trait panicle girth at genotypic level. Whereas, at phenotypic level, the highest and direct positive effect was recorded by plant height followed by the characters number of tillers per plant, panicle length, days to 50 per cent flowering and panicle girth.

A strong direct negative effect of days to maturity was recorded on seed yield at both genotypic and phenotypic levels, followed by the characters test weight and panicle girth. This indicated that the genotypes which exhibit lateness to maturity and low test weight produced low yield and should be avoided.

Although plant height had negative direct effect on yield, it has positive indirect effect on yield via days to 50 per cent flowering and panicle girth at genotypic level, but at phenotypic level it has positive indirect effect through panicle length.

The number of tillers per plant had positive indirect effect through days to maturity and test weight, while negative indirect effect through plant height, panicle length and days to

Table 5 : Path coefficient analysis showing direct and indirect effects of characters

Characters		Plant hight (cm)	No. of tillers	Panicle length (cm)	Panicle girth (cm)	Days to 50% flowering	Days to maturity	Test weight (g)	Grain yield / plant (r)
Plant height (cm)	G	**-0.041**	0.215	-1.785	4.129	4.733	-5.179	-1.429	0.642 **
	P	**0.465**	-0.128	0.303	0.012	0.046	-0.035	-0.024	0.639 **
No. of tillers	G	-0.013	**-0.654**	0.318	-0.049	-4.644	4.828	0.461	0.273
	P	-0.133	**0.445**	-0.071	-0.001	-0.040	0.028	0.013	0.240
Panicle length (cm)	G	-0.033	0.093	**-2.222**	6.050	5.606	-5.281	-3.516	0.697 **
	P	0.350	-0.078	**0.403**	0.017	0.052	-0.034	-0.056	0.656 **
Panicle girth (cm)	G	-0.024	0.004	-1.917	**7.012**	3.626	-3.252	-4.888	0.561 **
	P	0.211	-0.019	0.274	**0.026**	0.022	-0.013	-0.068	0.434
Days to 50 % flowering	G	-0.016	0.253	-1.039	2.121	**11.986**	-12.486	-0.577	0.242
	P	0.180	-0.152	0.178	0.005	**0.119**	-0.083	-0.010	0.237
Days to maturity	G	-0.016	0.247	-0.920	1.788	11.732	**-12.755**	0.153	0.230
	P	0.184	-0.142	0.153	0.004	0.111	**-0.894**	0.002	0.224
Test weight (g)	G	-0.010	0.051	-1.331	5.839	1.178	0.334	**-5.871**	0.191
	P	0.103	-0.052	0.202	0.016	0.010	0.002	**-0.111**	0.170

G = Genotypic, P = Phenotypic   ** = Singnificant at 1 per cent level.

50 per cent flowering at phenotypic level, but at genotypic level number of tillers per plant had positive indirect effect through days to maturity and plant height, and negative indirect effect via days to 50 per cent flowering.

The panicle length had positive indirect effect through panicle girth and days to 50 per cent flowering at genotypic level, but at phenotypic level, it had positive indirect effect through plant height and panicle girth. It had negative effect through days to maturity and test weight at genotypic level, while at phenotypic level, it had negative indirect effect through number of tillers per plant and test weight.

Panicle girth had direct effect at genotypic level only, it also had positive indirect effect through days to 50 per cent flowering at genotypic level. But at phenotypic level it had positive indirect effect through panicle length and plant height. Panicle girth had negative indirect effect through test weight, days to maturity and panicle length at genotypic level. At phenotypic level, it had negative indirect effect through days to maturity.

The character days to 50 per cent flowering had strong positive effect at genotypic level. It also had positive indirect effect through panicle girth at genotypic level, but at phenotypic level it has positive indirect effect through plant height. Days to 50 per cent flowering had strong indirect negative effect through days to maturity at genotypic level. But at phenotypic level it had negative indirect effect through number of tillers per plant and days to maturity.

Days to maturity had strong negative direct effect at genotypic level only. It also had positive indirect effect through days to 50 per cent flowering at genotypic level. At phenotypic level it had positive indirect effect through plant height, panicle length and days to 50 per cent flowering. Days to maturity had negative indirect effect through panicle length at genotypic level, while at phenotypic level, it had negative indirect effect through number of tillers per plant.

The character test weight had negative direct effect at genotypic and phenotypic levels. It had positive indirect effect through days to maturity, panicle girth and days to 50 per cent flowering at genotypic level, while at phenotypic level it had positive indirect effect through panicle length and plant height. Test weight had negative indirect effect through panicle length, while at phenotypic level, it had negative effect through number of tillers per plant.

Discussion

V. DISCUSSION

Transferring the country from chronic deficit of food to self reliant nation is the most significant achievement of independent India. Improved plant type has played very important role in cross pollinated as well as in self pollinated crops. The development of hybrids in cross pollinated cereals like sorghum, maize, pearl millet and recently rice and the HYV of wheat and rice has raised the production in the country to 195 million tonnes (Anonymous, 1998).

Pearl millet (*Pennisetum americanum*) one of the important cereals in semi-arid tropics in the country is playing important role in food security. The high yielding, downy mildew, ergot and drought resistant hybrids and population gave stability to this crop. Mbwanga and Mdolwa (1994) reported, ergot, leaf spot disease, rust, smut and downy mildew as frequently observed diseases on pearl millet.

It is necessary to intensify the research efforts for further elevating the productivity of this crop through isolating the newer male sterile and restorer lines. The hybrids viz. Shradha and Saburi are at present popular among farmers along with some of the private sector hybrids.

One of the cross combinations PHB-3 (PAMS 1A x ZIM-1) was found superior in multilocation testing programme (Anonymous, 1992-93) for yield and other characters. However, the PAMS-1B line was showing variation for some of the yield and morphological characters. The present investigation was, therefore taken up to isolate and study the variability of yield and yield contributing characters in nineteen selected genotypes. The results of the present study are discussed under the following headings.

5.1 Analysis of variance

The analysis of variance showed significant differences among the genotypes for all the characters studied. This indicated the presence of adequate variability for these characters among the selections. This also confirm that the PAMS-1B was having variation and the selection was effective to isolate the variation.

5.2 Mean performance

Mean performance for different characters of the genotypes studied presented in Table 2 indicated in general improvement for the important yield contributing characters including yield over the check and over the general mean.

Lowest plant height (109.42 cm) was recorded by the selection No. 19, followed by selection No. 17 (138.40 cm) which was significantly low than the PAMS-1B and general mean. Majority of the selections were tall.

In general majority of the selections were on par to the check. Selection No. 10 and No.13 were however promising for number of tillers per plant.

The selection No. 11 recorded maximum panicle length (35.06 cm) which was closely followed by selection No. 7 and 3.

Significant increase in panicle length over the check and general mean indicated the effectivity of selection. Importance of ear length in grain yield has been emphasized by several workers including Singh *et al.* (1979) and Vyas and Srikant (1986).

Maximum panicle girth was recorded by the selection No.12. Majority of the selections were on par to the check or general mean. Length and girth of panicle coupled with the compactness of panicle is most important for increased yield.

As regards to days to 50 per cent flowering and days required to maturity, the selection No. 17 was the earliest, which was followed by selection No. 16 and No. 13. Majority of the selections showed 50 per cent flowering and days to maturity around 52 and 92 days, respectively, which was near about the general mean.

The selection No. 19 showed the highest mean for test weight however it was on par to the check but significantly superior over the general mean.

The selection No.2 recorded the highest grain yield/plant (350.13 g) which was closely followed by selection No.3, No.11 and No. 4. Number of selections produced significantly higher grain yield/plant than the check and also superiority over the general mean. The increased yield over the check indicated the presence of variability which can be utilized for the development of superior male sterile lines using the appropriate breeding techniques.

5.3 Genetic variability

Improvement in grain yield per plant, related characters and tolerance to biotic stresses are the primary objectives in any breeding programme. The breeders are interested to isolate/select from the existing variability or to create variability for utilization in the crop improvement programme. It is necessary for a breeder to quantify the variability present in the breeding material for a given character and the progress of improvement depends on the magnitude of additive gene action and the additive x additive epistatis. The results of variability are presented in Table 3.

A wide range of variation was observed for the characters, plant height, panicle length, panicle girth, days to maturity, test weight and grain yield. A wide range of variation among these characters was also reported by Vyas and Srikant (1986), Hepziba *et al.* (1995) and Tomar *et al.* (1995). However, the range of variation for number of tillers per plant and days to 50 per cent flowering was not much encouraging.

The phenotypic variance was comparatively higher than the genotypic variance. The low values of genotypic variance for different characters indicated that the expression of the characters may be influenced by environment.

5.4 Genotypic and phenotypic coefficients of variability

The selection under field conditions may be strongly influenced by the environmental factors hindering the progress in the improvement programme. In the present study in general the genotypic coefficients of variability were low than the phenotypic coefficient of variability. The characters number of tillers per plant and panicle girth showed high phenotypic coefficient of variability values than the genotypic coefficient of variability values indicating that these characters are largely influenced by the environment and phenotypic selection may be less effective. Whereas, in all the remaining characters, the genotypic coefficient variability values and phenotypic coefficient of variability values are more or less equal indicate that phenotypic selection may be equally effective for these characters. Prakash (1983), Vyas and Srikant (1986) and Hepziba *et al.* (1993) reported high genotypic coefficient of variability among the characters viz. grain yield per plant, plant height and test weight. The characters viz. days to maturity, days to 50 per cent flowering and panicle girth showed low to moderate values of coefficient of variability. Considerable amount of variability for yield and related characters was also reported by Mukharji *et al.* (1982), Reddy (1985), Maiti *et al.* (1989), Savery and Prasad (1994), AL-Shurai *et al.* (1995), Suthamathi and Dorairaj (1995), and Tomar *et al.* (1995).

5.5 Heritability and genetic advance

Johnson *et al.* (1955) suggested that the heritability estimates along with genetic advance would be more useful in predicting yield under phenotypic selection than the heritability estimates alone.

The heritability estimates ranged from 50 per cent for number of tillers per plant to 99.78 per cent for grain yield per plant. The highest heritability estimate was observed for grain yield per plant (99.78 %) followed by plant height (99.46 %), days to maturity (95.23 %) and days to 50 per cent flowering (94.84 %).

The maximum expected genetic advance was observed for plant height (44.5 %) followed by panicle length (32.33 %) and test weight (29.38 %). Number of tillers per plant (18.49 %) and days to 50 per cent flowering (14.02 %) recorded moderate expected genetic advance. The grain yield per plant though observed highest heritability but recorded low expected genetic advance indicating that this character is not controlled by additive gene action alone. These conclusions support the findings of Sandhu *et al.* (1980), Sandhu and Phul (1984), Shinde *et al.* (1984), Ramma Das *et al.* (1986), Kunjir and Patil (1986), Vyas and Srikant (1986) and Hepziba *et al.* (1993). Ahuja *et al.* (1989) recorded low heritability for effective tillers and yield per plant.

The high heritability coupled with high expected genetic advance is an indication of the heritability due to additive gene effects and is desirable for effective selection in the breeding programme. Singh *et al.* (1979) on the basis of high heritability and high genetic advance reported that selection should be based on yield per plant, number of tillers per plant and ear length.

The high heritability and genetic advance for the characters plant height, panicle length and test weight indicated that these characters were not much influenced by the environment. High heritability with low genetic advance for grain yield per plant and days to maturity indicate the importance of non-additive gene action and therefore direct selections for these characters may not be effective.

5.6 Correlation studies

The correlation studies are mostly useful to understand the importance of different quantitative characters in contribution of yield and provide a guideline for effective selection. In the present case, genotypic and phenotypic correlations were calculated among eight characters including grain yield per plant and presented in Table 4.

The results revealed that, the character plant height was positively correlated with panicle length, panicle girth and grain yield both at genotypic and phenotypic level.

The character panicle length was positively and significantly correlated with grain yield per plant, panicle girth, days to 50 per cent flowering and test weight. Jadhav *et al.* (1994) and Tomar *et al.* (1995b) reported similar results in pearl millet.

The character panicle girth was positively and significantly correlated with grain yield per plant and test weight.

The character days to 50 per cent flowering showed correlation with days to maturity, however days to 50 per cent flowering, days to maturity and test weight showed positive but non-significant correlation with grain yield. Similarly, number of tillers per plant showed positive but non-significant correlation with grain yield. Several workers including, Reddy and Sharma (1982), Bhamre and Harinarayana (1992), Hepziba *et al.* (1993) and Jadhav *et al.* (1994) reported similar findings in pearl millet. In the present study, simultaneous selection for ear length, ear girth for the improvement of grain yield may be possible as reported by Navale *et al.* (1995).

5.7 Path analysis

Correlation coefficient analysis does not provide a definite clue for the relative importance of yield contributing characters in yield. Path coefficient analysis explain a cause and effect situation i.e. partitioning of the total effects in to direct and indirect causes, hence is more reliable technique for development of selection criterion. In the present study, path analysis between yield and yield contributing characters on genotypic and phenotypic levels was carried out. The results of path analysis revealed that, highest positive direct effect of days to 50 per cent flowering on grain yield per plant followed by the trait panicle girth at genotypic level. Whereas, at phenotypic level, the highest direct positive effect was recorded by plant height followed by the characters viz. number of tillers per plant, panicle length, days to 50 per cent flowering and panicle girth.

A strong direct negative effect of days to maturity was recorded on seed yield at both levels, followed by characters test weight and panicle girth. This indicates that the selections which exhibits lateness to maturity and low test weight produced low yield and should be avoided.

The characters days to 50 per cent flowering has highest indirect effect via days to maturity, while days to maturity had highest positive indirect effect through days to 50 per cent flowering. Several workers including Reddy and Sharma (1982), Ramma Das *et al.* (1986), Khairwal *et al.* (1990), Hepziba et al. (1993) and Jadhav *et al.* (1994) also reported similar results.

The present investigation suggest that emphasis should be given to days to 50 per cent flowering, panicle length and panicle girth as a selection criteria for the improvement of grain yield in pearl millet.

5.8 Implications in future breeding programme

The standardized `B' lines from this programme having better yielding ability and other desirable characteristics may be further utilized for development of PAMS-A new versions which inturn be utilized for development of hybrids. These lines as are having good yield potentials can also be used in population improvement programme.

Summary

VI. SUMMARY

The present investigation was undertaken to estimate the extent of genetic variability, heritability, genetic advance, character association and path analysis studies for yield and yield contributing characters in pearl millet (*Pennisetum americanum* L.). The material used for the present study comprised of 19 uniform selections made from the variable population of PAMS-1B and the check PAMS-1B. The material was raised in randomized block design with three replications during kharif season of 1998. Observations were recorded on the characters viz. plant height, number of tillers per plant, panicle length, panicle girth, days to 50 per cent flowering, days to maturity, 1000 seed weight and grain yield par plant.

The data were analysed and the results obtained are summarised below.

1. Analysis of variance showed significant differences for all the characters among the genotypes indicating the presence of wide genetic variability in the material.
2. In mean performance, selection No. 17 was early and selection No. 2 was late for days to maturity. The highest and the lowest plant height was observed in selection No. 11 and selection No. 19, respectively. The selection No 10 recorded highest number of productive tillers. The highest panicle length and girth were recorded in the selection No. 11 and selection No. 12, respectively. The maximum 1000

grain weight was recorded in the selection No. 19 and the selection No. 11 recorded the highest grain yield per plant.

3. The high genotypic and phenotypic variances were observed for grain yield per plant and plant height.

4. The high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for grain yield per plant and plant height.

5. Broad sense heritability estimates were high for all the characters and was highest for grain yield per plant and plant height.

6. The genetic advance was highest for grain yield per plant and also for plant height followed by panicle length.

7. The character grain yield per plant showed high heritability but low genetic advance indicating the predominant role of non-additive gene action in the inheritance of grain yield.

8. From the results of variability analysis, it is concluded that the traits : plant height, days to 50 per cent flowering and panicle length found to possess high heritability estimates coupled with high expected genetic advance indicating the role of additive gene effect in controlling these traits and can be improved by applying a phenotypic selection of the plant as a breeding method.

9. The correlation studies of different characters revealed that, panicle length, panicle girth are the most important characters contributing to the yield per plant. Similarly, plant height and days to 50 per cent flowering also showed a significant positive correlation with yield per plant.

10. Path coefficient analysis revealed that days to 50 per cent flowering and panicle length had the direct effect on grain yield, while panicle length and test weight had indirect effect on grain yield per plant via panicle girth and days to 50 per cent flowering.

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*** Original not seen.**