Int.J.Curr.Microbiol.App.Sci (2018) *7*(8): 199-215

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 08 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.708.027

Genetic Divergence Studies in Paprika (*Capsicum annuum* L.)

T. Lakshmi Tirupathamma[1], L. Naram Naidu[2], C. Venkata Ramana[2*] and K. Sasikala[3]

[1]Department of Vegetable Science, [3]Department of Agronomy, College of Horticulture, Dr. Y.S.R. Horticultural University, V.R. Gudem-534 101, India
[2]Horticulture Research Station, Dr. Y.S.R. Horticultural University, Lam Farm, Guntur-522 034, India

**Corresponding author*

Keywords

Capsicum annuum L., Paprika, Mahalanobis D^2 statistic, Tocher's method of clustering, Genetic divergence

Article Info

Accepted:
04 July 2018
Available Online:
10 August 2018

A B S T R A C T

Genetic divergence among forty four genotypes of paprika was assessed using Mahalanobis D^2 statistic for twenty characters at Horticultural Research Station, Lam, Guntur, Andhra Pradesh. The analysis of variance revealed significant differences among the genotypes for all the characters studied indicating considerable diversity in the material. Based on Mahalanobis D^2 statistic, the forty four genotypes were grouped into 6 clusters. The maximum contribution towards genetic divergence was by total extractable colour (21.56%) followed by red carotenoids (19.87%), yellow carotenoids (13.95%), ascorbic acid (7.29%). Among the clusters, clusters III was the largest containing 17 genotypes followed by cluster II (15) and cluster I (9), whereas the clusters IV, V and VI were solitary clusters. The highest inter cluster distance was observed between cluster V and VI (1675.44), whereas the lowest was observed between cluster I and II (217.58). Cluster III (275.34) has exhibited highest intra cluster distance and the lowest was observed in clusters IV, V and VI (0.00), respectively. Cluster analysis by Tocher's method revealed wide genetic distance (inter cluster) between the genotypes of cluster V (Byadagikaddi) and the cluster VI (Warangal chapatta double patti) and the crossing between genotypes of these two clusters can be exploited for the development of heterotic hybrids in future breeding programmes.

Introduction

Paprika (*Capsicum annuum* L.), 2n = 24 a member of the *Solanaceae* family has originated from South and Central America. It is an indispensable spice due to its pungency, taste, appealing colour and flavor and has its unique place in the diet as a vegetable cum spice crop. Paprika, a form of chilli is mainly valued for its high colour, low or no pungency and oleoresins. India is the largest producer, consumer and exporter of chilli in the world with an annual production of 1.8 million tonnes from 0.83 million ha (NHB, 2016). Andhra Pradesh leads the country in its production, productivity and export followed by Karnataka, West Bengal, Madhya Pradesh and Orissa.

Capsicinoids and carotenoids are the major chemical constituents of chilli fruits and add commercial value to the crop. The carotenoids contributing to fruit colour act as dietary precursors of vitamin A and play an important role in the regulation of vision, growth and reproduction. Among carotenoids 'capsanthin, capsorubin and capsanthin 5, 6 – epoxide are responsible for the final red colour (Davies *et al.*, 1970). Pungency (heat) is an important quality attribute of hot pepper besides colour. The nature of pungency has been established as a mixture of seven closely related alkyl-vanillyl amides, collectively referred as "Capsaicinoids". Among capsiacinoids, capsaicin (8-methyl-N-vanillyl-6- enamide) and dihydrocapsaicin account for more than 80, determine the pungency (Bosland and Votava, 2000). The degree of pungency varies widely with the genotypes of five cultivated species (Kumar *et al.,* 2006) and range from less than 0.05% in the mildly pungent types to as high as 1.3% in the hottest chillies. The 'capsaicin' is an alkaloid present in the placenta of the fruit, which can directly scavenge various free radicals (Reddy and Lokesh, 1992; Kogure *et al.,* 2002; Bhattacharya *et al.,* 2010) and has diverse prophylactic and therapeutic uses in Allopathic and Ayurvedic medicine (Sumathy and Mathew, 1984). The pharmaceutical application of capsaicinoids is attributed to its antioxidant, anticancer, antiarthritic and analgesic properties (Prasad *et al.,* 2006).

Chilli is a good source of vitamin C (ascorbic acid) used in food and beverage industries (Bosland and Votava, 2000). It has also acquired a great importance because of the presence of 'oleoresin', which permits better distribution of color and flavor in foods. Apart from developing traditional varieties through conventional breeding, exploitation of heterosis for yield and yield attributing characters through hybridization is also important in crop improvement. Screening of available germplasm helps in studying the variability and diversity and identification of superior parents for use in hybridization. A wide variability in chilli fruit morphology, pungency, bearing habit and crop duration is found throughout India (Asati and Yadav, 2004). Genetic divergence existing in the population helps in the selection of suitable parents for utilization in any crop breeding programme leading to reduction in the number of crosses (Guerra *et al.,* 1999). The information on the nature and degree of genetic divergence is essential for the breeder to choose the right type of parents for hybridization in heterosis breeding (Patel *et al.,* 1989). Moreover, evaluation of genetic diversity is important to know the source of genes for a particular trait within the available germplasm (Tomooka, 1991). In order to benefit transgressive segregation, the knowledge of genetic distance between parents is necessary (Khodadabi *et al.,* 2011). Hybrids produced from distantly related parents are expected to exhibit higher heterosis and minimize the inherent field genetic vulnerability (Moll *et al.,* 1962; Ramanujam *et al.,* 1974) than those from closely related parents. The knowledge of characters influencing divergence is important for a breeder to plan a successful breeding programme. Thus, the present study was undertaken to assess the genetic diversity in 44 genotypes of paprika (*Capsicum annuum* L.) and to identify suitable donors in respect of yield and quality for a successful breeding programme in this crop. Mahalanobis's D2 statistic of multivariate analysis is recognized as a powerful tool in quantifying the degree of genetic divergence among the populations and has been utilized in this study.

Materials and Methods

The experiment was carried out with 44 genotypes of paprika (Table 1) at Horticultural Research Station, Lam, Guntur, Andhra

Pradesh, India. The site of the experiment at Lam is situated on 16.280 North latitude and 80.440 East longitude at an altitude of 31.5 m above mean sea level which falls under humid tropical climate and the soils of the experimental site are rich black cotton soils.

The genotypes studied in a randomized block design were replicated twice. The nursery was raised during first week of August and the seedlings were transplanted at a spacing of 75 cm × 30 cm in a row 4m length during first fortnight of September. Each row consisted of 12 plants, of which five competitive plants were selected at random for recording the observations. The crop was raised as per the recommended package of practices. The observations were recorded on plant height (cm), plant spread (cm), number of primary branches per plant, days to 50 % flowering, days to maturity, number of fruits per plant, fruit length (cm), fruit diameter (cm), fruit pedicel length (cm), number of seeds per fruit, weight of seeds per fruit, 1000 seed weight and dry fruit yield per plant(g), ascorbic acid (mg 100g-1), oleoresin content (%), capsaicin content (SHU), total extractable colour (ASTA units), red carotenoids (%), yellow carotenoids(%) and total carotenoids (%). The red ripe fruits were sun dried and ground in an electronic grinder and passed through a 0.5 mm sieve and the dry chilli powder was used to measure biochemical constituents except Vitamin 'C' content, for which mature green fruits were used. The following procedures were used for estimating the biochemical constituents.

Ascorbic acid (mg/100g)

Ascorbic acid content of mature green fruits was estimated by volumetric method (Sadasivam and Balasubramanian, 1987). Dye solution was prepared by dissolving 42 mg of sodium bicarbonate in distilled water taken into 200 ml volumetric flask, to which 52 mg of 2-6 dichlorophenol indophenol was added and the volume was made up to 200 ml with distilled water. Stock solution was prepared by dissolving 100 mg ascorbic acid in 100 ml of 4% oxalic acid solution and 10 ml of this stock solution was diluted to 100 ml with 4% oxalic acid to get the working standard of 100 mg per ml.

5 ml of the working standard solution was pipetted into a 100 ml of conical flask to which 10 ml of 4% oxalic acid was added. The contents were titrated against the dye (V_1ml) to get a pink end point. The chilli sample (5 g) was extracted in 4% oxalic acid and the volume was made up to 100 ml and the contents were centrifuged. 5 ml of this supernatant was pipetted out, to which 10 ml of 4 per cent oxalic acid was added and titrated against the dye (V_2 ml). The ascorbic acid content was calculated using the formula given below

Ascorbic acid (mg/100 g) = (0.5 mg ÷ V_1) × (V_2 ÷ 5ml) × (100ml ÷ Wt. of the sample) × 100

Oleoresin content (%)

The oleoresin content was estimated as per the procedure given by Ranganna (1986). Finely mashed 25g chilli powder was transferred to a glass column, which was plugged by cotton plug on its narrow end. A thin layer of cotton was placed over chilli powder in the glass column and 25 ml of acetone was added. After all the acetone was decanted, 25 ml acetone was added each time till a total of 250 ml acetone was added to the contents. After decantation, the resulting red colored liquid in beaker contains all the principle constituents of chilli. The collected filtrate was transferred to a 250 ml volumetric flask and the volume was made up with acetone. The chilli extract was transferred to a 250 ml beaker of known weight (W_I g) and was kept in water bath at

50- 60oC for 15-30 minutes so that acetone gets evaporated. Then, weight of the beaker along with contents was recorded as W_2 g. The weight of the oleoresin content in the 25 g chilli powder was calculated and expressed in percentage using the given formula.

Oleoresin content (%) = ((W_2–$W_{1)}$ ÷ Weight of sample) × 100

Capsaicin content (SHU)

The capsaicin content of fruits was estimated by colorimetric method described by Bajaj *et al.,* (1980). 0.5g dry chilli powder was weighed into glass-stoppered test tube; 10ml dry acetone (add 25g anhydrous sodium sulphate to 500ml of acetone at least one day before use) was added into the test tube and kept overnight for extraction. Next day samples were centrifuged at 10000 rpm for 10min to get clear supernatant. 1ml of the supernatant was taken into a test tube and evaporated to dryness in a hot water bath. Then, the residue was dissolved in 5ml of 0.4% of NaOH solution and 3ml of 3% phosphomolybdic acid was added. The contents were shaken and left undisturbed for 1hr.

After 1hr, the solution was quickly filtered into centrifuge tubes to remove any floating debris, and then centrifuged at 5000 rpm for 15min. The clear blue coloured solution was directly transferred into the cuvette and absorbance was read at 650nm along with a reagent blank. A standard graph was prepared using 0-200µg pure capsaicin. Simultaneously 0.2, 0.4, 0.6, 0.8 and 1ml of working standard solution (stock standard capsaicin solution was prepared by dissolving 50mg capsaicin in 50ml of 0.4% NaOH solution (1000µg/ ml) and working standard solution prepared by diluting the 10ml of the stock standard to 50ml with 0.4% NaOH solution (200µg/ ml)) was taken into new test tubes and proceeded as mentioned above. Per cent capsaicin calculated using the formula mentioned below

Capsaicin content (%) = (µg capsaicin × 100 × 100) ÷ (1000 × 1000 × 1 × 0.5)

Whereas, 1 % = 1,60,000 SHU units

Total extractable colour (ASTA units)

Total extractable colour of fruits (ASTA-American Spice Trade Association units) was estimated as per the procedure given by Rosebrook *et al.,* (1968). 100mg of sieved fine chilli powder was weighed into a volumetric flask. Acetone was added and flask was closed tightly with stopper, then contents were kept for 16h at room temperature in dark and shaken intermittently. Solution was filtered using Whatman filter paper and final volume was made up to 100ml. Absorbance of final extract was read at 460nm using acetone as blank. ASTA color units were calculated as per the formula given below,

ASTA = (Absorbance at 460 nm × 16.4) ÷ (Weight of sample in g)

Determination of yellow and red fractions in chilli powder

Total red (CR; capsanthin, capsorubin and capsanthin-5, 6- epoxide) and yellow (CY; zeaxanthin, violaxanthin, antheraxanthin, β-cryptoxanthin, β-carotene and cucurbita xanthin A) carotenoid isochromic fractions were estimated following protocol of spectrophotometric method (Hornero-Mendez and Minguez-Mosquera, 2001). Dried chilli fruits were ground into a fine powder and 100mg of dried powder was extracted four times with acetone until the complete exhaustion of the color. The extract was filtered and transferred to 50ml volumetric flask and the volume was made up with acetone. The samples absorbance was read at

two wavelengths *i.e.,* 472 and 508nm using acetone as blank. The red and yellow fractions were calculated using the following formulae.

CR (µg/ml) = (A508×2144.0) — (A472× 403.0) ÷ 270.9

CY (µg/ml) = (A472× 1724.3) — (A508 × 2450.1) ÷ 270.9

Total colour = $C^R + C^Y$

The analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1985). The character contribution towards genetic divergence was computed using the method given by Singh and Chaudhary (1977). Percentage contribution towards genetic divergence was calculated using the following formula

Percentage contribution of the character = (N × 100) ÷ M Where, N = Number of genotype combinations where the character was ranked first.

M = All possible combinations of number of genotypes considered.

The genetic divergence was worked out among the genotypes using Mahalanobis D^2 statistics (Mahalanobis, 1936) and the D^2 values were calculated as,

$$D^2_{ij} = \sum_{t=1} (Y_i^t - Y_j^t)^2$$

Where,

Y_i^t is uncorrelated mean value of i^{th} genotype for character 't'

Y_j^t is uncorrelated mean value of j^{th} genotype for character 't'

D^2_{ij} is D^2 between i^{th} and j^{th} genotypes.

The genotypes were grouped into different clusters by employing Tocher's method as outlined by Rao (1952). For grouping of genotypes, D^2 values of all combinations of each genotype were arranged in ascending order of magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with, two populations having the closest distance from each other were considered, to which the third population having the smallest D^2 value from the first two populations was added.

Similarly, the next nearest fourth population was considered and this procedure was continued. At certain stage when it was felt that after adding a particular population there was an abrupt increase in the average D^2, that population was not considered for including in that cluster.

The genotypes of the first cluster were then eliminated and the rest were treated in a similar way. This procedure was continued till all the genotypes were included into one or other cluster.

The average intra and inter cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

Square of intra- cluster distance = ΣDi^2 / n

Square of inter- cluster distance = ΣDi^2 / ninj Where,

ΣDi^2 = Sum of distance between all possible combinations.

n = Number of all possible combinations

ni = Number of entries in clusteri

nj = Number of entries in clusterj

Results and Discussion

The analysis of variance (ANOVA) revealed significant differences among 44 genotypes for quantitative and qualitative traits indicating the existence of variability among genotypes for characters studied (Table 2).

These findings are in accordance with the results of many earlier works (Farhad *et al.,* 2010; Kumar *et al.,* 2010; Shrilekha *et al.,* 2011; Tasso *et al.,* 2014 Janaki *et al.,* 2016).

The per cent contribution towards genetic divergence by all the 20 contributing characters is presented in Table 3 and Figure 1. The maximum contribution towards genetic divergence was by total extractable colour (21.56%) followed by red carotenoids (19.87%), yellow carotenoids (13.95%), ascorbic acid (7.29%) and dry fruit yield per plant (7.29%), oleoresin content (6.98%), capsaicin content (6.87%), weight of seeds per fruit (5.92%), 1000 seed weight (4.33%), fruit diameter (2.96%), number of fruits per plant and fruit length (1.06%), number of seeds per fruit (0.42%), fruit pedicel length (0.21%), days to 50 per cent flowering and total carotenoids (0.11%), plant height, plant spread, number of primary branches per plant and days to maturity (0.01%). Hence, selection for divergent parents based on these characters will be useful for heterosis breeding in paprika.

The 44 genotypes were grouped into six clusters using the Tocher's method (Table 4 and Figure 2) with the criterion that the intra-cluster average D^2 values should be less than the inter-cluster D^2 values. The distribution of 44 genotypes into 6 clusters was at random with maximum number of genotypes were grouped in cluster III (17 genotypes) from different locations followed by cluster II with 15 genotypes as the second largest followed by cluster I with 9 genotypes. Whereas, clusters IV, V and VI were solitary in nature *i.e.,* one genotype in each cluster (LCA 480, Byadagi Kaddi, Warangal chapata double patti respectively). The formation of distinct solitary clusters may be due to the fact that geographic barriers preventing gene flow and intensive natural and human selection for diverse and adoptable gene complexes must be responsible for this genetic diversity.

The pattern of grouping of genotypes into different clusters was random and indicated that there is no parallelism between genetic divergence and geographical divergence of genotypes.

Therefore, selection of genotypes for hybridization should be based on genetic diversity rather than geographical diversity. Vani *et al.,* (2007) reported fourteen clusters with 55 genotypes, Dutonde *et al.,* (2008) observed seven clusters with 40 accessions, 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, Tasso*et al.,* (2014) observed six clusters with 30 chilli genotypes, Hasan *et al.,(*2014) observed seven clusters with 54 chilli genotypes and Rana *et al.,* (2015) reported three clusters with 24 genotypes and Razzaq *et al.,* (2016) observed five clusters with 25 chilli genotypes and Janaki *et al.,* (2016) reported eight clusters with 63 genotypes and these findings support the results of this investigation.

The intra and inter- cluster distance represent the index of genetic diversity among clusters (Table 5 and Figure 3). Of the 6 clusters formed, the mean intra-cluster D2 distance values ranged from a minimum of 0.00 (Clusters IV, V and VI) to a maximum of 275.34 (Cluster III). The intra cluster distance in other clusters *viz.,* cluster II (179.33) and cluster I (102.55) was in between this range.

Table.1 List of paprika genotypes used in the experiment and their source

Treatment	Accession Number	Treatment	Accession Number	Source
T_1	LCA 445	T_{23}	LCA 465	HRS, Lam farm, Guntur
T_2	LCA 447	T_{24}	LCA 475	HRS, Lam farm, Guntur
T_3	LCA 439	T_{25}	LCA 488	HRS, Lam farm, Guntur
T_4	LCA 442	T_{26}	LCA 499	HRS, Lam farm, Guntur
T_5	LCA 430	T_{27}	LCA 506	HRS, Lam farm, Guntur
T_6	LCA 457	T_{28}	LCA 503	HRS, Lam farm, Guntur
T_7	LCA 443	T_{29}	LCA 490	HRS, Lam farm, Guntur
T_8	LCA 437	T_{30}	LCA 501	HRS, Lam farm, Guntur
T_9	LCA 453	T_{31}	LCA 504	HRS, Lam farm, Guntur
T_{10}	LCA 450	T_{32}	LCA 510	HRS, Lam farm, Guntur
T_{11}	LCA 441	T_{33}	LCA 510	HRS, Lam farm, Guntur
T_{12}	LCA 425	T_{34}	LCA 511	HRS, Lam farm, Guntur
T_{13}	LCA 440	T_{35}	LCA 512	HRS, Lam farm, Guntur
T_{14}	LCA 446	T_{36}	LCA 513	HRS, Lam farm, Guntur
T_{15}	LCA 470	T_{37}	Warangal chappatta single patti	HRS, Lam farm, Guntur
T_{16}	LCA 436	T_{38}	Warangal chappatta double patti	HRS, Lam farm, Guntur
T_{17}	LCA 466	T_{39}	Byadagikaddi	HRS, Lam farm, Guntur
T_{18}	LCA 472	T_{40}	Byadagidabbi	HRS, Lam farm, Guntur
T_{19}	LCA 476	T_{41}	Kt-1	HRS, Lam farm, Guntur
T_{20}	LCA 480	T_{42}	Jangareddygudem local	HRS, Lam farm, Guntur
T_{21}	LCA 482	T_{43}	LCA 436	HRS, Lam farm, Guntur
T_{22}	LCA 498	T_{44}	LCA 424	HRS, Lam farm, Guntur

Table.2 Analysis of variance for various characters in paprika (*Capsicum annuum* L.)

S. No.	Character	Mean sum of squares		
		Replications	Genotypes	Error
1	Plant height (cm)	0.16	257.11**	122.38
2	Plant spread (cm)	12.45	698.05**	187.34
3	Number of primary branches per plant	0.02	0.17**	0.04
4	Days to 50 per cent flowering	0.40	52.46**	12.59
5	Days to maturity	405.92	840.97**	121.33
6	Number of fruits per plant	78.09	2217.27**	97.27
7	Fruit length (cm)	2.10	10.32**	0.78
8	Fruit diameter (cm)	0.13	2.92**	0.11
9	Fruit pedicel length (cm)	0.20	0.68**	0.13
10	Number of seeds per fruit	192.63	1204.12**	85.28
11	Weight of seeds per fruit (g)	0.001	0.09**	0.004
12	1000 seed weight (g)	1.73	16.86**	0.73
13.	Ascorbic acid (mg/100g)	145.89	4674.56**	151.61
14	Oleoresin content (%)	0.53	16.66**	0.66
15	Capsaicin content (SHU)	1784670.75	36198080.00**	157919.25
16	Total extractable colour (ASTA units)	22.99	2376.67**	115.58
17	Red carotenoids (%)	0.0005	0.02**	0.0007
18	Yellow carotenoids (%)	0.00004	0.015**	0.0009
19	Total carotenoids (%)	0.0003	0.03**	0.0019
20	Dry fruit yield per plant (g)	0.10	2316.47**	178.91

*: Significant at 5 per cent level; **: Significant at 1 per cent level

Table.3 Relative contribution of different characters towards genetic divergence in paprika (*Capsicum annuum* L.)

S. No.	Source	Times ranked 1st	Contribution %
1	Plant height (cm)	0	0.01
2	Plant spread (cm)	0	0.01
3	Number of primary branches per plant	0	0.01
4	Days to 50 per cent flowering	1	0.11
5	Days to maturity	0	0.01
6	Number of fruits per plant	10	1.06
7	Fruit length (cm)	10	1.06
8	Fruit diameter (cm)	28	2.96
9	Fruit pedicel length (cm)	2	0.21
10	Number of seeds per fruit	4	0.42
11	Weight of seeds per fruit (g)	56	5.92
12	1000 seed weight (g)	41	4.33
13	Ascorbic acid (mg /100g)	69	7.29
14	Oleoresin content (%)	66	6.98
15	Capsaicin content (SHU)	65	6.87
16	Total extractable colour (ASTA units)	204	21.56
17	Red carotenoids (%)	188	19.87
18	Yellow carotenoids (%)	132	13.95
19	Total carotenoids (%)	1	0.11
20	Dry fruit yield per plant (g)	69	7.29

Table.4 Clustering of 44 paprika (*Capsicum annuum* L.) genotypes by Tocher's method

Cluster	No. of genotypes	Name of genotypes
I	9	LCA 445, LCA 472, LCA 442, LCA 470, LCA 503, LCA 430, LCA 499, LCA 457, LCA 425.
II	15	LCA 488, LCA 501, LCA 447, LCA 504, LCA 506, LCA 441, LCA 439, LCA 437, LCA 475, LCA 465, LCA 466, LCA513, LCA 482, Byadagidabbi, LCA 450
III	17	LCA 511, Warngalchappatta single patti, LCA 512, LCA 498, LCA 440, LCA 510, LCA 510, LCA 476, Kt-1, LCA 436, LCA 446, LCA 490, LCA 453, LCA 443, Jangareddygudem local, LCA 424, LCA 436
IV	1	LCA 480
V	1	Byadagikaddi
VI	1	Warangal chappatta double patti

Table.5 Average intra (bold) and inter cluster D^2 values of six clusters in paprika (*Capsicum annuum* L.)

Cluster	1 Cluster	2 Cluster	3 Cluster	4 Cluster	5 Cluster	6 Cluster
I	**102.55**	217.58	281.96	400.09	338.74	1034.49
II		**179.33**	320.78	246.35	275.43	1124.39
III			**275.34**	429.56	481.32	886.88
IV				**0.00**	359.58	1414.04
V					**0.00**	1675.44
VI						**0.00**

Table.6 Mean performance of yield per plant and its component characters in various clusters of paprika (Tocher's method)

Cluster No.	PH	PS	NPBP	DFF	DM	NFP	FL	FD	FPL	NSP	WSP	1000 SW	AA	OC	CC	TEC	RC	YC	TC	DFYP
I	89.10	132.77	3.64	61.33	135.77	165.21	13.17	4.66	**4.05**	71.62	0.49	3.80	**55.74**	**6.95**	6959.77	134.25	**0.22**	0.13	0.36	**150.88**
II	85.80	124.57	3.44	**61.73**	137.56	168.43	12.06	4.20	3.55	57.81	0.38	5.65	94.80	8.21	8544.80	99.05	0.14	**0.26**	0.41	130.53
III	**92.17**	130.38	3.62	58.14	130.20	141.38	10.42	4.80	3.34	76.48	0.55	6.59	103.11	9.72	**11810.79**	105.71	0.22	0.17	0.40	118.79
IV	**83.10**	132.40	**4.00**	61.00	**138.00**	**197.10**	11.55	4.85	3.90	53.90	0.32	**2.59**	167.31	11.50	**4552.00**	**61.81**	**0.06**	**0.13**	**0.19**	144.00
V	83.30	**141.10**	**4.00**	**52.50**	**97.50**	**118.70**	**16.80**	**2.55**	3.70	**45.40**	**0.25**	8.40	**181.40**	11.35	6052.50	115.00	0.16	**0.26**	**0.42**	**82.00**
VI	91.80	**117.80**	**3.40**	59.00	112.00	120.50	**8.30**	**9.70**	**2.40**	**154.00**	**1.35**	**18.10**	72.93	**14.55**	5463.00	**147.35**	0.16	0.25	0.41	95.00

Bold values indicate maximum and minimum mean performance

Note: PH – Plant height (cm), PS-Plant spread (cm), NPBP – Number of primary branches per plant, DFF – Days to 50 per cent flowering, DM- Days to maturity, NFP – Number of fruits per plant, FL – Fruit length (cm), FD – Fruit diameter (cm), FPL- Fruit pedicel length(cm), NSF – Number of seeds per fruit, WSF- Weight of seeds per fruit (g), 1000 SW- 1000 Seed weight (g), AA-Ascorbic acid(mg/100mg), OC - Oleoresin content (%), CC - Capsaicin content (SHU),TEC- Total extractable colour (ASTA units), RC- Red carotenoids (%), YC- Yellow carotenoids (%), TC- Total carotenoids (%), DFYP – Dry fruit yield per p lant (g).

Fig.1 Relative contribution of different characters towards genetic divergence in paprika

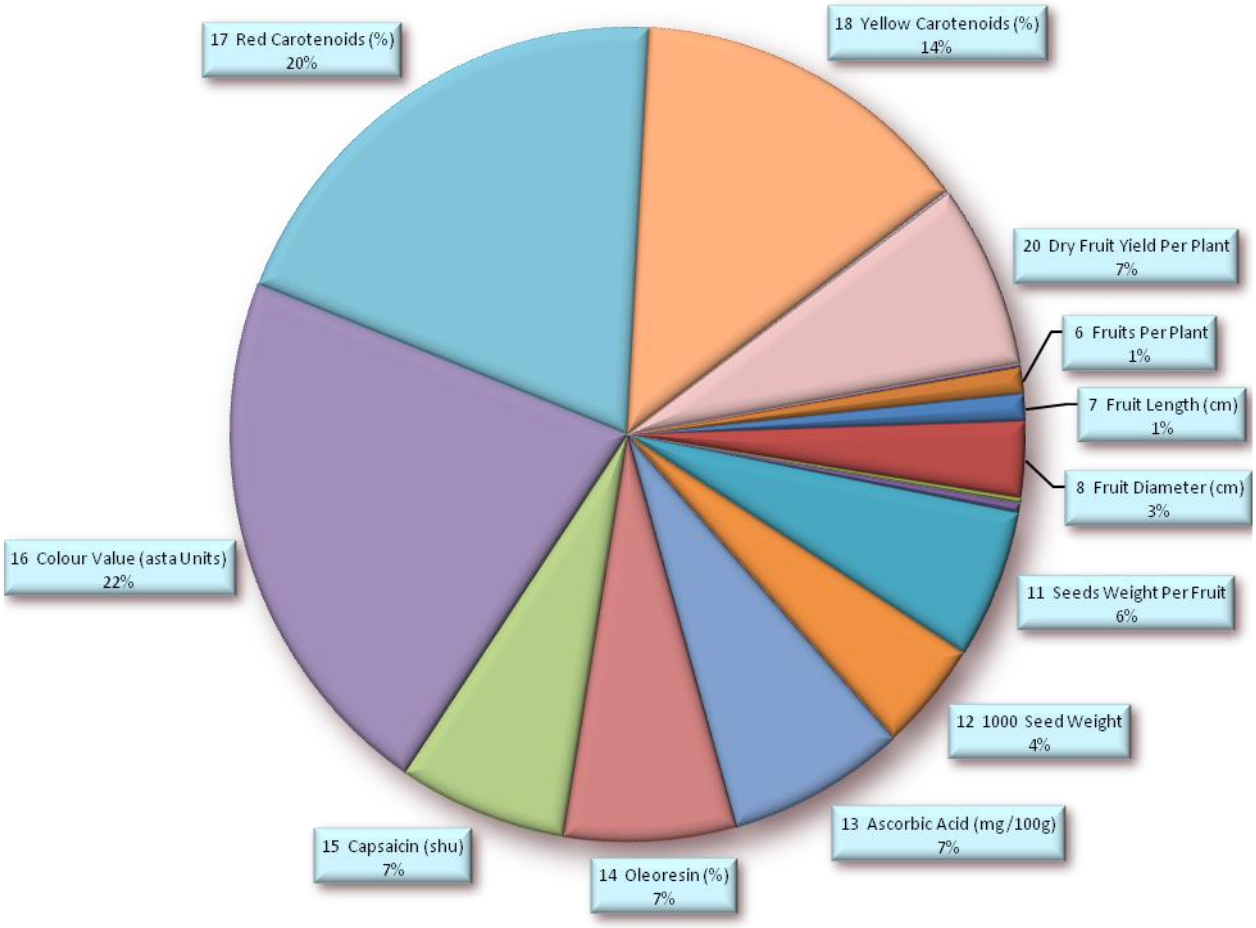


Fig.2 Dendrogram showing clustering pattern of 44 paprika (*Capsicum annuum* L.) genotypes (Tocher's method)

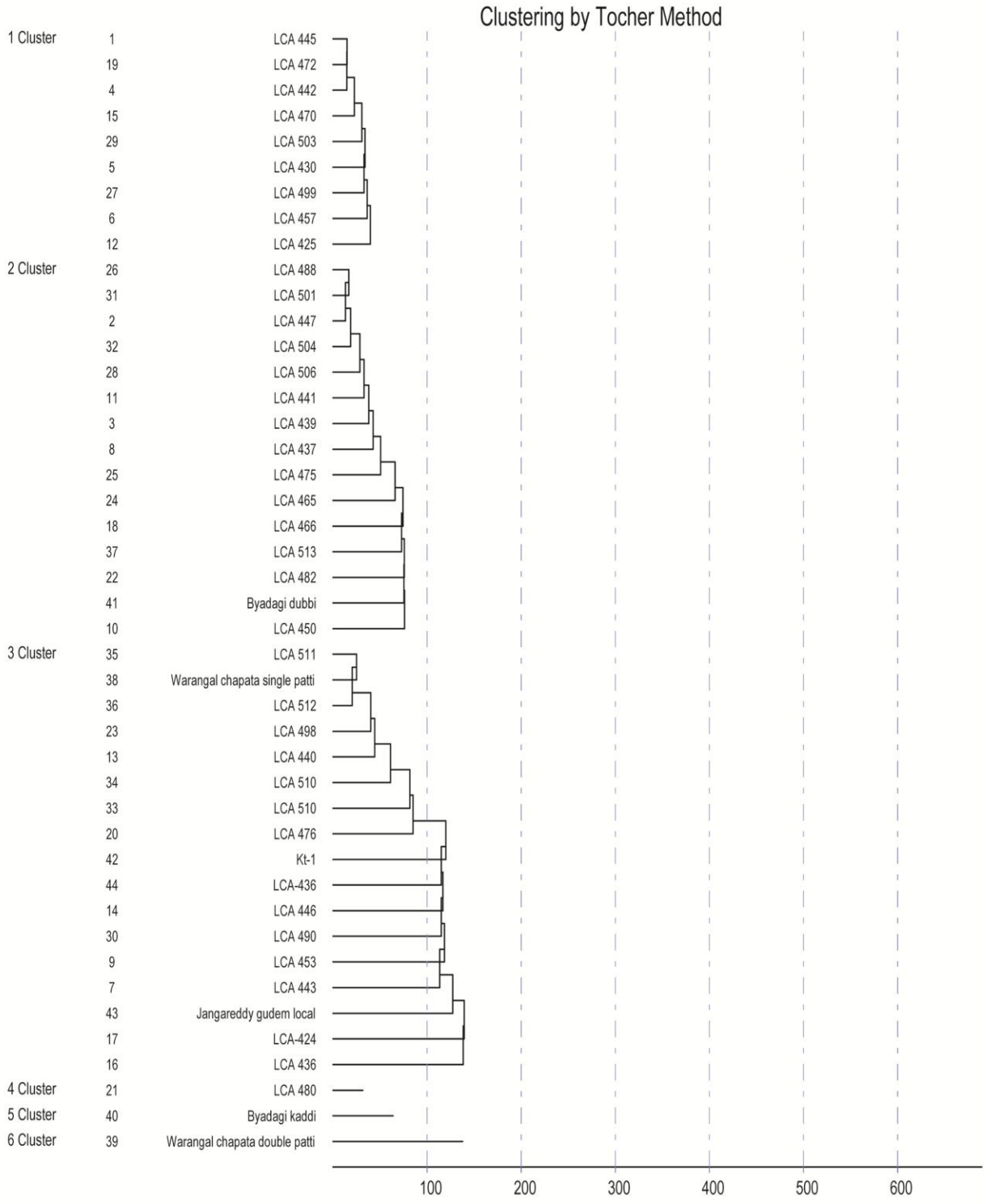
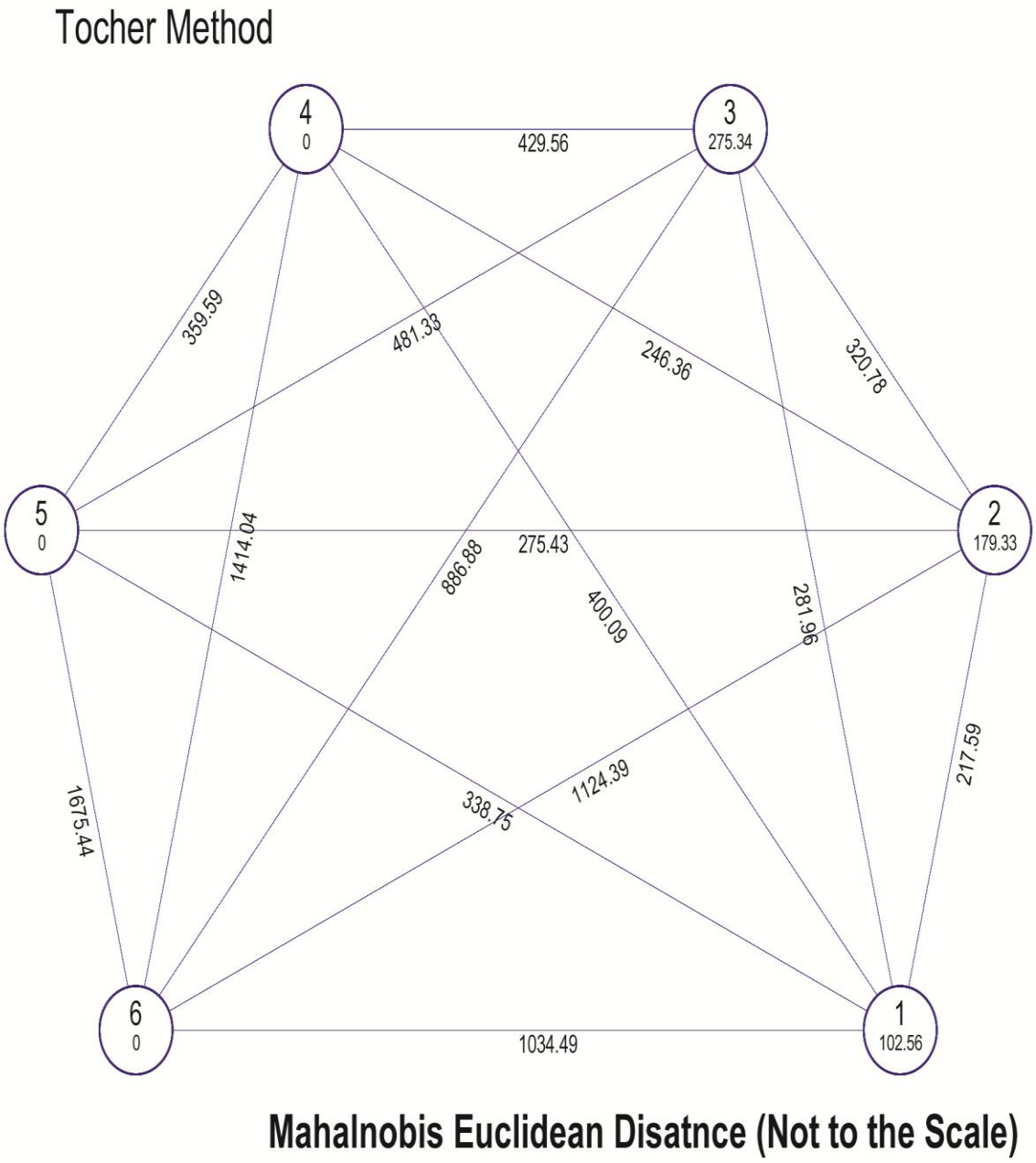


Fig.3 Average intra and inter cluster D^2 values of six clusters in paprika (*Capsicum annuum* L.)



The high intra-cluster distance in cluster III indicates the presence of genetic diversity among the genotypes present of the same cluster. The maximum inter-cluster distance was observed between cluster V and VI (1675.44) followed by cluster IV and VI (1414.04) and cluster II and VI (1124.39) and cluster I and VI (1034.49) and cluster III and VI (886.88). The hybrids of distant genotypes are reported to yield better (Kumar *et al.*, 2010) and thus crosses between the genotypes from cluster V and VI can be used in chilli breeding to achieve maximum heterosis and to obtain heterotic hybrids and desirable

segregants. The minimum inter-cluster distance was observed between genotypes of cluster I and II (217.58) which can be used for backcrossing programmes. The genotypes of cluster II and IV (246.35), cluster II and V (275.43) and cluster I and III (281.96) also have recorded minimum inter-cluster distance. The lowest inter-cluster distance between these cluster pairs suggested close proximity of genotypes of one cluster with those of the other cluster in respect of their genetic constitution. Several earlier reports (Mishra *et al.,* 2004; Ajjapplavara, 2009; Kumar *et al.,* 2010; Suryakumari *et al.,* 2010; Pandit *et al.,* 2010, Tasso *et al.,* 2014, Janaki *et al.,* 2016, Rana *et al.,* 2015; Razzaq *et al.,* 2016) also indicate the presence of a high genetic divergence among chilli genotypes in their respective experiments. The genotypes grouped into the same cluster presumably diverge very little from one another and crossing of genotypes belonging to the same cluster is not expected to yield desirable segregants. Consequently, a crossing programme should be conducted with putative parents. Thus, crosses between the members of clusters separated by inter-cluster distances are likely to be beneficial for further improvement. D2 cluster analysis revealed wide genetic distance (inter cluster) between the genotypes of cluster V (Byadagikaddi) and the cluster VI (Warangal chappatta double patti. The crossing between genotypes of cluster V & VI can be exploited for the development of heterotic hybrids in future breeding programmes.

Cluster I earned highest cluster mean value for fruit pedicel length (4.05), red caroteniods (0.22) and dry fruit yield per plant (150.88) and lowest cluster mean value for ascorbic acid (55.74) and oleoresin content (6.95) (Table 6). On the other hand, Cluster II produced highest mean value for days to 50 per cent flowering (61.73) and yellow caroteniods (0.26). Cluster III had the highest mean value for plant height (92.17) and capsaicin content (11810.79) and cluster IV showed highest mean value for no. of primary branches per plant (4.00), days to maturity (138.00), number of fruits per plant (197.10) and lowest mean value for plant height (83.10), 1000 seed weight (2.59), capsaicin content (4552.00), total extractable colour (61.81), red (0.06), yellow (0.13) and total carotenoids (0.19) and cluster V recorded highest mean value for plant spread (141.10), no. of primary branches per plant (4.00), fruit length (16.80), ascorbic acid (181.40) and yellow (0.26) and total (0.42) carotenoids and had lowest mean value for days to 50 per cent flowering (52.50), days to maturity (97.50), number of fruits per plant (118.70), fruit diameter (2.55), number of seeds per fruit (45.40), weight of seeds per fruit (0.25) and yield per plant (82.00) and cluster VI had highest mean value for fruit diameter (9.70), number of seeds per fruit (154.00), weight of seeds per fruit (1.35), 1000 seed weight (18.10), oleoresin content (14.55), total extractable colour (147.35) and had lowest mean value for plant spread (117.80), no. of primary branches per plant (3.40), fruit length (8.30) and fruit pedicel length (2.40). The genotypes in cluster I were recorded higher yield. Genotypes of clusters V and VI showed better performance for quality traits. These clusters can be used in breeding programme for introgression of their desired quality genes into the high yielding varieties.

D2 cluster analysis revealed wide genetic distance (inter cluster) between the genotypes of cluster V (Byadagikaddi) and the cluster VI (Warangal chappatta double patti). The crossing between genotypes of cluster V and VI can be exploited for the development of heterotic hybrids in future breeding programmes. The clusters V, VI, IV, I and II were found superior for one or more characters. Therefore, a multiple crossing programme can be proposed involving

genotypes from these clusters for the development of superior segregants in advanced generations with high yield potential combined with better quality in paprika

Acknowledgements

I extend my deep sense of reverence and gratitude to Associate Dean, College of Horticultural and Research Institute, Venkataramannagudem, Dr. Y.S.R.H.U for allotting me to HRS, Lam to take up my research work. I am highly thankful to Dr. Y.S.R. Horticultural University, Venkataramannagudem for providing financial assistance in the form of stipend to complete this endeavour

References

Ajjapplavara, P.S. 2009.Genetic diversity in chilli (*Capsicum annuum* L.). *The Asian Journal of Horticulture.* 4(1): 29-31.

Asati, B.S and Yadav, D.S. 2004. Diversity of horticultural crops in north eastern region. *ENVIS Bulletin: Himalayan Ecology.* 12 (2): 1-11.

Bajaj, K.L., Kaur, G and Sooch, B. 1980 Varietal variation in some important chemical constituents in chilli (*Capsicum annuum* L.) fruits. *Vegetable Science.*7: 48-54.

Bhattacharya, A., Chattopadhyay, A., Mazumdar, D., Chakravarty, A and Pal, S. 2010 Antioxidant constituents and enzyme activities in chilli peppers. *International Journal of Vegetable Science.* 16: 201- 211.

Bosland, P.W and Votava, E.J. 2000. *Peppers: Vegetable and spice capsicums*. CABI Publishing, CAB International, Walingfort, U.K.

Davies, B.H., Matthews, S and Kirk, J.T.O. 1970. The nature and biosynthesis of the carotenoids of different colour varieties of *Capsicum annuum* L. *Phytochemistry*.9: 797-805.

Dutonde, S.N., Bhalekar, M.N., Patil, B.T., Kshirsagar, D.B and Dhumal, S.S. 2008. Genetic diversity in chilli (*Capsicum annuum* L.). *Agricultural Science Digest.*28 (1):45-47.

Farhad, M., Hasanuzzaman, M., Biswas, B.K., Arifuzzaman, M. and Islam, M.M. (2010). Genetic divergence in chilli (*Capsicum annum* L.). *Bangladesh Research Publications Journal.* 3(3): 1045- 1051.

Guerra, E.P., Destro, D., Miranda, L.A and Montalvan, R. 1999. Parent selection for intercrossing in food type soybean through multivariate genetic divergence. *The Acta Scientiarum.* 21(3): 429- 437.

Hasan, M.J, Kulsum, M.U, Ullah, M.Z, Manzur Hossain, M and Eleyash Mahmud, M. 2014. Genetic diversity of some chili (*capsicum annuum* L.) genotypes. *International Journal of Agricultural Research, Innovation and Technology*. 4 (1): 32-35.

Hornero-Mendez, D and Minguez-Mosquera, I.M. 2001. Rapid spectrophotometric determination of red and yellow isochromic carotenoid fractions in paprika and red pepper oleoresins. *Journal of Agricultural and Food Chemistry.* 49: 3584-3588.

Janaki, M, Naram, N.L, Venkata, R.C and Paratpara, R. M. 2016. Genetic divergence among chilli (*capsicum annuum* L.). Genotypes based on quantitative and qualitative traits. *International Journal of Science and Nature*.7 (1): 181-189.

Khodadabi, M., Fotokian, M.H and Miransari, M. 2011. Genetic diversity of wheat genotypes based on cluster and principal component analysis for breeding strategies. *Australian Journal of Crop Science.* 5(1): 17-24.

Kogure, K., Goto, S., Nishimura, M., Yasumoto, M., Abe, K and Ohiwa, L. 2002. Mechanism of potent antiperoxidative effect of capsaicin. *Biochimicaet BiophysicaActa.* 1573 (1): 84-92.

Kumar, D.B.M., Anand, K and Mallikarjunaiah, H. 2010.Genetic divergence in chilli accessions. *Electronic Journal of Plant Breeding.* 1(5): 1363-1366.

Kumar, S., Kumar, R., and Singh, J. 2006. Cayenne/American pepper (*Capsicum species*). In: Peter KV (ed), Handbook of herbs and spices. Vol3.WoodheadPubl, Cambridge, UK, pp299-312.

Lahbib, K., Bnejdi, F and Mohamed, El. G. 2012. Genetic diversity evaluation of pepper (*Capsicum annuum* L.) in Tunisia based on morphologic characters. *African Journal of Agricultural Research.* 7: 3413- 3417.

Mahalanobis, P.C. 1936. On the generalized distance in statistics. *Proceedings of National Academic Science.* 2. 55-79.

Mishra, A.C., Singh, R.V and Ram, H.H. 2004. Studies on genetic divergence in capsicum (*Capsicum annuum* L.) in Uttaranchal. *Capsicum and Eggplant Newsletter.* 23: 45-48.

Moll, R.H., Salhwana, W.S and Robinson, H.F. 1962. Heterosis and genetic diversity in variety crosses in maize. *Crop Science.* 2: 197-198.

National Horticulture Board. 2013. *Indian Horticulture Database*, Ministry of Agriculture, Government of India, Gurgaon, New Delhi.

Pandit, M.K., Muthukumar, P and Mukhopadhyay, T.P. 2010. Study of genetic divergence through multivariate analysis in chilli (*Capsicum annuum L.*) germplasms. *Journal of Interacademicia.* 14 (3): 298-301

Patel, M.Z., Reddi, M.V., Rana, B.S and Reddy, B.J. 1989.Genetic divergence in safflower (*Carthamus tinctorius* L.). *The Indian Journal of Genetics and Plant Breeding.* 49(1): 113-118.

Prasad, N.B.C, Gururaj, H.B, Kumar, V, Giridhar, P, Parimalan, R, Sharma, A, Ravishankar, G.A. 2006. Influence of 8-methyl nonenoicacid on capsaicin biosyn- thesis *in vivo* and *in vitro* cell cultures of *Capsicum* spp. *Journal of Agricultural and Food Chemistry.* 54: 1854-1859.

Ramanujam, S., Tiwary, A.S and Mehra, R.B. 1974.Genetic divergence and hybrid performance in mungbean. *Theoretical and Applied Genetics.* 44(5): 211-214.

Rana, M., Sharma, R., Sharma, P., Bhardwaj, S.V., Sandeep Kumar., Navjot Singh, B.. Sharma, M and Rajesh, D. 2015. Studies on genetic variability and divergence in Capsicum for fruit yield and quality traits in North- Western Himalayas. *Ecology Environment and Conservation.* 21: 415-421

Ranganna, S. 1986.*Handbook of analysis and quality control for fruits and vegetable products*. 2nd edition. p: 259. Tata McGraw Hill Publ Com, New Delhi, India.

Rao, C.R. 1952. *Advanced Statistical Methods in Biometrical Research*. John Wiley and Sons Inc., New York. 236-272.

Razzaq, A, Tariq, M.K, Asif, S, Sohail, K, Alam, Z. 2016. Genetic diversity and association analysis for different morphological traits in *Capsicum annuum* L. *International Journal of Biomolecules and Biomedicine*.5 (1): 20-28.

Reddy, A.C.P and Lokesh, B.R. 1992. Changes in catalase and ascorbic acid oxidase activity in response to lead nitrate treatments. *Indian Journal of Plant Physiology.* 34: 143-146.

Roserbrook, D.D., Proize, C.C and Barney, J.E. 1968. Improved method for determination of extractable colour in capsicum spices. *Journal of Association of Official Analytical Chemists.* 51: 637-643.

Sadasivam, S and Balasubramanian, T. 1987. *Practical manual in Biochemistry*. TNAU, Coimbatore, p: 14.

Shrilekha, M., Lal, R.K., Darokar, M.P and Khanuja, S.P.S. 2011. Genetic variability in germplasm accessions of *Capsicum annuum* L. *American Journal of Plant Sciences.* 2(5): 629-635.

Singh, R.K and Chaudhary, B.D. 1977.*Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers. New Delhi. pp 215-218.

Sumathy, K.M.A and Mathew, A.G. 1984. Chilli processing. *Indian Cocoa, Arecanut and Spice Journal*.7: 112-113.

Suryakumari, S., Umajyothi, K., Srihari, D., Sankar, A.S and Sankar, C.R. 2010. Variability and genetic divergence in paprika (*Capsicum annuum* L.). *Journal of Spices and Aromatic Crops*. 19 (1 & 2), 71–75.

Tasso, Y, Rakesh, K, Dubey, Vikas, S and Garima, U. 2014. Genetic diversity of chilli (*Capsicum annuum* L.) genotypes of India based on morpho-chemical traits. *Australian Journal of Crop Science*. 8(1): 97-102.

Vani, S.K., Sridevi, O and Salimath, P.M. 2007.Genetic divergence in chilli (*Capsicum annuum* L.). *Annales de biologie Clinique.* 23(2): 123-128.

How to cite this article:

Lakshmi Tirupathamma, T., L. Naram Naidu, C. Venkata Ramana and Sasikala, K. 2018. Genetic Divergence Studies in Paprika (*Capsicum annuum* L.). *Int.J.Curr.Microbiol.App.Sci.* 7(08): 199-215. doi: https://doi.org/10.20546/ijcmas.2018.708.027