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Research Article

Evaluation of proso millet (*Panicum miliaceum* L.) germplasm collections

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Abstract :
Evaluation of three hundred and sixty four proso millet germplasm accessions were done during *rabi*, 2008-2009 at Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore to study genetic variability, diversity, correlation and path analysis of yield and its components. High variability observed for most of the characters indicated the scope of improvement of these characters by direct selection. Among the characters studied highest variability was observed for grain yield per plant and total number of productive tillers showed highest heritability. High genetic advance as per cent of mean was recorded for all characters except days to fifty per cent flowering and plant height. High heritability coupled with high genetic advance was observed for grain yield, number of productive tillers and total number of tillers indicated the scope of simple selection for improvement of these characters. All characters exhibited highly significant positive correlations with grain yield. Positive direct effect of plant height, number of productive tillers and hundred grain weight indicated direct selection for these characters would improve the grain yield in proso millet. This study indicated that, great yield advantage can be achieved by selecting accessions with more productive tillers, tall stature and medium duration. Seventeen distinct clusters were observed by cluster analysis. Principal component analysis indicated that panicle length, days to 50 per cent flowering, grain yield per plant, plant height, total number of tillers and hundred grain weight could be used as characters to distinguish the germplasm entries.

Key words: Proso millet; Germplasm; Variability; Grain yield; Correlation; Path analysis.

Introduction

Proso millet (*Panicum miliaceum* L.) is widely cultivated as a cereal across India, Nepal, Western Burma, Sri Lanka, Pakistan and South East Asian countries. It was domesticated in Manchuria and introduced to Europe about 3000 years ago, followed by introduction in the Near East and India. Prosomillet is grown throughout India in more than half a million hectare mainly in the states of Tamil Nadu, Karnataka, Andhra Pradesh and Uttarkhand. Grains are comparable or even superior to major cereals nutritionally and grain protein is rich in essential amino acids. It is grown both in the tropics and sub-tropics even at an altitude of 2700 feet above MSL. It is a short season crop with low water requirement and highly tolerant to heat and drought. It is preferred for extreme soil and climatic conditions as it yields reasonable harvest even in degraded soils under unfavorable weather conditions.

Germplasm is the basic raw material in any crop improvement programme. Characterization and evaluation are important pre-requisites for its effective utilization and also to identify sources of useful genes. Progress in any crop improvement programme depends mainly on the variability existing in the base population. Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop. Heritability gives the information on the magnitude of inheritance of quantitative traits, while genetic advance will be helpful in formulating suitable selection procedures. Correlation studies provide an opportunity to study the magnitude and direction of association of yield with its components and also among various components. To get the information on actual contribution of each component character to yield it is necessary to partition correlation coefficients into direct and indirect effects through path analysis. Correlation in conjunction with path analysis would help in identifying suitable selection criteria for improving the yield. Multivariate hierarchial cluster analysis helps in initial grouping of accessions. Principal component analysis is used to confirm the diversity pattern brought about by cluster analysis. Hence the present study was planned to characterise the germplasm materials for different yield and yield

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contributing traits, to study the variability parameters and to understand the association of various characters, their cause with yield and its components in proso millet and to estimate diversity through classification of genotype using multivariate hierarchial cluster analysis and principal component analysis.

Materials and methods

The experiment was conducted during *rabi*, 2008-2009 at Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, which is situated at about 11^{o}N latitude and 77^{o}E longitude at an altitude of 427 metres above MSL. The average annual rainfall is around 700 mm. Experimental materials consisted of 364 proso millet germplasm accessions maintained at small millets section of Department of Millets. Each accession was grown in single row of 3 meters length with a spacing of 30 cm between rows and 10cm between plants in Randomized Block Design with three replications for characterization and evaluation. Observations were recorded on five randomly selected competitive plants in each accession in every replication for seven yield and yield contributing characters such as days to 50 per cent flowering, plant height (cm), total number of tillers per plant, number of productive tillers per plant, panicle length (cm), grain yield per plant (g) and hundred grain weight (g) as per descriptors for *P. miliaceum* and *P. sumatrense* (IBPGR 1985).

The estimation of mean, variance, standard deviation, standard error, variance, coefficient of variation, skewness and kurtosis were worked out by adopting the standard methods (Panse and Sukhatme, 1964). Phenotypic variance and genotypic variance were estimated according to the formula given by Lush (1940). Phenotypic coefficient of variation and genotypic coefficient of variation were computed according to the method suggested by Burton (1952). Heritability in broad sense was calculated as per the formula given by Allard (1960). Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson *et al.* (1955). Correlation coefficients were worked out using the formula as suggested by Falconer (1960). The correlation coefficient was partitioned in to direct and indirect causes according to Dewey and Lu (1959). Mean values of 364 genotypes for seven quantitative traits were subjected to multivariate hierarchial cluster analysis and principal component analysis (PCA) using the computer software NTSYS pcv2.02i (Rholf, 1992).

Results and discussion

Descriptive statistics

Mean values were subjected to statistical analysis to study the descriptive statistics like mean, range, standard deviation, standard error, coefficient of variation, variance, skewness and kurtosis (Table 1). Wide range was observed for characters like plant height, grain yield per plant, number of tillers per plant and panicle length in the evaluated proso millet germplasm indicating the extent of variability for these characters. Variation observed in inflorescence compactness and shape is given in Plate.1. Estimate of mean serves as a basis for eliminating the undesirable genotypes. There are accessions in the collection, which can flower as early as 34 days and as late as 56 days after sowing with a mean of 41 days. Plant height ranged from 39 to 173cm with a mean height of 97.7 cm. Total numbers of tillers is one of the important yield contributing characters and it ranged from 4 to 27 with a mean of 13. Number of productive tillers varied from 2 to 23 with a mean of 8. Panicle length ranged from 14 to 48 cm with a mean of 30.9 cm. Hundred grain weight ranged from 0.32 to 0.71g with a mean of 0.49 g. Grain yield per plant showed a wide range of 5.14 to 64 g with a mean of 25.20 g. Among the traits studied grain yield per plant and plant height showed higher variance. All the characters showed positive skewness except panicle length indicating non- additive gene action.

Accessions were categorized in to three different classes based on the range observed for each character. Relative frequencies and corresponding percentage values of different classes were given in Table 2. Most of the accessions were earlier in flowering (76%), dwarf in plant stature (63.7), low in tillering (54.9%), intermediate in panicle length (92.6), high in hundred grain weight (48%) and low in grain yield per plant (56%). Histogram has been provided for grain yield per plant to illustrate the frequency distribution available in the material (Fig. 1).

Studies on variability

Relative magnitude of variation available in a population can be measured by coefficient of variation. Estimates on genotypic and phenotypic co-efficient of variation, heritability and genetic advance as per cent of mean are furnished in Table 2. The magnitude of phenotypic coefficient of variation was higher than that of genotypic coefficient of variation for all characters under study (Fig.2). It means that apparent variation is not only due to genotypes but also due to the influence of environment. However the narrow differences between phenotypic and genotypic coefficient of variation indicated little influence of environment on the expression of these characters and variability was due to genetic constitution only. This implied phenotypic variability to be a reliable measure of genotypic variability. Genotypic coefficient of variation for various characters ranged from 8.93 to 39.04%. The highest genotypic coefficients of variation were recorded by grain yield per plant (39.04%) followed by number of productive tillers (37.24%). The lowest genotypic coefficient of variation was recorded in days to 50 per cent flowering (8.93%).

High estimates of genotypic and phenotypic coefficients of variation were recorded for grain yield per plant, number of productive tillers and total number of tillers which indicated these characters are more variable in these genotypes. Hawlader (1991) reported high genotypic and phenotypic coefficients for grain yield and total number of tillers, Chidambaram and Palanisamy (1995) for grain yield and Prasad *et al.* (1995) for total number of tillers. Medium genotypic and phenotypic coefficients of variation were observed for plant height, hundred grain weight and panicle length which indicated variation for these characters were medium among these genotypes. Similar results were reported by Prasad *et al.* (1995) for plant height and Panwar and Kapila (1992) for panicle length. Low genotypic and phenotypic coefficients of variation were observed for days to 50 per cent flowering indicating that this character was less variable among these genotypes. These results were in accordance with Manoharan (1978) and Hawlader (1991).

Heritability for a given character is the extent to which the variability is transferred to the progeny and genetic advance is the measure of expected improvement of a trait under selection process. In the present study the estimates of heritability were found to be high for all the characters under study and it ranged from 81.2 (days to 50 per cent flowering) to 89.4% (number of productive tillers). Heritability was more than 80 per cent (Fig.2) for all the characters studied which indicated that these characters were less influenced by environmental conditions and selection would be effective on the basis of phenotype alone with equal probability of success. Panwar and Kapila (1992) reported similar results for plant height, number of tillers, panicle length, thousand grain weight and grain yield per plant.

Genetic advance as per cent of mean ranged from 17.1 (days to 50 per cent flowering) to 72.92% (grain yield per plant). High genetic advance as per cent of mean was observed for all characters except days to 50 per cent flowering indicated that these characters are governed by additive genes and selection will be rewarding for improvement of these traits. Medium genetic advance observed for days to 50 per cent flowering indicated that these characters are governed by non additive genes and heterosis breeding may be useful.

High heritability coupled with high genetic advance was observed for all characters except days to 50 per cent flowering which indicated that most likely the heritability is due to additive gene effects and can be improved by simple selection. High heritability coupled with medium genetic advance observed for days to 50 per cent flowering indicated non additive gene action and high genotype x environment interaction. High heritability is being due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding.

Correlation studies

Grain yield is a complex character and its expression depends up on the interplay of a number of component characters. An insight into the association between grain yield and other traits helps to improve the efficiency of selection. Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be relied upon for genetic improvement of yield. At genetic level, a positive correlation occurs due to coupling phase of linkage and negative correlation occurs due to repulsion phase of linkage of genes controlling two different traits.

Among the possible twenty one correlation combinations twelve character pairs showed significant correlation either in positive or negative direction. Genotypic correlation coefficient values were higher than the phenotypic correlation coefficient values for all the traits, indicating that the strong associations between the traits were mainly governed by genetic factors.All seven characters studied except panicle length and hundred grain weight exhibited significant positive correlation with grain yield per plant (Table 3). Similar results were obtained by Sen and Hamid (1986), Hawlader (1991), Panwar and Kapila (1992), Prasad *et al.* (1995) and Chidambaram and Palanisamy (1995). Significant positive association suggested high association between these characters and increase in one character will increase the other also. Highest significant positive correlation was observed by plant height (0.429), followed by number of productive tillers (0.144), days to 50 per cent flowering (0.126) and total number of tillers (0.114). Significant positive correlation of most of the characters on grain yield indicated that all these characters can be simultaneously improved and it also suggested that increase in any one of them would lead to improvement of other character.

Most of the characters had positive inter correlation with each other. Days to 50 per cent flowering recorded positive and significant inter correlation with plant height and panicle length. Plant height showed positive significant correlation with panicle length. Total number of tillers had significant positive correlation with number of productive tillers. Number of productive tillers showed significant positive correlation with panicle length. From the above results, it is evident that most of the traits were associated with grain yield and inter correlated among themselves. It indicated that the selection in any one of these yield attributing traits will lead to increase in the other traits, thereby finally boosting the grain yield. Hence, primary selection for traits like tiller number, plant height and days to 50 per cent flowering may be given importance in selection to obtain genotypes with increased grain yield per plant. In addition the significant associations between these component traits suggest the possibility of simultaneous improvement of these traits by single selection.

Some of the correlations between the components of yield such as that of days to fifty per cent flowering with total number of tillers was found to be negative. It is difficult to exercise simultaneous selection of these characters for improving grain yield and negative association between important characters is undesirable. Such negative correlation could arise primarily from developmentally induced relationships such as two developing components competing for limited resources such as nutrients and water supply. As a consequence, progress through grain yield has depended on combination of characters designated largely by chance combination which may be better than those of existing cultivars. The components of grain yield as selection criteria suffer the disability that they tend to be mutually compensating so that the advance in any one component tends to be affecting the other. Thus negative associations may act as deterrent for the formulation of comprehensive selection schedule involving these traits and therefore, while formulating a comprehensive selection schedule, these factors must also be considered.

Path analysis

Path coefficient analysis permits the partition of correlation coefficients into direct and indirect effects and helps in identifying the effective components and to get information on actual contribution of each component character to yield. The path analysis takes into account the cause and effect relationship between the variables by partitioning the association into direct and indirect effects through other independent variables. Path analysis along with correlation studies provides information on the nature and association between any two metric traits.

Plant height, number of productive tillers per plant and hundred grain weight showed positive direct effect. High magnitude of positive direct effect was exhibited only by plant height. Sen and Hamid (1986) also reported high positive direct effect for plant height. The high direct effect of plant height revealed the true relationship of this trait with grain yield and hence direct selection for this trait could be rewarding for the improvement of grain yield and to reduce the undesirable effect of other component traits studied. Low direct effect was observed for number of productive tillers per plant. Negligible positive direct effect was observed for hundred grain weight. Negative direct effects were negligible in this study.

Medium positive indirect effect was shown by days to 50 per cent flowering through plant height. Total number of tillers had positive medium indirect effect through number of productive tillers. Panicle length showed medium positive direct effect through plant height. Even though days to 50 per cent flowering and total number of tillers per plant showed negligible negative direct effect significant positive correlation of these characters may be due to these indirect effects and indirect selection through these traits which had high direct effect will be effective in yield improvement.

Cluster analysis and principal component analysis

Based on Euclidean distance 364 genotypes were grouped in to seventeen distinct clusters at a similarity coefficient of 3.22 (Fig.3). Cluster I was largest with 236 accessions followed by 36 in cluster II, 12 in cluster X, 14 each in cluster VI and XV. were found with, , 14, 14, accessions respectively. Cluster IX comprised of 10 accessions , Cluster VIII had 8 accessions, cluster XII with 6 accessions and cluster XI and V with 4 accessions each. Clusters III and IV consisted of 2 accessions and remaining clusters were found with single accessions (Table 5).

Principal component analysis showed that first five eigen vectors explained about 93.2 per cent of total variance of quantitative traits of the germplasm accessions. Of these first three principal component with eigen values greater than one accounted for 73.3 per cent of the entire variability. To this effect the first principal component which alone explained about 32.5 per cent of gross variability among the accessions had been mainly due to panicle length, plant height, grain yield, days to 50 per cent flowering , number of productive tillers and total number of tillers. Second principal component accounted for 26.2 per cent of overall variability originated primarily from days to 50 per cent flowering and plant height. On the other hand fourth principal component which accounted for 11.5 per cent variation resulted largely from days to 50 per cent flowering and hundred grain weight. Fifth principal component accounted for 8.4 per cent of total variation through days to 50 per cent flowering and grain yield. Sixth and seventh principal component which accounted for 4.2 and 2.4 per cent of variation originated from panicle length and total number of tillers respectively. From these results it can be concluded that panicle length, days to 50 per cent flowering, grain yield per plant, plant height, total number of tillers and hundred grain weight could be used as characters to distinguish the germplasm entries.

Conclusion

All the accessions studied showed wide range of variation for all the characters including grain yield per plant and this genetic diversity can be effectively utilized for crop improvement. Grain yield per plant, number of productive tillers and total number of tillers showed high genotypic and phenotypic coefficients of variation indicating that there is great scope for improvement of these characters by direct selection among the genotypes. High heritability was observed for all the characters indicates that these characters are least influenced by environmental effects High genetic advance as per cent of mean was observed for all characters except days to 50 per cent flowering. High heritability coupled with high genetic advance was observed for all characters except days to 50 per cent flowering which indicated that most likely the heritability is due to additive gene effects and can be improved by simple selection. In the present study, all the characters studied showed significant positive correlation with grain yield per plant. It would be inferred that selection in positive direction for all these traits will increase the grain yield. Plant height, number of productive tillers per plant and hundred grain weight showed positive direct effect indicated that direct selection for these traits will be rewarding for yield improvement.

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Table 1. Mean values of different yield and yield contributing traits in proso millet

Particulars	Days to 50 per cent flowering	Plant height (cm)	Total number of tillers	No. of productive tillers	Panicle length (cm)	Grain yield per plant (g)	Hundred grain weight (g)
Mean	41.26	97.65	13.34	7.99	30.88	25.20	0.49
Minimum	34	39.00	4.00	2.00	14.00	5.14	0.32
Maximum	56	173.00	27.00	23.00	48.00	69.00	0.71
Standard deviation	3.89	17.96	4.27	3.17	5.10	10.81	0.08
Standard error	0.20	0.94	0.22	0.17	0.27	0.57	4.45
Coefficient of variation	9.44	18.39	31.85	39.51	16.47	42.88	17.40
Variance	15.11	322.4	18.20	10.04	25.98	116.83	7.21
Skewness	1.42	0.48	0.39	1.30	-0.61	0.79	0.01
Kurtosis	1.84	2.48	-0.02	3.01	1.99	0.68	-1.40

Table 2. Characterization and preliminary evaluation of proso millet germplasm

Characters	Variation	Frequency	Percentage	Coefficient of variation (%)		Heritability in broad sense (%)	Genetic advance as % of mean
				GCV	PCV		
Days to 50 per cent flowering	Early (34-44)	277	76.1				
	Medium(44-54)	82	22.5	8.93	10.80	81.24	17.08
	Late (54-59)	5	1.4				
Plant height (cm)	Dwarf (39-99)	232	63.7				
	Medium(99-129)	106	29.1	17.42	18.63	87.48	33.57
	Tall (129-189)	26	7.2				
Total number of tillers	Low (2-12)	200	54.9				
	Medium (12-22)	159	43.7	30.19	32.27	87.55	58.19
	High (22-32)	5	1.4				
No.of productive tillers	Low (4-14)	329	90.4				
	Medium (14-24)	34	9.3	37.24	39.39	89.40	72.53
	High (24-34)	1	0.3				
Panicle length (cm)	Short (14-24)	24	6.6				
	Medium (24-44)	337	92.6	15.69	17.02	84.95	29.78
	Long (44-54)	3	0.8				
Hundred grainweight(g)	Low (0.32-0.42)	97	26.6				
	Medium(0.420.62)	90	24.7	15.62	16.88	85.71	29.56
	High(0.62-0.72)	175	48.1				
Grain yield per plant (g)	Low (5-25)	206	56				
	Average (25-65)	157	38.2	39.04	43.05	88.24	72.92
	High (65-85)	1	52				

Table 3. **Genotypic correlation coefficients between grain yield per plant and component characters**

Characters	**Plant height (cm)**	**Total number of tillers**	**No. of productive tillers**	**Panicle length (cm)**	**Hundred grain weight (g)**	**Grain yield per plant (g)**
Days to 50 per cent flowering	0.461**	-0.174**	-0.078	0.165**	-0.092	0.126*
Plant height (cm)	1	0.036	0.029	0.218**	0.031	0.429**
Total number of tillers		1	0.813**	0.106*	0.108*	0.114*
No. of productive tillers			1	0.125*	-0.026	0.144**
Panicle length (cm)				1	0.056	0.084
Hundred grain weight (g)					1	0.029

*Significant at P = 0.05 ** Significant at P = 0.01

Table 4. Direct (diagonal) and indirect effects of six characters on grain yield

Characters	Days to 50percent flowering	Plant height (cm)	Total number of tillers	No. of productive tillers	Panicle length (cm)	Hundred grain weight (g)	Correlation with grain yield per plant (g)
Days to 50 percent flowering	**-0.08179**	0.21537	0.01069	-0.01376	-0.00325	-0.00166	0.126*
Plant height (cm)	-0.03768	**0.46747**	-0.00223	0.00509	-0.00430	0.00055	0.429**
Total number of tillers	0.01424	0.01696	**-0.06143**	0.14413	-0.00208	0.00194	0.114*
No.of productive tillers	0.00635	0.01343	-0.04996	**0.17722**	-0.00247	-0.00046	0.144**
Panicle length (cm)	-0.01351	0.10195	-0.00650	0.02224	**-0.01969**	-0.00101	0.084
Hundred grain weight (g)	0.00755	0.01436	-0.00662	-0.00455	0.00111	**0.01802**	0.029

Table 5. Distribution of 368 proso millet germplasm accessions in seventeen different clusters

Cluster	Constituent accessions
I	PV 186, TNAU 55, GPMS 95, GPMS 64, GPMS 595, GPMS 127, CO 2, GPMS 104, GPMS 136, GPMS 215, GPMS 72, GPMS 255, PV 1457/1, PV 1491, PV 1608, PV 1650, PV 1664, PV 4890, TNAU 6, GPMS 619, PV 1660, GPMS 115, GPMS 862, PV 1623, TNAU 38, TNAU 51, GPMS 16, PV 4968, GPMS 86, Sel 2, PV 1449, PV 5202, GPMS 613, TNAU 193, PV 1473, TNAU 31, GPMS 22, PV 4891, CO3, PV 4920, GPMS 530, M 5, PV 1450, PV 1452/1, PV 4897, GPMS 357, GPMS 606, GPMS 631, PV 1672, GPMS 38, TNAU 10, GPMS 193, PV 1501, PV 1503/1, GPMS 98, GPMS 399, DC 204, TNAU 29, TNAU 48, PV 194, PV 196, TNAU 30, GPMS 210, PV 1409, PV 1421, GPMS 217, GPMS 190, GPMS 214, GPMS 81, GPMS 117, GPMS 596, GPMS 88, GPMS 188, GPMS 208, GPMS 122, CO 1, GPMS 111, PV 1622, PV 4922, PV 1663, TNAU 27, TNAU 18, TNAU 33, PV 1475, TNAU 37, TNAU 35, GPMS 106, TNAU 14, PV 1421/2, TNAU 164, PV 1454, TNAU 169, GPMS 615, Sel 2, Sel 4, PV 4917, GPMS 7, GPMS 782, CO 4, PC 1, GPMS 618, PV 4911, TNAU 155, GPMS 39, GPMS 105, GPMS 18, GPMS 103, GPMS 221, PV 1309, PV 1453, PV 1503, PV 1580, PV 1583, GPMS 145, GPMS 60, Sel 7/1, GPMS 537, GPMS 62, K 1, PV 1430, PV 1673, GPMS 420, Sel 3, PV 1669, PV 186/1, PV 1458, PV 1676, GPMS 83, GPMS 610, PV 1665, GPMS 75, GPMS 71, IPM 27, GPMS 253, TNAU 40, IPM 2443, PV 193, PV 4824, GPMS 546, PV 1443, PV 1504, GPMS 818, TNAU 20, GPMS 622, PV 1422/1, TNAU 24, GPMS 392, GPMS 607/2, GPMS 197, GPMS 656/1, GPMS 657, RAU 1, GPMS 229, GPMS 266, GPMS 294, GPMS 529, GPMS 775, EC 109359/1, GPMS 574, VL 21, GPMS 626, GPMS 904, GPMS 816, GPMS 866, IPM 19, PV 1307, GPMS 555, GPMS 261, GPMS 313, PV 1315, GPMS 644/1, PV 1328, GPMS 643, GPMS 885, PV 1421/A, PV 4422, GPMS 220, GPMS 181, TNAU 22, TNAU 25, GPMS 581, GPMS 664, GPMS 47, GPMS 257, EC 109359,PV 1402, TNAU 58, GPMS 34, GPMS 163, TNAU 23, TNAU 26, TNAU 57, PV 1507,GPMS 520, GPMS 656,GPMS 660, GPMS 350, GPMS 628, GPMS 360, GPMS 306, GPMS 373, GPMS 286, GPMS 287,GPMS 318, GPMS 607, GPMS 872, GPMS 314, GPMS 391, IPM 2230, PV 1586, PV 1692, GPMS 541, GPMS 254, IPM 1545, TNAU 28, GPMS 51, GPMS 608, GPMS 352, GPMS 526, GPMS 270, GPMS 659, EC 109381, PV 1506, GPMS 594, GPMS 379, GPMS 557, GPMS 458, GPMS 483, GPMS 631/1, GPMS 325, GPMS 361, GPMS 646, GPMS 421, GPMS 833, GPMS 844, GPMS 559.
II	PV 1403,GPMS 443, GPMS 296, TNAU 1/78, GPMS 631/A, GPMS 8, GPMS 893, GPMS 393, GPMS 433, GPMS 516, GPMS 649, GPMS 267, GPMS 335, GPMS 367, GPMS 411, GPMS 477, GPMS 412, GPMS 481, PV 1676/A, TNAU 1/79, PV 5204, TNAU 4/78, GPMS 424, GPMS 525, PV 4922/1, TNAU 3, GPMS 432, GPMS 163, GPMS 410, GPMS 21, GPMS 453, GPMS 505, GPMS 454, GPMS 457, GPMS 472, GPMS 607/1
III	GPMS 860, GPMS 886
IV	TNAU 2/78, TNAU 4
V	TNAU 2, TNAU 17, TNAU 179, GPMS 157
VI	PV 1316, GPMS 878, GPMS 785, GPMS 789, GPMS 880, EC 109381/3, PV 1320, GPMS 681/1, GPMS 777, GPMS 680, EC 109359/1, GPMS 879, GPMS 906, GPMS 909, EC 109381/1
VII	Sel 5
VIII	PV 1420, PV 1315, GPMS 409, TNAU 123, PM 29/1, GPMS 482, EC 109381/2, Sel 5/1
IX	GPMS 285, GPMS 402, GPMS 411, GPMS 644/1-1, GPMS 871,GPMS 658, GPMS 856, GPMS 859, GPMS 895, GPMS 778
X	PV 191, CO 5, TNAU 19, TNAU 34, PV 1670, PV 1257, PV 1667, GPMS 269, GPMS 224, TNAU 21, GPMS 473, GPMS 532, GPMS 564, GPMS 783, GPMS 647, Sel 9, GPMS 576, GPMS 592, GPMS 625, TNAU 176, GPMS 857
XI	PV 1674, TNAU 159, GPMS 907, TNAU 188
XII	TNAU 15, TNAU 183, TNAU 151, GPMS 28, TNAU 7, TNAU 174
XIII	GPMS 436
XIV	GPMS 609
XV	GPMS 806, IPM 2253, IPM 2254, IPM 2256, IPM 2257, IPM 2816, IPM 2710, IPM 1536, IPM 2900, IPM 2236, TNAU 39, IPM 2165
XVI	EC 109360
XVII	IPM 2229

Table 6. Extraction of eigen vectors, eigen values, per cent of variation and cumulative variation for seven principal components of proso millet germplasm accessions

Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Days to 50 per cent flowering	0.4615	0.5225	0.1320	0.5127	0.4738	0.0870	0.0402
Plant height	0.8076	0.3644	-0.0823	0.0170	-0.1801	-0.4187	-0.0149
Total number of tillers	0.4171	-0.8491	0.0172	0.1313	0.0149	-0.0355	0.2933
Number of productive tillers	0.4332	-0.8136	0.1842	0.1210	0.1463	-0.0288	-0.2820
Panicle length	0.8165	0.1609	0.0470	0.0686	-0.4375	0.3296	-0.0220
Grain yield	0.6159	0.0684	-0.1670	-0.6775	0.3473	0.0899	0.0196
Hundred grain weight	0.0176	-0.1341	-0.9649	0.2147	0.0270	0.0420	-0.0463
Eigen value	2.2730	1.8374	1.0194	0.8048	0.5913	0.3034	0.1703
Per cent variation	32.4722	26.2486	14.5640	11.4985	8.4478	4.3347	2.4342
Cumulative variation	32.4722	58.7208	73.2848	84.7833	93.2311	97.5658	100.00

Fig. 1 Frequency distribution for grain yield per plant

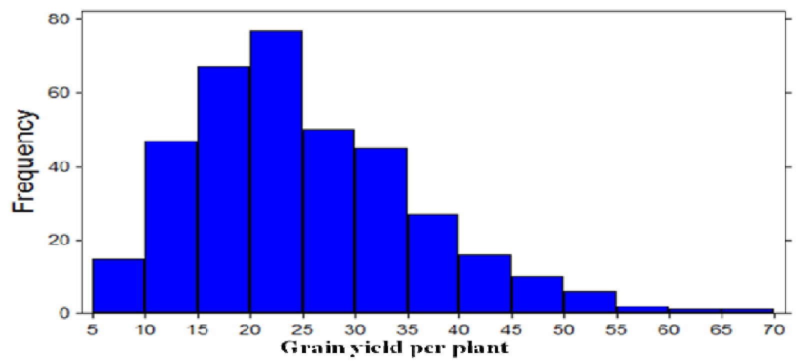

Fig. 2 Comparison of GCV, PCV, H^2 and GAM for different characters in proso millet

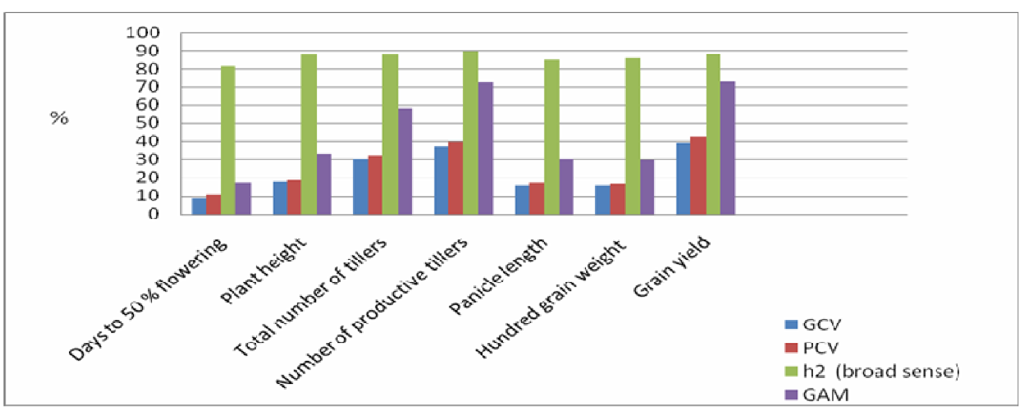

Fig 3.clustering pattern of 364 proso millet germplasm accessions obtained through cluster analysis

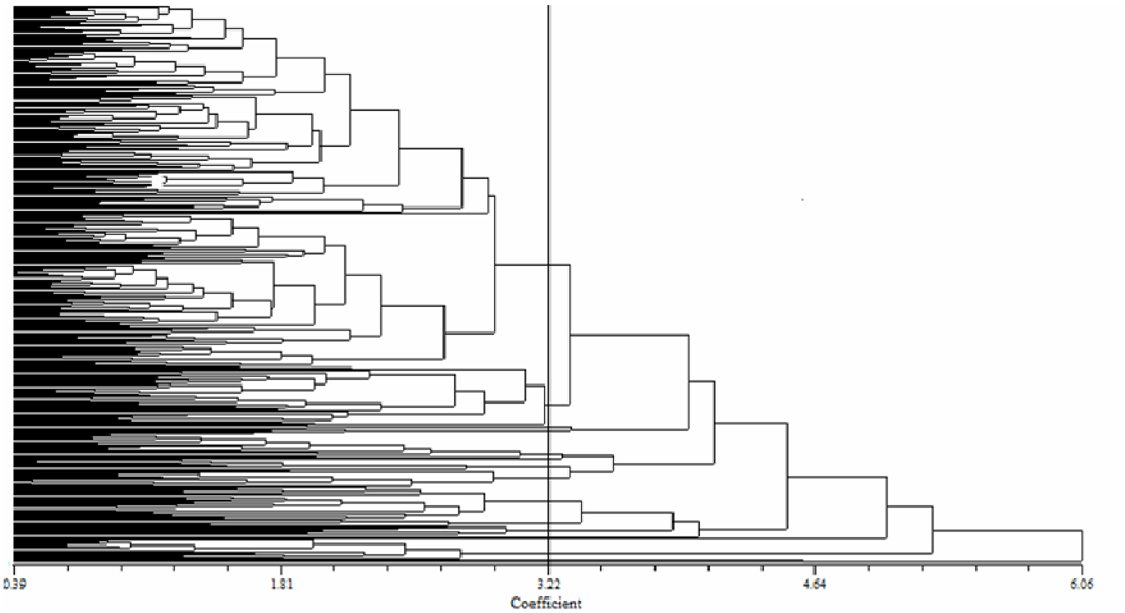

Fig 4. Two dimensional ordination of 364 prosomillet germplasm accessions for seven quantitative traits

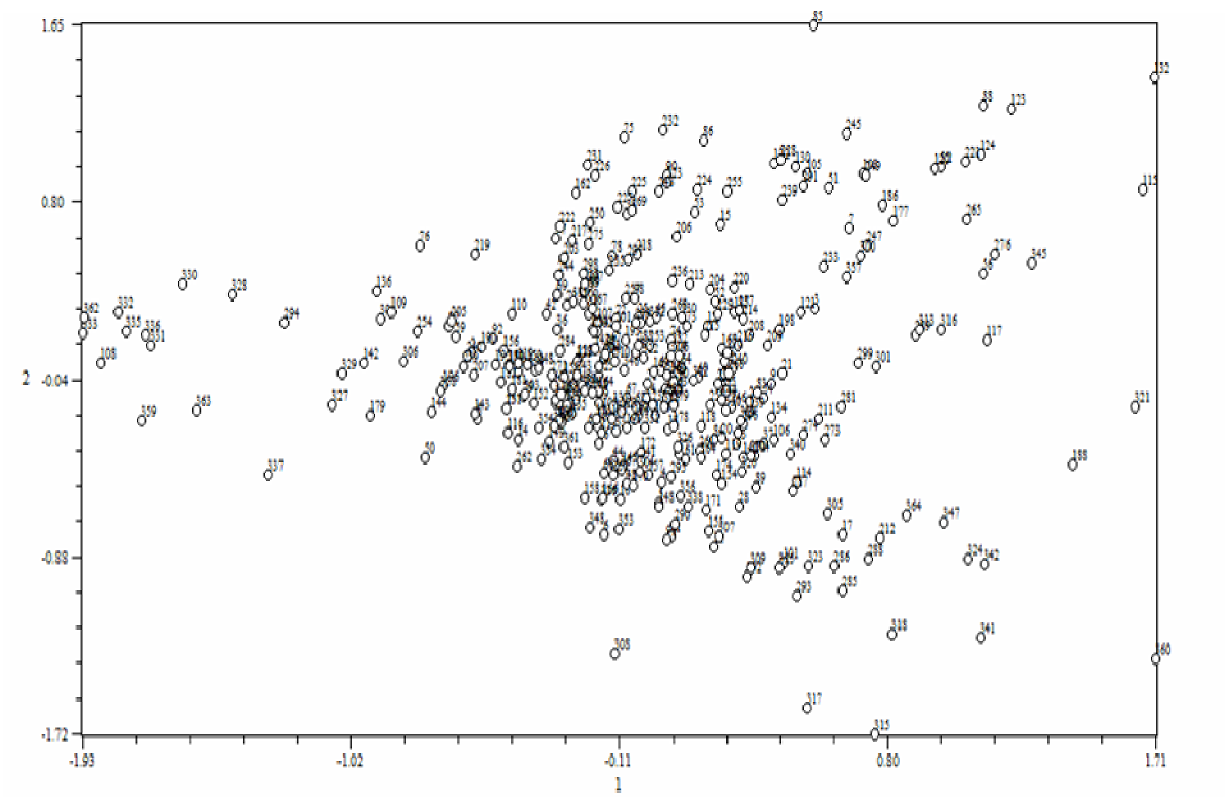

Plate 1. Variation in inflorescence compactness and shape in proso millet