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RESEARCH ARTICLE

Morphological Characterization of 58 Chilli Genotypes

Parthsinh M Rahevar[1,2,*], Jyotindra N Patel[1], Sushil Kumar[2] and Dinesh J Parmar[3]
[1]*Department of Genetics and Plant Breeding, B.A. College of Agriculture, Anand Agricultural University, Anand-388110, Gujarat, India*
[2]*Department of Agricultural Biotechnology, Anand Agricultural University, Anand-388110, Gujarat, India*
[3]*Department of Agricultural Statistics, Anand Agricultural University, Anand-388110, Gujarat, India*

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Chilli is an important vegetable and condiment crop having immense commercial and therapeutic value with great export potential. Current research was aimed to characterize resolving power of morphological traits for reliable identification of 58 chilli accessions using 25 morphological descriptors. All the characters genotypes showed a wide range of variation. UPGMA based clustering using morphological markers distributes all genotypes into three separate major clusters and six sub clusters with unique traits specific genotypes in each. Fruit calyx cover, fruit neck (basal end) and stem pubescence were the most prominent descriptors as that were showing highest PIC value. High discriminating power of number of petals and anthers was found in our study.

Key Words: Chilli, Diversity, DUS, Morphotypes, Variability

Introduction

Chilli (*Capsicum annuum* L.) is an important vegetable and condiment crop having immense commercial and therapeutic value with great export potential (Kaur *et al*. 2018); also known as bird pepper, cayenne, paprika, hot and sweet pepper belongs to the genus *Capsicum* of Solanaceae family, subfamily Solanoideae and tribe Capsiceae (Hunziker, 2001; Knapp *et al*., 2004). It is a diploid (2n = 2X = 24), annual or short-lived perennial herb with several cultivated forms. The Genus *Capsicum* consists of approximately 22 wild and 5 cultivated species, which includes *C. annuum*, C. *baccatum*, *C. chinense*, *C. frutescens*, and *C. pubenscens*. Molecular analysis confirmed that the center of domestication of *C. annuum var. longum*, the cultivated variety, is the upland region of central-eastern Mexico (Loaiza Figueroa *et al.,* 1989), while Guatemala is considered as a secondary centre of origin (Salvador, 2002). In the world, the production of Chilli in green form is about 7 to 8 million tons and 2 to 3 million tons in dry form. India is the largest producer of Chilli in the world accounting for 1.1 million tons of production annually (Rahevar *et al.* 2019).

With the introduction of Indian Legislation Protection of Plant Varieties and Farmers Rights Act (PPV and FRA, 2001), the release of new crop varieties is possible only if it is distinct (D) from other varieties, uniform (U) in their characteristics and generally stable (S) over the time (DUS). To identify cultivars, standardized descriptor list based on morphological traits developed by the International Union for the Protection of New Varieties of Plants (UPOV) was used as published in the Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability (UPOV 2006; available online at: www.upov.int/edocs/tgdocs/en/tg0 76_08.pdf). The UPOV system of plant variety protection based on individual test guidelines represent an agreed and harmonized approach for the examination of new cultivars of a species of interest. Morphological characters of both qualitative and quantitative have long been used to identify species and to discriminate between varieties. DUS study based on morphological characters is carried out with the strident visual observations in the field during seedling, vegetative and reproductive stages, but it is an expensive and time-consuming process and the purity of seed will be known only after the seed harvest. There is no general rule for cultivar identified or rejection purely by examining only seed or morphological characters in the field. Therefore, for keeping the purity of cultivars, stable visual diagnostic characters of seed, seedling, and plant morphology are utmost essential to know (Lalitha, 2007). Keeping this in view, the present investigation was carried out to differentiate fifty-eight chilli genotypes based on morphological characters.

[*]*Email: parthrahevar@gmail.com*

Table 1. Details of genotypes and their sources

Genotypes	Source	Genotypes	Source	Genotypes	Source
ACGP – 2	A.A.U., Anand, Gujarat	ACGP-74	A.A.U., Anand, Gujarat	GAVC – 112	A. A. U., Anand,
ACGP –7		ACGP –76		Anugraha	N. A. U., Navsari, Gujarat
ACGP –10		ACGP –78		Byadagi Dabbi	
ACGP –15		ACGP –84		Ajeet-6	
ACGP –19		ACGP –88		Arka Abhir	
ACGP –25		ACGP –96		DCL-2	
ACGP –26		ACGP –99		PC-56	
ACGP –27		ACGP –111		Kashi Anmol	I.I.V.R., UP.
ACGP –29		ACGP –112		Mathania Type – 1	C.I.A.H, RJ.
ACGP –37		ACGP –113		Arka Lohit	I.I.H.R., KA.
ACGP –38		ACGP –119		Arka Suphal	
ACGP –46		ACGP –125		Jaweri Vani	Nipani, KA.
ACGP –48		ACGP –129		Gondal Dhholar	Gondal, GJ.
ACGP –49		ACGP –130		US Agri 702	
ACGP –50		ACGP –134		Seedco – 202	Anand (Pvt.), GJ.
ACGP –57		ACGP –135		Gujarat Chilli – 1	S. D. A. U., GJ.
ACGP –58		AVNPC – 131		Gujarat Chilli – 3	
ACGP –66		GVC – 101		Local Selection	Modasa, GJ.
ACGP –67		GVC – 111			
ACGP –69		GVC – 121			

Materials and Methods

Plant materials: Fifty-eight diverse chilli accession (Table 1) collected from different research stations were evaluated at the Main Vegetable Research Station, Anand Agricultural University, Anand during the late rainy season in 2017.

Field experiments: The thirty-five days old seedlings were transplanted using 60.0 cm × 60.0 cm plant to plant and row to row distance using a randomized complete block design. Data on twenty-five morphological characters such as plant habit, plant spread (cm), stem pubescence, stem shape, length of leaf blade, width of leaf blade, plant anthocyanin colouration of nodes, leaf colour, leaf shape, petal colour, anther colour, flower orientation, fruit orientation, fruit bearing habit, fruit colour (mature stage), fruit curvature, fruit neck (basal end), fruit shape of apex, fruit sinuation of pericarp, fruit shape at the base, fruit calyx cover, fruit calyx margin, fruit calyx constriction, stigma length, and number of petals and anthers etc., were recorded on five randomly selected plants.

Cluster analysis: The qualitative trait data were subjected to cluster analysis. Genetic association between genotypes was evaluated by calculating the similarity matrix coefficient for pairwise comparisons based on the morphological characters using software power marker 3.25; Euclidean distance was calculated and a dendrogram was constructed using the unweighted pair group method on arithmetic average (UPGMA).

Results and Discussion

Morphological Characters

Twenty-five morphological characters of fifty-eight chilli genotypes were characterized. All the traits were recorded and genotypes were classified based on phenotypic observations following DUS guidelines specified by Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA) of India.

Plant Habit: In accordance with plant habit, fifty-eight genotypes were categorized into three different classes as spreading, semi-upright and upright plant growth habit with 19, 13 and 26 genotypes in each class, respectively. GVC – 101, GVC – 121, byadagi dabbi, arka abhir and kashi anmol were found to have a spreading type of growth habit, whereas DCL-2, PC-56, jaweri vani, gondal dhholar and gujarat chilli–1 were observed with semi upright growth habit. AVNPC – 131, GVC – 111, GAVC – 112, anugraha, ajeet-6, arka lohit, arka suphal and gujarat chilli–3 were observed with upright plant growth habit. Similar classes concerning plant growth

habits were reported by Farwah *et al.* (2019), Padma *et al.* (2017), Sood *at al.* (2011), Sudre *et al.* (2010) and Manju and Sreelathakumary (2002).

Plant Spread: Fifty-eight genotypes were classified into three different classes as broad, medium and narrow plant spread (cm) with 17, 22 and 19 genotypes in each class, respectively. Gujarat chilli–1, arka abhir, kashi anmol, mathania type–1, seedco – 202, GVC – 111, ajeet-6 and arka lohit were found having broad plant spread, whereas PC-56, jaweri vani, gondal dhholar, GVC – 121, byadagi dabbi, US Agri 702, local selection, AVNPC – 131, GAVC – 112, arka suphal and gujarat chilli–3 were observed with medium plant canopy spread. DCL-2, GVC – 101 and anugraha were observed with narrow plant spreading habits. Farwah *et al.* (2019) observed the same result concerning plant spread.

Stem Pubescence: Based on stem pubescence, fifty-eight genotypes were categorized into two altered sets as presence and absence of stem pubescence with 35 and 23 genotypes in each set, respectively. Stem pubescence was present in gujarat chilli–1, arka abhir, mathania type–1, seedco – 202, GVC – 111, ajeet-6, arka lohit, PC-56, gondal dhholar, GVC – 121, AVNPC – 131 and GAVC – 112, whereas absent in kashi anmol, jaweri vani, byadagi dabbi, US Agri 702, local selection, arka suphal, gujarat chilli–3, DCL-2, GVC – 101 and anugraha. Similar variation along with two different classes for stem pubescence was observed by Farwah *et al.* (2019), Padma *et al.* (2017), Sood *at al.* (2011) and Manju and Sreelathakumary (2002).

Stem Shape: Stem shape classified fifty-eight genotypes into two classes as round and angled with 36 and 22 genotypes in each class, respectively. Stem shape was round in jaweri vani, US Agri 702, local selection, arka suphal, gujarat chilli–3, DCL-2, gujarat chilli–1, Mathania type–1, seedco – 202, GVC – 111, arka lohit, PC-56, gondal dhholar, GVC – 121, AVNPC – 131 and GAVC – 112, whereas angled in kashi anmol, byadagi dabbi, GVC – 101, anugraha, arka abhir and ajeet-6. A similar result for stem shape was observed by Farwah *et al.* (2019) and Sood *at al.* (2011).

Length of the Leaf Blade: Following the length of the leaf blade, fifty-eight genotypes categorized into three different classes as long, medium and short with 6, 47 and 5 genotypes in each class, respectively. GVC – 101, anugraha, ACGP –10, arka suphal, gujarat chilli–1 and GAVC – 112 were found having long leaf blade, whereas kashi anmol, byadagi dabbi, arka abhir, ajeet-6, jaweri vani, US Agri 702, gujarat chilli–3, DCL-2, GVC – 111, arka lohit, PC-56, gondal dhholar, GVC – 121 and AVNPC – 131 were observed with medium length of leaf blade. ACGP –111, local selection, mathania type–1, seedco – 202, ACGP –15 were observed with a short length of leaf blade. Farwah *et al.* (2019) observed the same result with respect to plant spread.

Width of Leaf Blade: Fifty-eight genotypes were categorized into three different classes as broad, medium and narrow width of leaf blade with 1, 19 and 38 genotypes in each class, respectively. Broad width of leaf blade was observed for genotype ACGP – 10, whereas arka suphal, gujarat chilli–1, GAVC – 112, ajeet-6, US Agri 702, gujarat chilli–3, arka lohit and GVC – 121 were observed with medium width of leaf blade. GVC – 101, anugraha, kashi anmol, byadagi dabbi, arka abhir, jaweri vani, DCL-2, GVC – 111, PC-56, local selection, mathania type–1 and seedco – 202 were observed with narrow width of leaf blade. Farwah *et al.* (2019) observed the same result with respect to width of leaf blade.

Plant Anthocyanin Coloration of Nodes: Plant Anthocyanin coloration of nodes was the visual assessment by a single observation on a group of plants. Fifty-eight genotypes categorized into two different classes as present and absent with 37 and 21 genotypes in each class, respectively. Plant Anthocyanin coloration of nodes was present in AVNPC – 131, GVC – 121, anugraha, byadagi dabbi, ajeet-6, PC-56, kashi anmol, mathania type–1, arka suphal, jaweri vani and gujarat chilli–1, whereas absent in GVC – 101, GVC – 111, GAVC – 112, arka abhir, DCL-2, arka lohit, gondal dhholar, gujarat chilli–3 and local selection. Similar variation along with two different classes for stem pubescence was observed by Farwah *et al.* (2019), Padma *et al.* (2017), Sudre *et al.* (2010) and Manju and Sreelathakumary (2002).

Leaf Colour: Leaf colour was green for all the fifty-eight genotypes, so all the genotypes were fallen in the same class. Farwah *et al.* (2019), Padma *et al.* (2017), Sood *at al.* (2011) and Manju and Sreelathakumary (2002) also have a similar result.

Leaf Shape: In accordance with leaf shape fifty-eight genotypes categorized into three different classes as broad elliptic, lanceolate and ovate type of leaf shape with 6, 34 and 18 genotypes in each class, respectively.

GVC – 101, ACGP –67, AVNPC – 131 and US Agri 702 were found having the broad elliptic type of leaf shape, whereas GVC – 111, GAVC – 112, arka abhir, DCL-2, arka lohit, gujarat chilli–3, local selection, GVC – 121, byadagi dabbi, ajeet-6, kashi anmol, mathania type–1 and seedco – 202 were observed with lanceolate type of leaf shape. Gondal dhholar, anugraha, PC-56, gujarat chilli–1 were observed with the ovate type of leaf shape. Similar classes with respect to leaf shape were reported by Farwah *et al.* (2019), Padma *et al.* (2017) and Sood *at al.* (2011).

Petal Colour: Following petal colour fifty-eight genotypes categorized into three different classes as purple, white and yellow green petal colour with 2, 55 and 1 genotypes in each class, respectively. ACGP –15 and ACGP –29 were found having purple petal colour, whereas GVC – 101, AVNPC – 131, US Agri 702, GVC – 111, GAVC – 112, arka abhir, DCL-2, arka lohit, gujarat chilli–3, local selection, gondal dhholar, anugraha and PC-56 were observed with white petal colour. ACGP –129 was observed with yellow green petal colour. Farwah *et al.* (2019) observed the same result with respect to petal colour.

Anther Colour: In keeping with anther colour fifty-eight genotypes categorized into four different classes as green, pale blue, purple and yellow anther colour with 8, 44, 5 and 1 genotypes in each class, respectively. DCL-2, GVC – 121, ACGP –10, ACGP –50, ACGP –130 and ACGP –129 were found having green anther colour, whereas GVC – 101, AVNPC – 131, US Agri 702, GVC – 111, GAVC – 112, gondal dhholar, anugraha, PC-56 and gujarat chilli–1 were observed with pale blue anther colour. Genotypes with purple anther colour were ACGP –29, ACGP –69, arka lohit, ACGP –66, ACGP –26, whereas genotype mathania type–1 was fall in fourth class with yellow anther colour. Farwah *et al.* (2019), Padma *et al.* (2017) and Manju and Sreelathakumary (2002) observed the same result with respect to anther colour.

Flower Orientation and Fruit Orientation: Generally, flower orientation and fruit orientation remains always alike; so we can assume one character by observing another one. Compliant with flower and fruit orientation fifty-eight genotypes were categorized into three different classes as drooping, semi drooping and erect type of flower and fruit orientation with 50, 5 and 3 genotypes in each class, respectively. Genotypes DCL-2, arka abhir, gujarat chilli–3, local selection, ajeet-6, arka lohit and mathania type–1 were observed with drooping type of flower and fruit orientation, whereas ACGP –76, ACGP –48, byadagi dabbi, ACGP –27 and ACGP –66 were fall in semi drooping type and ACGP –49, ACGP –129 and anugraha were fall in erect type of flower and fruit orientation. Similar classis with respect to flower and fruit orientation were reported by Farwah *et al.* (2019), Padma *et al.* (2017) and Sudre *et al.* (2010).

Fruit Bearing Habit: Fifty-eight accessions of chilli were classified in two distinct classes as cluster and solitary fruit bearing habit with 4 and 54 genotypes in each class, respectively. Genotypes ACGP –48, ACGP –66, ACGP –76 and ACGP –99 were found having fruit bearing habit in cluster, whereas all the other genotypes were found having fruit bearing habit of solitary. Similar variation along with two different classes for fruit bearing habit was observed by Farwah *et al.* (2019).

Fruit Colour (Mature stage): In accordance with fruit colour (Mature stage), fifty-eight genotypes were categorized into four different classes as green with 55 genotypes, while greenish white (ACGP –57), orange (ACGP –25) and purple (ACGP –29) fruit colour (Mature stage) had 1 genotype in each class. Similar classis with respect to fruit colour (Mature stage) was reported by Farwah *et al.* (2019), Sood *at al.* (2011), Sudre *et al.* (2010), Pradheep and Veeraragavathatham (2006) and Manju and Sreelathakumary (2002).

Fruit Curvature and Fruit Neck (Basal end): Observations of fruit curvature and fruit neck (basal end) were recorded by visual assessment of a group of plants which dispense fifty-eight genotypes in two different classes as presence and absence of fruit curvature and fruit neck (basal end) with 14 and 44 genotypes in each class of fruit curvature and with 35 and 23 genotypes in each class of fruit neck (basal end), respectively. Fruit curvature was absent in genotypes AVNPC – 131, GVC – 101, GVC – 121, anugraha, ajeet-6, arka abhir, PC-56 and local selection, whereas all the other genotypes have fruit curvature, whereas fruit neck (basal end) was absent in genotypes AVNPC – 131, GVC – 121, byadagi dabbi, ajeet-6, arka abhir, and gondal dhholar. Result was in accordance with findings of the Farwah *et al.* (2019), Sudre *et al.* (2010) and Manju and Sreelathakumary (2002).

Fruit Shape of Apex: In accordance with fruit shape of apex fifty-eight genotypes categorized into three different classes as acute, blunt and depressed with 43, 13 and 2

genotypes in each class, respectively. GVC – 121, byadagi dabbi, ajeet-6, PC-56, anugraha, DCL-2, kashi anmol, mathania type–1, arka lohit, gujarat chilli–1, gujarat chilli–3 and local selection were found having acute type of fruit shape at apex, whereas AVNPC – 131, arka abhir, arka suphal and jaweri vani were observed with blunt type of fruit shape at apex. ACGP –84 and ACGP –135 were observed with depressed fruit shape at apex. Farwah *et al.* (2019) and Manju and Sreelathakumary (2002) have the similar result for fruit shape at apex.

Fruit Sinuation of Pericarp: In keeping with fruit sinuation of pericarp; fifty-eight genotypes were categorized into three different classes as week, medium and strong sinuation with 36, 13 and 9 genotypes in each class, respectively. AVNPC – 131, GVC – 101, GVC – 121, GAVC – 112, ajeet-6, kashi anmol, arka suphal and local selection were found having week sinuation, whereas mathania type–1, Arka lohit, Gondal dhholar, Gujarat chilli–1 and Gujarat chilli–3 were observed with medium sinuation. Genotypes with strong sinuation were GVC – 111, anugraha, byadagi dabbi, arka abhir, DCL-2, PC-56 and jaweri vani. Farwah *et al.* (2019) observed the same result with respect to fruit sinuation of pericarp.

Fruit Shape (At the base): Fifty-eight genotypes of chilli were categorized in to three classes based on fruit shape (at the base) as acute, round and sunken with 42, 14 and 2 genotype in each class. Genotypes mathania type–1, arka lohit, byadagi dabbi, anugraha, DCL-2, ajeet-6, GVC – 101, GAVC – 112, kashi anmol, US Agri 702, seedco – 202, local selection and AVNPC – 131 were found having acute fruit shape at the base, whereas gondal dhholar, arka abhir, jaweri vani and arka suphal were found having round fruit shape at the base while genotypes PC-56 and ACGP –84 had sunken fruit shape at the base. Farwah *et al.* (2019) and Manju and Sreelathakumary (2002) have the similar result for fruit shape at the base.

Fruit Calyx Cover: Fruit Calyx Cover at the base of the fruit was a good visual character for differentiating two genotypes as enveloping and non-enveloping type. Fifty-eight genotypes of chilli were categorized in to two different classes as enveloping and non-enveloping with 35 and 23 genotypes in each class based on fruit calyx cover. Genotypes mathania type–1, arka lohit, anugraha, DCL-2, GVC – 121, ACGP –15, GAVC – 112, kashi anmol, US Agri 702, seedco – 202, local selection and AVNPC – 131 were fall in to class enveloping, whereas genotypes gondal dhholar, byadagi dabbi, PC-56, arka abhir, jaweri vani, ajeet-6, GVC – 101 and arka suphal were fall in to class non enveloping. Farwah *et al.* (2019) have the similar result for fruit calyx cover at the base.

Fruit Calyx Margin: Fifty-eight accessions of chilli were classified into two distinct classes as dented and smooth fruit calyx margin with 41 and 17 genotypes in each class, respectively. Genotypes mathania type–1, GVC – 111, anugraha, DCL-2, GVC – 121, GAVC – 112, AVNPC – 131, gondal dhholar, byadagi dabbi, PC-56, arka abhir, jaweri vani, GVC – 101 and arka suphal were found having dented fruit calyx margin, whereas all the other genotypes were found having smooth fruit calyx margin. Similar result with respect to fruit calyx margin was observed by Farwah *et al.* (2019).

Fruit Calyx Constriction: Fifty-eight genotypes categorized into two different classes as presence and absence of fruit calyx constriction with 48 and 10 genotypes in each class, respectively. Fruit calyx constriction was present in ACGP –37, ACGP –112, ACGP –25, ACGP –50, ACGP –66, GAVC – 112, AVNPC – 131, ACGP –67, ACGP –57 and ACGP –26, whereas absent in mathania type–1, gujarat chilli–1, gujarat chilli–3, GVC – 111, anugraha, DCL-2, GVC – 121, gondal dhholar, byadagi dabbi, PC-56, arka abhir, jaweri vani, GVC – 101, arka suphal, arka lohit, kashi anmol local selection and ajeet-6. Similar variation along with two different classes for fruit calyx constriction was observed by Farwah *et al.* (2019).

Stigma Length: Based on flower stigma length; chilli was classified into three different classes as short (Stigma was shorter then anther length so remains inside anther cone), medium (Stigma was same in length to anther) and long (Stigma was longer then anther so appears out of the anther cone). Compliant with stigma length fifty-eight genotypes were categorized into three different classes as short, medium and long with 24, 22 and 12 genotypes in each class, respectively. DCL-2, GVC – 121, byadagi dabbi, arka abhir, arka suphal and ajeet-6 were found having short stigma length, whereas mathania type–1, anugraha, gondal dhholar, PC-56, GVC – 101, arka lohit, US Agri 702, seedco – 202, GAVC – 112, and AVNPC – 131 were observed with medium stigma length. Sood *at al.* (2011) observed similar result for stigma length.

Number of Petals and Anthers: Based on petal and anther number, fifty-eight genotypes were categorized into four different classes as 5, 6, 7 and 8 petals and anthers with 24, 27, 6 and 1 genotypes in each class, respectively. Gujarat chilli–1, jaweri vani, kashi anmol, PC-56, DCL-2, GVC – 121 and byadagi dabbi were found having 5 petals and anthers, whereas local selection, mathania type–1, anugraha, GVC – 101, arka lohit, GAVC – 112, AVNPC – 131 and arka suphal were observed with 6 petals and anthers. Genotypes with 7 petals and anthers were ACGP –66, gondal dhholar, ACGP –96, ACGP –134, arka abhir and ACGP –25, whereas genotype Ajeet-6 was fall in fourth class with 8 petals and anthers. The number of petals and anther were serving large variability, but due to the absence of DUS guidelines to evaluate them; these characters were

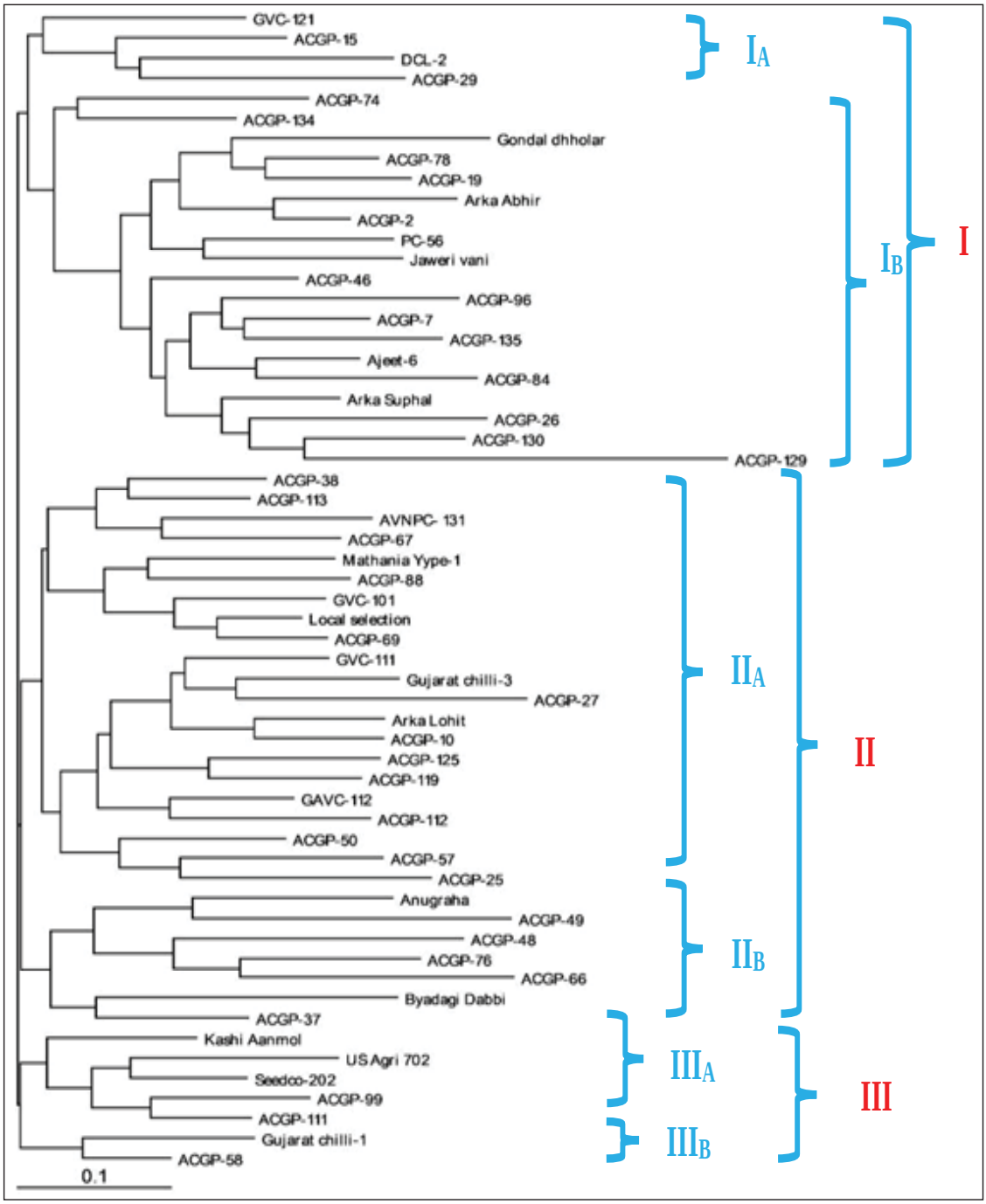

Fig. 1. Grouping of 58 chilli genotypes

not studied till today. The authority should add them and publish a proper guideline to investigate them well.

Cluster analysis: Cluster analysis based on dissimilarity matrix was performed using the UPGMA. Three clearly defined clusters have been detected (Fig. 1); representing distinct morphotypes. The dendrogram depicted 23, 21 and 14 genotypes have diverged under cluster I, II and III, respectively. Cluster I represent genotypes with lanceolate leaf shape, drooping flower orientation, drooping fruit orientation, solitary fruit bearing habit, acute fruit shape of apex, acute fruit shape at the base, dented fruit calyx margin, absence of fruit calyx constriction, short stigma length, green fruit colour (mature stage), absence of fruit curvature and 5 number of petals. Sub cluster I_A composed of 4 genotypes and represent genotypes with lanceolate leaf shape and short stigma length, whereas sub-cluster I_B consists of 19 genotypes and represents genotypes with the absence of fruit curvature. Genotypes of Cluster I_A and I_B have dissimilar fruit Calyx Cover as enveloping and non-enveloping, respectively. Cluster II contain 28 genotypes with 21 genotypes in sub-cluster II_A and 7 in II_B. Cluster II represent genotypes with white petal colour and 6 number of petals in flower. 7 out of 58 genotypes were falling under cluster III with 2 sub-clusters and 5 genotypes in sub-cluster III_A whereas 2 in sub-cluster III_B. Cluster III represent genotypes with Pale blue anther colour and presence of fruit neck (basal end). Padma *et al.* (2017) studied 11 genotypes and detected comparable output with 3 clusters.

Clusters based on distinct morphotypes unfold the evolutionary development of studied chilli. Highest euclidean (0.8443) was observed between genotypes ACGP – 129 and ACGP – 99 suggesting best diverse genotypes for hybridization program and creating transgressive segregants. Second highest distance was observed between genotype (0.8021) ACGP-129 and ACGP-66, whereas lowest distance (0.1266) was observed between ACGP – 69 and local selection, suggesting most similar genotypes among all the studied genotypes.

A total of twenty-five phenotypic markers were taken under consideration; as each phenotypic variable was a one selection marker for varietal identification. Fruit calyx cover, fruit neck (basal end) and stem pubescence were the most prominent descriptors as that were responsible for showing the highest PIC value (0.3641) followed by stem shape (0.36) and plant anthocyanin coloration of nodes (0.3553), whereas lowest PIC (0.00) was observed for green leaf colour. All the descriptors were well explanatory for available diversity in the germplasm understudy with high (0.7774) mean major allele frequency and mean allele number (2.68), whereas low mean PIC (0.2437) value in the study suggests either to use of more descriptors or elimination of extra descriptors with poor discriminating power from the study.

Conclusion

It was concluded that the fifty-eight chilli genotypes could be effectively distinguished by its' morphological characters based as twenty-five characters.

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References

Farwah S, K Hussain, K Wani, Z Dar, Z Bhat, S Rizvi, S Hussain, M Rashid and S Lone (2019) Distinctiveness, uniformity and stability characterization of Chilli (*Capsicum annuum* L.) genotypes under temperate conditions of Kashmir. *SKUAST J. Res.* **21(2):** 152-165.

Hunziker AT (2001) Genera Solanacearum: The Genera of Solanaceae illustrated, arranged according to a new system. Gantner Verlag, Ruggell: Liechtenstein, pp.516.

Kaur S, SS Kang, A Sharma, S Jindal and M Dhaliwal (2018) Evaluation of hot pepper germplasm for multiple disease resistance against root knot nematode and viruses. *Indian J. Plant Genet. Resour.* **31**: 243.

Knapp S, L Bohs, M Nee and DM Spooner (2004) Solanaceae-A model for linking genomics with biodiversity. *Comp. Funct. Genomics.* **5**: 285-291.

Lalitha A (2007) Varietal Characterization of chickpea (*Cicer arietinum*) varieties (Doctoral dissertation, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad).

Loaiza Figueroa F, K Ritland, J Laborde and SD Tanksley (1989) Patterns of genetic variation of the genus *Capsicum* (Solanaceae) in Mexico. *Plant Syst. Evol.* **165**: 159-188.

Manju P and Sreelathakumary I (2002) Genetic cataloguing of hot chilli (*Capsicum chinense* JACQ) types of Kerala. *J. Trop. Agric.* **40**: 42-44.

Padma J, S Anbu and Sivasubramaniam K (2017) Efficacy of Morphological Characters for Varietal Identification of Chilli. *Int. j. curr. microbiol. appl. sci.* **6(2):** 690-700.

Pradheep K and Veeraragavathatham, D (2006) Characterization of Capsicum spp. germplasm. *Indian J. Plant Genet. Resour.* **19(2):** 180-183.

Rahevar PM, JN Patel, S Kumar and RR Acharya (2019)

Morphological, biochemical and molecular characterization for genetic variability analysis of *Capsicum annuum. Vegetos.* **32**: 131-141.

Salvador MH (2002) Genetic resources of chilli (*Capsicum annuum* L.) in Mexico. Proceedings of the 16th International Pepper Conference, Tampico, Tamaulipas, Mexico, 10-12.

Sood S, R Sood and Vidyasagar R (2011) Morphological characterization of bell pepper (*Capsicum annuum var. grossum*) genotypes and their application for distinctness, uniformity and stability testing. *Indian J. Agric. Sci.* **81**: 240-246.

Sudre C, L Goncalves, R Rodrigues, A Junior, E Riva-Souza and C Bento (2010) Genetic variability in domesticated *Capsicum spp*. as assessed by morphological and agronomic data in mixed statistical analysis. GMR. **9**: 283-94.

UPOV (2006) Available online at: www.upov.int/edocs/tgdocs/en/tg0 76_08.pdf