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Research Article

Genetic divergence among Ramnad mundu chilli (*Capsicum annuum* L.) genotypes for yield and quality

J. Phani Kumar*[1]. P. Paramaguru[2], T. Arumugam[3], N. Manikanda Boopathi[4] and K. Venkatesan[5]

[1,3&5]Horticultural College & Research Institute, TNAU, Periyakulam, Tamil Nadu-625604, India
[2]Horticultural College & Research Institute (Women), TNAU, Tiruchirappalli, Tamil Nadu-620027,India
[4]Department of Plant Biotechnology, CPMB&B, Tamil Nadu Agricultural University, Tamil Nadu-641003, India
***E-Mail**: phani515202@gmail.com

Abstract
Genetic diversity among forty-seven genotypes of Mundu chilli (*Capsicum annuum* L.) was assessed for fifteen yield and quality characters during *kharif* 2018. The analysis of variance disclosed that significant difference present for most of the parameters studied, which indicated the existence of wide diversity among all Mundu chilli genotypes. Mahalanobis D^2 statistic stated that the forty-seven genotypes were grouped into six clusters. The highest contribution for genetic divergence was dry fruit yield per plant (25.7%), Ascorbic acid (11.56%), 1000 seed weight (10.85%) and the number of seeds per fruit (10.5%). Among the clusters, the largest was cluster II containing 21 genotypes followed by cluster III (13 genotypes) and cluster I (10 genotypes) whereas, clusters IV, V and VI were grouped as solitary clusters (one genotype in each cluster). The highest inter-cluster distance was noted between clusters IV and VI (1588.27) whereas, the lowest was recorded between clusters II and V (192.44). Cluster III (144.94) has recorded the highest intra-cluster distance and the lowest was observed in clusters IV, V and VI (0.00). D^2 cluster analysis revealed wide genetic distance (inter-cluster) between the genotypes of cluster I (PKMCA-38), II (PKMCA-20, PKMCA-32, PKMCA-33) and V (PKMCA-08). Hence, genetic improvement by crossing among these groups can exploit heterotic hybrids.

Key words
Ramnad Mundu chilli (*Capsicum annuum* L), Genetic divergence, Mahalanobis D^2 statistic, Quality breeding, Spices.

INTRODUCTION

Chilli (*Capsicum annuum* L., 2n = 24) is the important spice of India. It is mainly used as a spice, condiment, and culinary supplement. Also, its utilities as medicine, vegetable and ornamental plant. Chilli is originated in Mexico, Guatemala and Bulgaria (Safford, 1926). It was introduced from Brazil to India at the end of the 15th century by the Portuguese. It is belonging to the family Solanaceae which comprises about 30 species in the tropics and subtropics of the world. Modern taxonomists recognize five major cultivated species. Of these, *Capsicum annuum* L. is a largely cultivated species for hot and humid climate (Greenleaf, 1986). It is a tropical and sub-tropical crop grown in up to 2000 meters mean sea level altitude with an annual rainfall of 600-1500 mm. Among all Indian states, Andhra Pradesh stood top first in chilli cultivation followed by Karnataka, West Bengal, Madhya Pradesh, Orissa, Tamil Nadu (NHB, 2019).

Ramnad Mundu chilli (**Fig. 1**) is a local round/oblong type especially grown as a rainfed crop exclusively for spice in Tamil Nadu, India. It measures 0.6 to 1.5-inch in length, 2.7 to 5.11-inch diameter with thick pericarp (0.25 mm). It is mainly grown under the coastal saline belt of Ramanathapuram, Viruthunagar and Tuticorin districts of Tamil Nadu, where soils are moderate to high alkalinity (soil pH 7.5-9.0) with less annual rainfall (460.0 mm). Farmers preferred this type for rainfed regions since it has adopted to this climate and fetches a high market price than the samba type. Mundu chilli has moderate pungency (Capsaicin content 0.26 to 0.38%) with rich oleoresin content (13%), and ASTA colour value-70.95 units, which are the most preferable characters for chilli powder as a spice. Therefore, the farmer community prefers this Mundu chilli as the best alternate to samba chilli.

Capsaicin and capsanthin are the important chemical constituents of chilli fruit, which are in huge demand in the market. Among all carotenoids, the red colour in chilli is due to capsanthin, capsanthin 5,6-epoxide and capsorubin (Davies *et al.*, 1970). Capsaicin is mainly present in the placenta of the fruit, the level of pungency mainly depends on capsaicin and dihydrocapsaicin which contributes more than 80 *per cent* (Bosland and Votava, 2000). According to Kumar *et al.* (2012), capsaicin ranged in some chillies from 0.05 to 1.3 *per cent* and was grouped the lowest to highest pungency types, respectively.

Fig. 1. Ramnad Mundu Chilli (*Capsicum annuum L.*)

Capsaicin is rich in anti-oxidants, which fights against anticancer, also act as antiarthritic and analgesic (Prasad *et al*., 2006; Bhattacharya *et al.,* 2010). Hence, it is used in Allopathic and Ayurvedic medicine (Kogure *et al.,* 2002). It has wide utilization in the food and beverage industries owing to a rich source of vitamin C (Bosland and Votava, 2000). Apart from this, chilli has great importance for colour and flavour in foods due to the presence of 'oleoresin' (Sumathy and Mathew, 1984).

For crop improvement, exploitation of heterosis for yield and quality characters through hybridization is an important aspect. In this regard, the evaluation of available germplasm helps to study the variability and diversity among the germplasm to select superior parents for effective hybridization (Asati and Yadav, 2004). The knowledge of the genetic distance between parents is necessary to harvest transgressive segregation (Khodadabi *et al.,* 2011).

Hence, the present work was taken to screen the variation among 47 genotypes of Mundu chilli (*Capsicum annuum* L.) collected from rainfed tracts of Tamil Nadu and to identify suitable parents for a successful hybridization programme.

MATERIALS AND METHODS

Forty seven mundu chilli genotypes (**Table 1**) were collected from different rainfed regions of Ramanathapuram, Viruthunagar and Tuticorin districts of Tamil Nadu. The genotypes were evaluated in randomized block design and all the treatments were replicated twice. The seedling was raised during the last week of September 2018 and transplanted at a spacing of 60 × 30 cm in a row of 10 m length during the last week of October 2018. All the cultural practices followed were outlined in TNAU Agri Portal (https://agritech.tnau.ac.in/horticulture/horti_vegetables_chilli_index.html). The observations were recorded for 15 quality and yield contributing characters: plant height (cm), days to 50 % flowering, the number of primary branches per plant, fruit length (cm), fruits girth (cm), the number of seeds per fruits, the number of fruits per plant, ripened fruit yield per plant (g), 1000-seed weight (g), ascorbic acid (mg/100g), oleoresin (%), capsaicin content (%), capsanthin (ASTA), colour value (ASTA) and dry fruit yield per plant (g) and analysed using Mahalanobis D^2 statistics (Mahalanobis, 1936).

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) stated that significant differences among 47 Mundu chilli genotypes for yield and quality traits indicated enormous variability present among all Mundu chilli genotypes (**Table 2**). These results are following earlier works in chilli (Kumar *et al.,* 2010; Shrilekha *et al.,* 2011; Lahbib *et al.,* 2012 and Yatung *et al.,* 2014). The maximum contribution towards genetic divergence (**Table 3**) was recorded by dry fruit yield per plant (25.7%) followed by ascorbic acid (11.56 %), 1000 seed weight (10.85 %), the number of seeds per fruit (10.5

%), fruit girth (7 %), the number of primary branches per plant (6.01 %), fruit length (6.0 %), the number of fruits per plant (5.0 %), ripened fruit yield per plant (4.62 %), capsanthin (4.26 %), capsaicin ASTA (3.20 %), oleoresin% (2.0 %), colour value ASTA (2.0 %), days to 50% flowering (0.93 %) and plant height (0.37 %).

Table 1. Experimental material and source of mundu chilli used in the experiment

S. No	Genotypes	Source	S. No	Genotypes	Source
1	PKMCA-01	Perunali, Viliathikulam	25.	PKMCA-25	Kulanthi
2	PKMCA-02	Ram, Pamboor-2	26.	PKMCA-26	Rangasamy, Guruvarpatti-6
3	PKMCA-03	Rangasamy, Guruvarpatti	27.	PKMCA-27	Rasu, Pamboor-2
4	PKMCA-04	Pondy, Kovilpatti	28.	PKMCA-28	Rangasamy, Guruvarpatti-2
5	PKMCA-05	Perumavathi, Kodangipatti	29.	PKMCA-29	Ramalingam, Kathalampatti
6	PKMCA-06	Nagarajaperumal, Kelvilathikulam	30.	PKMCA-30	Santhy-2
7	PKMCA-07	Kasi, Manthikulam	31.	PKMCA-31	Gopal, Pudupatti
8	PKMCA-08	Muthusamy, Kathalampatti	32.	PKMCA-32	Alagupal
9	PKMCA-09	Pothuraj, Ariganagipuram	33.	PKMCA-33	Santhi-1
10	PKMCA-10	Perumal, Kelvilathikulam	34.	PKMCA-34	UDK Pamboor
11	PKMCA-11	Rangasamy, Guruvarpatti	35.	PKMCA-35	Anthoor
12	PKMCA-12	Murugan, Pasanur	36.	PKMCA-36	Muruganandham
13	PKMCA-13	Selvaraj, Kelvilathikulam	37.	PKMCA-37	Rasu, Pamboor-3
14	PKMCA-14	Marimuthu, Elanthkulam	38.	PKMCA-38	Ramu, Ramanathapuram
15	PKMCA-15	Azharamalingam, K. Duraisamypuram	39.	PKMCA-39	Coimbatore-Mundu
16	PKMCA-16	Balamurugan, Vilathikulam	40.	PKMCA-40	Kadaladi-1
17	PKMCA-17	Rasu, Pamboor-4	41.	PKMCA-41	Kadaladi-2
18	PKMCA-18	Pavur	42.	PKMCA-42	Kadaladi-3
19	PKMCA-19	Rangasamy, Guruvarpatti-3	43.	PKMCA-43	Paramakudi-1
20	PKMCA-20	U K Pamboor	44.	PKMCA-44	Paramakudi-2
21	PKMCA-21	Rangasamy, Guruvarpatti-4	45.	PKMCA-45	Nainarkoil-1
22	PKMCA-22	Rangasamy, Guruvarpatti-5	46.	PKMCA-46	Nainarkoil-2
23	PKMCA-23	Anthoni-2	47.	PKMCA-47	Nainarkoil-3
24	PKMCA-24	Raguramachandran			

Table 2. Analysis of variance for yield and its contributing characters in mundu chilli

S. No	Plant Character	Mean sum of square		
		Replication	Genotypes	Error
1	Days to 50% Flowering	8.4	60.136**	3.651
2	Plant height	374.0**	189.30**	19.243
3	Number of primary branches per plat	1.358 *	6.067**	0.263
4	Fruit length	0.007	0.284**	0.028
5	Fruit girth	0.701	5.239**	0.274
6	Number of fruits per plant	1.043	465.28**	18.08
7	Ripened fruits yield per plant	135.48	13301.9**	146.279
8	Dry fruit yield per plant	150.52**	528.07**	7.875
9	Number of seeds per fruit	328.03*	704.22**	60.869
10	1000 Seed weight	0.199	1.619**	0.107
11	Ascorbic acid	166.86**	592.84**	15.238
12	Capsaicin	0.006	0.014**	0.002
13	Oleoresin	13.55*	9.798**	2.036
14	Colour Value (ASTA)	0.006	186.03**	54.784
15	Capsanthin (ASTA)	408.42	7326.47**	334.687

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

Table 3. Relative contribution of yield and quality parameters towards genetic divergence in mundu chilli

S. No	Source	Per cent Contribution	Times ranked 1st
1	Days to 50% Flowering	0.93	10
2	Plant height	0.37	4
3	Number of primary branches per plat	6.01	67
4	Fruit length	6.00	67
5	Fruit girth	7.00	78
6	Number of fruits per plant	5.00	56
7	Ripened fruits yield per plant	4.62	51
8	Dry fruit yield per plant	25.7	286
9	Number of seeds per fruit	10.5	117
10	1000 Seed weight	10.85	121
11	Ascorbic acid	11.56	128
12	Capsaicin	3.20	36
13	Oleoresin	2.00	22
14	Colour value (ASTA)	2.00	22
15	Capsanthin (ASTA)	4.26	47

The forty-seven Mundu chilli genotypes were grouped into 6 clusters (**Table 4**). Among all clusters, cluster II was the largest accommodated 21 genotypes, followed by cluster III (13), cluster I (10), cluster IV (1), cluster V (1) and cluster VI (1) cluster IV (1). The method of grouping genotypes into different clusters was arbitrary and indicated that there was no homogeneity between genetic divergence and geographical divergence of genotypes. Therefore, the selection of parents for hybridization should be based on genetic diversity rather than geographical diversity. Earlier workers have noted similar results. Farhad *et al*. (2010) reported six clusters with 45 chilli genotypes, Shrilekha *et al*. (2011) reported seven clusters with 38 genotypes, Lahbib *et al*. (2012) grouped 11 landraces into three clusters and Yatung *et al*. (2014) observed six clusters with 30 chilli genotypes and these findings support the results of this investigation.

Table 4. Clustering of 47 mundu chilli genotypes

Cluster	Number of Genotypes	Name of the Genotypes
Cluster I	10	PKMCA-16, PKMCA-25, PKMCA-12, PKMCA-14, PKMCA-47, PKMCA-11, PKMCA-38, PKMCA-15, PKMCA-47, PKMCA-06
Cluster II	21	PKMCA-20, PKMCA-33, PKMCA-32, PKMCA-21, PKMCA-31, PKMCA-35, PKMCA-22, PKMCA-39, PKMCA-46, PKMCA-26, PKMCA-18, PKMCA-28, PKMCA-44, PKMCA-43, PKMCA-04, PKMCA-38, PKMCA-19, PKMCA-30, PKMCA-23, PKMCA-40, PKMCA-41
Cluster III	13	PKMCA-09, PKMCA-10, PKMCA-02, PKMCA-01, PKMCA-29, PKMCA-36, PKMCA-13, PKMCA-05, PKMCA-17, PKMCA-27, PKMCA-42, PKMCA-03, PKMCA-24
Cluster IV	1	PKMCA-07
Cluster V	1	PKMCA-08
Cluster VI	1	PKMCA-37

Genetic diversity among clusters was represented through intra and inter-cluster distance in **Table 5 and Fig. 2**. The mean intra-cluster D^2 distance values ranged from 0.00 (clusters IV, V and VI) to 291.31 (cluster III) of 6 clusters. Cluster III showed high intra-cluster distance represents the presence of broad genetic diversity among the Mundu chilli genotypes present within this cluster. The maximum inter-cluster distance was noted between IV and VI clusters (1588.27) followed by I and VI clusters (1526.21). The hybrids of diversified genotypes were better yielders according to (Kumar *et al.,* 2010; Janaki *et al.,* 2015; Udachappa *et al.,* 2017; Sindhusha and Monisha, 2020). Hence, crossing between the genotypes from IV (PKMCA-07) and VI clusters (PKMCA-37) could be expected better hybrids and to attain maximum heterosis along with desirable segregants.

The minimum inter-cluster distance was recorded between II and V clusters (192.44) which can be used for backcrossing. The lowest inter-cluster distance represents the closeness of genotypes of one cluster with other clusters, through their genetic constitution.

Several workers reported that (Mishra *et al*., 2004; Suryakumari *et al*., 2010; Yatung *et al.,* 2014; Ajjapplavara *et al.,* 2009) the presence of a huge genetic variation among chilli genotypes in their respective experiments.

Table 5. Average intra and inter-cluster D^2 values of six clusters in Mundu Chilli

	1 Cluster	2 Cluster	3 Cluster	4 Cluster	5 Cluster	6 Cluster
Cluster I	112.89	755.9	317.38	157.07	660.61	1526.21
Cluster II		144.83	291.31	887.78	192.44	463.63
Cluster III			144.94	343.33	310.76	786.68
Cluster IV				0.000	785.03	1588.27
Cluster V					0.000	516.07
Cluster VI						0.000

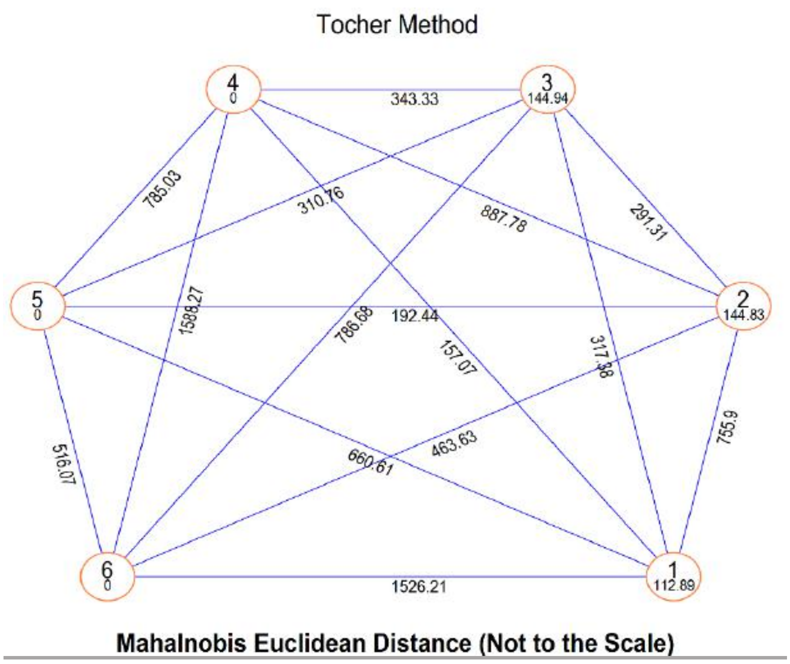

Fig. 2. Inter and intra cluster distance of 47 mundu chilli genotypes in six clusters based on Mahalnobi's D^2 values

Cluster IV earned the highest cluster mean value for days to 50% flowering (61.55) (**Table 6)**. On the other hand, Cluster V produced the highest mean value for plant height (3.95 cm) and the number of primary branches per plant (11.5). Cluster III had the highest mean value for fruit length (2.58 cm). Cluster IV showed the highest mean value for fruit girth (9.66 cm). Cluster V showed the highest mean value for the number of fruits per plant (79.40), The number of seeds per fruit (151.20), 1000 seed weight (6.22 g), capsaicin (0.38 %), and capsanthin ASTA (304.37). Cluster VI showed the highest mean value for ripened fruit yield per plant (486.79 g) and dry fruit yield per plant (g) (93.70), oleoresin (13.5 %) and colour value ASTA (69.23).

The genotypes in cluster V flowered earlier and recorded an average high yield. Genotypes of V, VI and IV clusters, exhibited better performance for yield and quality. Therefore, using the genotypes of these clusters in the breeding programme could be useful for the introgression of desired quality genes into the high yielding varieties.

Mahalanobis D^2 cluster analysis disclosed that wide genetic distance (inter-cluster) between the genotypes of cluster I (PKMCA-38), II (PKMCA-20, PKMCA-32, PKMCA-33) cluster IV (PKMCA-07) and V (PKMCA-08), cluster VII (PKMCA-37) and the crossing between genotypes of these three clusters can be exploited for the development of heterotic hybrids in future breeding programmes.

Table 6. Mean performance of dry fruit yield per plant and its constituent characters in six clusters of mundu chilli

Cluster Number	D50%F	PH	NPBPP	FL	FG	NFPP	RFYPP	DFYPP	NSPF	1000SW	AC	Capsaicin	OC	CV	Capsanthin
Cluster 1	51.78	77.14	7.23	2.47	7.43	37.89	222.37	46.55	121.59	4.94	81.03	0.25	8.86	55.48	215.47
Cluster 2	54.47	79.91	7.66	2.36	7.50	72.47	405.12	83.59	140.18	5.61	81.24	0.31	9.16	58.13	218.97
Cluster 3	54.91	76.55	6.61	2.58	7.77	52.54	311.64	65.90	126.58	4.86	66.34	0.28	8.46	58.44	170.43
Cluster 4	61.55	72.60	7.50	2.34	9.66	35.70	200.90	42.12	130.60	4.23	44.92	0.27	7.13	58.6	105.31
Cluster 5	47.30	87.45	11.5	1.96	9.31	79.40	390.55	80.11	151.20	6.22	77.65	0.38	8.33	65.87	304.37
Cluster 6	48.80	60.40	9.90	1.97	9.54	58.75	486.79	93.70	109.90	4.26	80.28	0.35	13.65	69.23	173.89

D50%F-Days to 50% flowering, PH-plant height (cm), NPBPP-Number of primary branches per plant, FL-Fruit length (cm), FG -Fruit girth (cm), NFPP-Number of fruits per plant, RFYPP- Ripened fruits yield per plant (g), DFYPP- Dry fruit yield per plant (g), NSPF-Number of seeds per fruit, 1000SW-1000 seed weight (g), AC-Ascorbic acid (mg/100g), Capsaicin (%), OC- Oleoresin (%), CV-Colour value (ASTA), Capsanthin (ASTA)

The clusters II, IV, V and VI were found best for one or more characters. Thus, a multiple crossing programme can be advocated to utilize genotypes from these clusters for the development of hybrids in further generations for high yield and better quality in Mundu chilli.

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