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Genetic divergence studies in pearl millet (*Pennisetum glaucum* (L). R. Br)

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Abstract
The present investigation was conducted to evaluate the genetic divergence among fifty pearl millet germplasms using Mahalanobis D^2 statistics for fourteen different traits. Analysis of variance indicated considerable diversity among genotypes showing significant variability for all the characters. D^2 clustering grouped the genotypes into sixteen clusters. The maximum (191.2) inter cluster distance was observed between cluster XV and XVI followed by clusters V and XV (144.9), clusters X and XV (139.7), clusters XIII and XV (137.8), clusters XI and XV (120.2) and clusters VI and XVI (117.3). The genotypes PPBI-04 from cluster XI, PPBI-34 from cluster V, PPBI-38 from cluster XVI and PPBI-39 from cluster IX were considered on the basis of higher inter cluster distances and superior performance for yield and yield contributing characters. Though the inter cluster distances of cluster I with other clusters were low, PPBI-31 and PPBI-44 from cluster I were selected based on high grain yield and important yield contributing characters. Hybridization among these genotypes produce heterotic combinations for improving grain yield per plant. Inclusion of genotypes, PPBI-34 and PPBI-44 in the crossing programme would produce drought tolerant varieties as they were found superior for SPAD chlorophyll meter reading at 45 DAS.

Keywords: Pearl millet, clusters and divergence

Introduction
Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a highly cross pollinated crop with protogynous mechanism, which fulfils one of the essential biological requirements for hybrid development. It is the fifth most important cereal in the world. It is extensively cultivated for grain as well as fodder in dry areas of South Asia, particularly in India and Africa (Khannan *et al*., 2014). The crop can adapt to diverse and ecological conditions, hence is grown in environments of low and erratic rainfall, high temperature and low soil fertility. Genetic diversity is one of the criteria for selection of parents in hybridization programme. Choosing genetically diverse parents will enable the expansion of genetic base, development of superior types and greater success can be achieved through judicious choice of parents for hybridization based on genetic divergence. (Moll and Stuber, 1971) [12] reported that crossing between divergent parents usually produce greater heterosis than those between closely related ones. Quantification of genetic diversity through biometrical procedures such as Mahalanobis D^2 statistic has made possible to choose genetically diverse parents. The divergence analysis has a definite role to play in an efficient choice of divergent parents for hybridization to exploit maximum heterosis for improving the grain yield. Hence, the present study was aimed to determine the genetic diversity among 50 pearl millet genotypes using Mahalanobis's D^2 statistics.

Materials and Methods
The present investigation was carried out with 50 pearl millet inbred lines. The experiment was conducted in RBD with three replications during *Kharif*, 2018 at Agricultural Research Station, Perumallapalle farm, Tirupati situated at an altitude of 182.9 m above mean sea level, 13°N latitude and 79°E longitude. Data was recorded on five randomly selected plants from each replication of each accession for the 12 quantitative characters, namely plant height, number of productive tillers per plant, ear head length, ear head diameter, leaf area index at 45 DAS, SPAD chlorophyll meter reading at 45 DAS, specific leaf area at 45 DAS, specific leaf weight at 45 DAS, dry fodder yield per plant, harvest index, 1000 seed weight and grain yield per plant. The characters *viz*., days to 50% flowering and days to maturity were recorded on

plot basis. Means were computed and data were analysed for divergence studies Mahalanobis D^2 statistics (1936).

Results and Discussion

Analysis of variance indicated considerable diversity among genotypes for all the characters (Table. 1) In the present investigation, D^2 values were calculated for 1225 possible pairs of combinations (n (n-1)/2) from means of fifty genotypes for fourteen characters and were grouped in to sixteen clusters (Table. 2). Among sixteen clusters, cluster I and III had maximum number of eighteen genotypes each. Similarly, clusters II, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV and XVI had one genotype showing these genotypes highly divergent from each other. The maximum (191.2) inter cluster distance was observed between cluster XV and XVI and minimum (14.8) inter cluster distance was present between clusters IV and VIII (Table. 5). Genotypes in clusters I, V, IX, XI and XVI were identified for crossing programme which would result in wide spectrum of variability to operate selection in segregating population. Diversity among pearl millet genotypes of the present study is in accordance with earlier findings of (Yadav, 1994; Hepziba *et al*., 1995; Kumar *et. al*., 2015) [8, 6, 7]. The existence of diversity among the genotypes was also assessed by the considerable amount of variation in cluster means for different characters. Based upon the cluster mean performance, the cluster V had high mean values for grian yield per plant (120 g), 1000 seed weight (13.2) and harvest index (56.9) followed by cluster XV for early flowering (39 days) and maturity (77 days), XVI for plant height (212.5 cm), cluster XIV for number of productive tillers per plant (3.8), cluster IV for ear head length, cluster V for ear head diameter, cluster XI for leaf area index at 45 DAS, cluster XII for SPAD chlorophyll meter reading at 45 DAS, cluster VII for specific leaf area at 45 DAS and cluster XI for fodder yield per plant. Similar observations were recorded Quendeba *et al*. (1995) [3], Narkhede *et al.* (2000) [2], Anantharaju and Meenakshiganeshan (2008), Wolie *et al*. (2013) [4]. There was considerable variation among the cluster means for the characters studied. (Table. 3). Grain yield per plant contributed maximum to diversity followed by days to 50% flowering, number of productive tillers per plant, days to maturity, fodder yield per plant, SPAD chlorophyll meter reading at 45 DAS, ear head diameter, 1000 seed weight, ear head length and specific leaf area at 45 DAS (Table. 4). These results corroborates with findings of Shanmuganathan *et al*. (2006) for ear head diameter, plant height and number of productive tillers per plant; Govindaraj *et al*. (2011) [5] for plant height; Kumari *et al.* (2016) for days to maturity and ear head length and Sumathi *et al.* (2016) [10] for 1000 seed weight and grain yield per plant. The genotypes, PPBI-31 and PPBI-44 from cluster I followed by PPBI-04 from cluster XI, PPBI-34 from V, PPBI-38 from XVI and PPBI-39 from IX recorded high mean performance for number of productive tillers per plant, ear head length, dry fodder yield per plant and grain yield per plant. Hybridization among these genotypes produce heterotic combinations for improving grain yield per plant. Inclusion of genotypes, PPBI-34 and PPBI-44 in the crossing programme would produce drought tolerant varieties as they were found superior for SPAD chlorophyll meter reading at 45 DAS.

Table 1: Mean performance of 50 Pearl millet genotypes

Sl. No	Characters	Mean Sum of Squares		
		Replications (df:2)	Genotypes (df:48)	Error (df:98)
1	Days to 50% flowering	21.84	38.42**	1.75
2	Days to maturity	7.04	9.41**	0.63
3	Plant height (cm)	354.88	567.47**	178.42
4	Number of productive tillers/plant	0.06	0.82**	0.05
5	Ear head length (cm)	3.72	20.60**	2.74
6	Ear head diameter (cm)	0.05	0.12**	0.02
7	Leaf area index at 45 DAS	0.017	0.05**	0.012
8	SPAD Chlorophyll meter reading at 45 DAS	21.42	88.30**	6.86
9	Specific leaf area at 45 DAS(cm^2 g^{-1})	124.55	619.08**	135.29
10	Specific leaf weight at 45 DAS (g cm-^{2})	0.00	0.01**	0.00
11	Fodder yield/plant (g)	20.92	460.35**	29.97
12	Harvest index (%)	4.83	47.41**	6.76
13	1000 seed weight (g)	0.13	2.21**	0.48
14	Grain yield/plant (g)	30.32	696.67**	12.64

*Significant at 5% level; ** Significant at 1% level

Table 2: Cluster composition of 50 pearl millet genotypes based on Tochers's method

Cluster number	No. of genotypes	Genotypes
I	18	PPBI-5, PPBI-7, PPBI-8, PPBI-10, PPBI-12, PPBI-15, PPBI-16, PPBI-18, PPBI-25, PPBI-26, PPBI-28, PPBI-31, PPBI-32, PPBI-41, PPBI-44, PPBI-47, ICTP-8208, PHB-03
II	1	PPBI-02
III	18	PPBI-3, PPBI-6, PPBI-11, PPBI-20, PPBI-21, PPBI-22, PPBI-23, PPBI-24, PPBI-27, PPBI-30, PPBI-36, PPBI-37, PPBI-40, PPBI-42, PPBI-43, PPBI-45, PPBI-46, pittganti
IV	1	PPBI-14
V	1	PPBI-34
VI	1	PPBI-35
VII	1	PPBI-13
VIII	1	PPBI-17
IX	1	PPBI-39
X	1	PPBI-09

XI	1	PPBI-04
XII	1	PPBI-29
XIII	1	PPBI-19
XIV	1	PPBI-01
XV	1	PPBI-33
XVI	1	PPBI-38

Table 3: Cluster means with respect to yield and yield component characters in Pearl milllet

	Days to 50% flowering	**Days to maturity**	**Plant height (cm)**	**Number of productive tillers /plant**	**Ear head length (cm)**	**Ear head diameter (cm)**	**Leaf area index at 45 DAS**	**SPAD chlorophyll meter reading at 45 DAS**	**Specific leaf area at 45 DAS (cm^2 g^{-1})**	**Specific leaf weight at 45 DAS (g cm^{-2})**	**Dry fodder yield/ plant (g)**	**Harvest index (%)**	**1000 seed weight (g)**	**Grain yield/ plant (g)**
I cluster	45	79	159.8	2.8	28.1	2.9	1.44	39.5	157.2	0.01	79.0	55.1	12.2	99.8
II cluster	47	80	147.6	3.5	23.8	2.7	1.40	44.3	150.3	0.01	64.3	55.4	11.8	80.0
III cluster	47	80	156.8	2.5	25.9	2.8	1.31	36.2	161.4	0.01	67.5	52.3	12.1	74.3
IV cluster	53	81	166.3	2.5	32.1	3.1	1.43	35.0	162.4	0.01	84.3	48.3	12.4	78.7
V cluster	43	78	180.1	3.4	27.6	3.3	1.37	38.8	152.6	0.01	90.9	56.9	13.2	120.0
VI cluster	44	79	168.4	1.2	29.7	3.1	1.50	38.4	139.6	0.01	65.3	56.3	11.7	84.0
VII cluster	46	77	160.7	2.1	27.1	3.0	1.37	37.7	208.5	0.01	75.5	53.7	10.5	87.0
VIII cluster	52	81	171.2	2.6	28.1	3.2	1.33	32.6	130.9	0.01	92.3	40.3	13.0	85.7
IX cluster	49	78	156.7	2.7	32.0	2.6	1.47	33.0	174.6	0.01	59.6	50.7	11.9	106.1
X cluster	54	84	183.3	3.0	28.1	2.9	1.37	26.7	169.5	0.01	82.9	50.3	12.0	83.9
XI cluster	53	78	186.7	2.9	31.3	3.2	1.57	34.5	167.3	0.01	103.5	45.1	12.9	88.0
XII cluster	40	80	147.9	2.3	27.6	2.9	1.23	48.0	142.0	0.01	79.4	52.8	10.7	88.6
XIII cluster	52	84	187.6	2.5	28.1	3.2	1.47	36.9	138.2	0.01	77.4	55.7	12.7	97.3
XIV cluster	51	79	176.7	3.8	21.7	2.9	1.37	26.9	175.0	0.01	73.1	47.7	12.8	66.7
XV cluster	39	77	161.4	2.5	23.8	2.7	1.33	44.9	165.2	0.01	66.1	47.3	10.8	59.3
XVI cluster	51	84	212.5	3.1	31.1	2.9	1.40	29.9	176.8	0.01	98.7	51.0	12.7	110.0
Cluster means	48	80	170.2	2.7	27.9	2.9	1.40	36.5	160.7	0.01	78.7	51.2	12.1	88.1

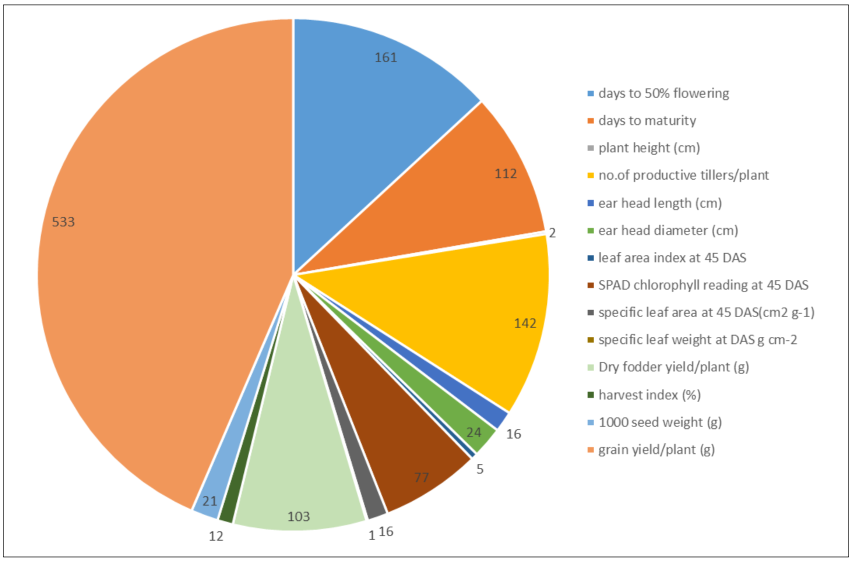

Table 4: Contribution of different grain yield and Physiological characters to diversity in Pearl millet

Table 5: Intra cluster (diagonal) and inter-cluster distances of sixteen clusters in pearl millet

	I cluster	II cluster	III cluster	IV cluster	V cluster	VI cluster	VII cluster	VIII cluster	IX cluster	X cluster	XI cluster	XII cluster	XIII cluster	XIV cluster	XV cluster	XVI cluster
I cluster	20.5 (4.5)	30.6 (5.5)	43.0 (6.5)	52.2 (7.2)	36.1 (6.0)	45.1 (6.71	34.6 (5.88	48.9 (6.9)	32.5 (5.7)	57.8 (7.6)	51.3 (7.1)	34.1 (5.8)	40.4 (6.3)	68.0 (8.2)	79.9 (8.9)	55.4 (7.4)
II cluster		0 (0.00)	26.0 (5.1)	51.9 (7.2)	70.7 (8.4)	56.3 (7.5)	46.5 (6.8)	57.5 (7.6)	53.6 (7.3)	56.1 (7.5)	65.3 (8.1)	34.3 (5.8)	50.1 (7.1)	37.7 (6.1)	46.2 (6.8)	83.5 (9.1)
III cluster			24.5 (4.9)	36.7 (6.1)	97.0 (9.8)	37.7 (6.1)	36.3 (6.0)	47.9 (6.9)	54.3 (7.3)	54.1 (7.3)	57.2 (7.5)	43.4 (6.5)	56.2 (7.4)	43.0 (6.5)	45.8 (6.7)	92.6 (9.6)
IV cluster				0 (0.0)	104.6 (10.2)	45.7 (6.7)	44.6 (6.6)	14.8 (3.8)	54.0 (7.3)	19.3 (4.3)	19.1 (4.3)	72.8 (8.5)	26.7 (5.1)	48.4 (6.9)	99.6 (9.9)	54.8 (7.4)
V cluster					0 (0.0)	98.0 (9.9)	66.7 (8.2)	80.7 (9.0)	59.4 (7.7)	97.8 (9.9)	68.0 (8.2)	74.4 (8.6)	68.0 (8.2)	100.8 (10.0)	144.9 (12.0)	57.6 (7.6)
VI cluster						0 (0.0)	29.0 (5.4)	53.1 (7.3)	52.1 (7.2)	83.4 (9.1)	69.6 (8.3)	30.0 (5.5)	56.9 (7.5)	95.7 (9.8)	52.1 (7.2)	117.3 (10.8)
VII cluster							0 (0.0)	50.2 (7.0)	37.0 (6.0)	72.0 (8.4)	45. (6.7)	39.1 (6.2)	65.6 (8.1)	65.0 (8.1)	54.6 (7.4)	89.9 (9.5)
VIII cluster								0 (0.0)	53.0 (7.2)	22.8 (4.7)	15.8 (3.9)	77.8 (8.8)	22.3 (4.7)	46.9 (6.8)	111.6 (10.5)	48.6 (7.0)
IX cluster									0 (0.0)	62.0 (7.8)	57.2 (7.5)	63.5 (7.9)	53.2 (7.2)	82.5 (9.0)	103.5 (10.1)	60.5 (7.8)
X cluster										0 (0.0)	31.0 (5.5)	102.0 (10.1)	18.0 (4.2)	38.6 (6.2)	139.7 (11.8)	26.1 (5.1)
XI cluster											0 (0.0)	94.3 (9.7)	39.6 (6.2)	42.3 (6.5)	120.2 (10.9)	47.1 (6.9)
XII cluster												0 (0.0)	73.4 (8.5)	104.9 (10.2)	37.5 (6.1)	110.6 (10.5)
XIII cluster													0 (0.0)	69.0 (8.3)	137.8 (11.7)	28.2 (5.3)
XIV cluster														0 (0.0)	83.2 (9.1)	84.1 (9.2)
XV cluster															0 (0.0)	191.2 (13.8)
XVI cluster																0 (0.0)

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