



Genetic Diversity for Fruit Quality Traits in Elite Capsicum (*Capsicum annuum* L.) Germplasm Lines

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study aimed to assess the genetic diversity of twenty-two elite capsicum (*Capsicum annuum* L.) germplasm lines across nine quantitative traits. The research was conducted at the research farm of ICAR-Indian Institute Horticultural Research, Hessaraghatta, Bengaluru, Karnataka, during 2014-2015 period. The experimental design employed was a randomized complete block design with three replications. The quality parameters under study included fruit length (cm), fruit width (cm), pericarp thickness (mm), placenta length (cm), placenta width (cm), total soluble solids (^oBrix), fruit to seed ratio, seed number and total capsaicinoids (Scoville Heat Units). Based on the performance of the study, a cluster analysis of twenty-two chilli germplasm lines were grouped into three clusters. Cluster I had a maximum of sixteen genotypes and clusters III had a minimum of one genotype. The highest inter-cluster distance (60.521) was observed in between clusters I and II

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and the lowest (17.964) in between clusters I and III. Among the traits examined, fruit length and total capsaicinoids contributed the most to the genetic divergence. Considering group cluster analysis, mean performance and variability, it is recommended to explore inter genotypic crosses between cluster I and cluster II, as well as cluster I and cluster III, for future hybridization programmes in chilli crop improvement.

Keywords: Genetic diversity; fruit quality; capsicum; germplasm; TSS; cluster analysis.

1. INTRODUCTION

Chilli also known as hot pepper, sweet pepper, paprika, pimiento, cayenne or bird eye pepper, is an economically important crop belonging to the botanical species *Capsicum annum* within the Solanaceae family. Chilli is believed to have originated around 7000 B.C in Mexico and Central America [1]. Peppers are considered one of the earliest spices used by humans, with archaeological evidence dating back as far as 6000 years ago [2]. Currently, there are five recognized cultivated species (*C. annum*, *C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubescens*) and there are at least 20-30 reported wild species, all of which are diploid with a chromosome count of $2n=2x=24$. Most of these species are self-compatible and self-pollination predominates among the cultivated varieties. It was introduced to India in 1498 by Portuguese traders, since its arrival, chilli has become an indispensable commodity in every Indian cuisine due to its pungency, spicy taste, appealing color and flavor. Today, India stands as the world's leading producer and exporter of chilli, contributing 42% of global chilli production. In India, chilli cultivation covers an area of 8.82 thousand hectares, yielding a production of 18.36 lakh tons [3]. Genetic diversity and the relationships between various genotypes play a crucial role in enhancing crop quality. Morphological characteristics are often difficult since most of these characteristics are under the influence of environmental factors. However, genetic diversity estimation among plant genotypes allows for more reliable differentiation of the genotypes. Analyzing genetic diversity proves valuable for selecting diverse parental combinations, reliably classifying accessions, and precisely identifying varieties. Given that fruit quality improvement is a significant challenge for chilli breeders, it is crucial to examine genetic diversity, particularly for pungency, alongside other key fruit quality traits across the Capsicum species. Genetic diversity is essential to meet the diversified goals of plant breeding, such as breeding for increasing yield, wider adaptation,

desirable quality, and pest and disease resistance [4].

The characterization of germplasm is important for the conservation and effective utilization of plant genetic resources [5]. The presence of genetic divergence within a population serves as a valuable tool for selecting suitable parents and utilization in any crop breeding programmes, leading to a reduction in the number of required crosses [6]. The selection of parents depends on the specific objectives of the research programme and their performance. Various statistical analyses are available to aid in the selection of suitable parents. Understanding the nature and extent of genetic divergence is essential for breeders when selecting the most suitable parents for purposeful hybridization in heterosis breeding [7,8,9]. In order to benefit transgressive segregation, knowledge of the genetic distance between parents is essential [10,11]. The Euclidean distance can be employed as a theoretical measure to estimate the genetic distance between parents, with the aim of maximizing transgressive segregation [11]. It is important to note that a higher genetic distance between parents leads to increased heterosis in the progeny [12]. In the present study, twenty-two chilli genotypes were collected from various regions and cultivated following a standard package of practices at the research farm of ICAR-Indian Institute of Horticultural Research, Bengaluru. Subsequently, these genotypes were accessed for their genetic diversity concerning fruit quality traits within elite capsicum germplasm lines, with the aim of identifying suitable genotypes for future hybridization programmes.

2. MATERIALS AND METHODS

The experimental study was conducted at Research Farm of Vegetable crops Block number VIII of ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, during 2014-2015. The soil of the experimental site is red loamy, comes under zone-5 of

Table 1. *Capsicum* germplasm lines used in the study

Sl. No.	Accession No.	<i>Capsicum</i> species
1.	IHR 500	<i>Capsicum annuum</i>
2.	IHR 1485	<i>Capsicum annuum</i>
3.	IHR 2451	<i>Capsicum annuum</i>
4.	IHR 3014	<i>Capsicum annuum</i>
5.	IHR 324	<i>Capsicum baccatum</i>
6.	IHR 3241	<i>Capsicum baccatum</i>
7.	IHR 3315	<i>Capsicum annuum</i>
8.	IHR 3443	<i>Capsicum annuum</i>
9.	IHR 3447	<i>Capsicum annuum</i>
10.	IHR 3448	<i>Capsicum annuum</i>
11.	IHR 3449	<i>Capsicum annuum</i>
12.	IHR 3453	Derivative of <i>Capsicum chinense</i>
13.	IHR 3455	<i>Capsicum annuum</i>
14.	IHR 3476	<i>Capsicum annuum</i>
15.	IHR 4357	<i>Capsicum chinense</i>
16.	IHR 4500	<i>Capsicum chinense</i>
17.	IHR 4501	Natural cross between <i>Capsicum chinense</i> and <i>Capsicum frutescens</i>
18.	IHR 4502	<i>Capsicum chinense</i>
19.	IHR 4503	<i>Capsicum annuum</i>
20.	IHR 4506	<i>Capsicum annuum</i>
21.	IHR 4517	<i>Capsicum annuum</i>
22.	IHR 4550	<i>Capsicum chinense</i>

region-3 among the agro-climatic zones of Karnataka state and is situated in the eastern dry zone at 12.58 °N latitude and 77.45 °E longitude at an altitude of 930 meters above mean sea level. The average rainfall in this region is 800 mm, well-distributed over a period of five to six months from May to October, with peaks during September. The experimental study was laid out in randomized complete block design with three replications. The four weeks old seedlings of twenty-two chilli germplasm lines (Table 1) were transplanted with a spacing of 60 cm x 20 cm. Recommended doses of fertilizers and standard cultivation practices were followed. Weeding and irrigation were given to the plants when necessary. The fruits were harvested at the fully matured red-ripe stage, oven-dried and powdered. Important fruit qualitative characters such as fruit length (cm), fruit width (cm), pericarp thickness (mm), placenta length (cm), placenta width (cm), total soluble solids [TSS (°Brix)], fruit to seed ratio, seed number, and total capsaicinoids (SHU) were recorded and estimated from the fruits of randomly selected five plants in each plot and the collected data of two-season crops were subjected to statistical analysis. The genetic diversity was evaluated through the application of Mahalanobis D² statistics [13] and the accessions were then

categorized into clusters using Tocher's method, following the recommendation by Rao [14]. The computation of Intra and inter cluster distances was carried out using the formula described by Singh and Chaudhary [15].

3. RESULTS AND DISCUSSION

3.1 Cluster Analysis

The analysis of variance exhibited significant variations among the genotypes for all nine fruit quality traits under studied, which indicated considerable amount of genetic diversity. Subsequently, a diversity analysis was conducted. The non-hierarchical clustering analysis of Mahalanobis D² values was performed based on a distance matrix derived from twenty-two chilli genotypes, resulting in their classification into three distinct clusters, as shown in Table 2. It was explained that cluster I contained the highest number of genotypes (16), followed by Cluster II, which consisted of five *Capsicum* genotypes. Cluster III was composed of a single genotype which is IHR 3443. This indicated that this genotype is different from other genotypes used in this study.

Table 2. Distribution of *Capsicum* germplasm lines into three different clusters in the study

Cluster No.	Number of germplasm lines	Germplasm lines
I	16	IHR 1485, IHR 2451, IHR 3014, IHR 3240, IHR 3241, IHR 3315, IHR 3447, IHR 3448, IHR 3449, IHR 3453, IHR 3455, IHR 3476, IHR 4502, IHR 4503, IHR 4506, IHR 4517,
II	5	IHR500, IHR 4357, IHR 4500, IHR 4501, IHR 4550
III	1	IHR 3443

Cluster analysis allowed a natural grouping of the genotypes, although groupings of different clusters indicate that there is no firm conclusion regarding the relation between genetic divergence and geographical distance in capsicum. Similar observations were made by Mubarak [16] where close derivatives of Byadagi chilli were grouped under different clusters in his study. Accordingly, different measurement techniques can be appropriately used for genotype grouping [17,18]. Evaluation of genetic diversity can be useful for the selection of efficient genotypes and if such efforts result in reduction of diversity, the production of crop plants with higher uniformity may assure the supply of nutrients to under nourished population of the world. Consequently, it is suggested that choosing a parent for hybridization or in other crop improvement programmes need not necessarily be based on geographical distance. Some of the desirable genotypes identified by the study include: IHR 4506, IHR 1485, IHR-3453, IHR 2451, IHR 4517, IHR 3448, IHR 3240, IHR4503, IHR 3455, IHR 3315, IHR3447, IHR3449, IHR 3014, IHR 3241, IHR 4502 in cluster I, IHR 4550, IHR 4357, IHR 4500, IHR4501, IHR 500, in cluster II, and IHR 3443 in cluster III. The D^2 statistic has been found as a tool to estimate genetic divergence and being a numerical estimate, it has added advantage over other criteria permitting precise comparison among all possible pairs of population in any group.

Breeding and development of superior varieties requires prior quantitative assessment of genetic divergence in the available gene pool. The genetic distance was observed between clusters I and II (60.521). According to Mahalanobis D^2 statistics, the intra and inter-cluster distance (D^2) values are presented in Table 3. The inter-cluster distances were larger than the intra cluster distances. The inter-cluster distance was the maximum between clusters I and II (60.521), indicating wide genetic diversity between these two-cluster

followed by the distance between cluster II and III (60.337).

Table 3. The inter and intra cluster distances (D^2) of twenty- two *Capsicum* germplasm lines

Cluster	Cluster1	Cluster 2	Cluster 3
Cluster 1	22.603	60.521	17.964
Cluster 2		27.697	60.337
Cluster 3			0.000

Genotypes from these two clusters if they involve hybridization, may occur across a wide spectrum of segregating populations as genetic diversity is very distinct among the groups. The selection of divergent genotypes from clusters would produce a broad spectrum of variability for the morphological and quality traits studied, which may enable further selection and improvement. The minimum inter-cluster distance was observed between cluster I and cluster III (17.964), suggesting that the genotypes within these clusters were closely related genetically, indicating minimal divergence between them [19]. As reported by Kumar et al. [20], crossing genotypes from clusters I and II, which have the maximum genetic distance between them, has been shown to yield high quality fruits. Therefore, utilizing this cross in capsicum breeding can be an effective approach to maximize heterosis. The minimum distance was between the genotypes of clusters I and III (17.964), which can be used for backcrossing programmes. This finding aligns with the research of Sundaram et al. [21], which highlighted the utility of cluster analysis in identifying high quality capsicum genotypes. Additionally, further studies reported by Indira [22]; Roy & Sorma [23]; Mubarak [16]; Senapati et al. [24]; Mishra et al. [25]; Misra et al. [26]; Hasan et al. [27]; Yattung et al. [28] and Sen et al. [19] have also revealed significant genetic divergence among capsicum genotypes in their respective experiments. Table 4 displays the proportional genetic divergence attributed to nine

contributing characters. The highest contribution to genetic divergence was associated with the total capsaicinoids content (20.95%), followed by fruit length (11.43%), fruit width (8.09%), placenta width (4.73%), and seed number (2.86%). However, there was no significant factors contribute to genetic divergence by pericarp thickness, fruit to seed ratio and TSS (°Brix) in this study. In confirmation to this result, Yattung et al. [28] observed that the characters such as capsaicin content and ascorbic acid contributed maximum towards divergence among 30 chilli genotypes of Indian origin were evaluated for genetic diversity in their study.

3.1.1 Performance of fruit quality characters in various clusters

The cluster mean values of nine different characters for three clusters are summarized in Table 5. Differences in cluster means existed for almost all the characters studied. The highest mean values for fruit width (cm), pericarp thickness (mm), placenta length (cm), placenta width (cm), total soluble solid (°Brix), fruit to seed ratio and total capsaicinoids (SHU) were

observed in cluster II, which means the genotypes in cluster II group have the genetic potential to contribute to better performance for maximization of chilli genotypes. Cluster III had the genotypes that showed the lowest mean value for almost all the characters studied, indicating that the selection of genotypes from these cluster for future chilli breeding programmes has no positive impact.

Crop improvement is achieved by inducing variation in desired characteristics, which is then followed by a rigorous selection process. The ongoing progress in crop improvement can only be realized when significant variability is identified and harnessed within a population. The allelic disparity between any two parent plants is manifested through their divergence [29]. Crossing genotypes within the same cluster is unlikely to yield segregants with distinct fruit characteristics. As a result, a crossbreeding programme should involve potential parents from diverse character groups. Thus, crosses between members of clusters separated by inter-cluster distances are more likely to contribute to further improvements.

Table 4. Percent contribution of nine traits to total divergence in twenty-two *Capsicum* germplasms

Sl. No.	Characters	Number of times ranked first	Contribution %
1.	Fruit length (cm)	24	11.4286
2.	Fruit width (cm)	17	8.0952
3.	Pericarp thickness (mm)	0	0.0000
4.	Placenta length (cm)	1	0.4762
5.	Placenta width (cm)	10	4.7619
6.	TSS (°Brix)	0	0.0000
7.	Fruit to seed ratio	0	0.0000
8.	Seed number	6	2.8571
9.	Total capsaicinoids (SHU)	44	20.9524

Table 5. Mean values of different fruit quality traits cluster-wise among twenty-two *Capsicum* germplasm lines

Sl. No.	Characters	I	II	III
1.	Fruit length (cm)	7.855	4.265	8.525
2.	Fruit width (cm)	1.435	1.835	0.800
3.	Pericarp thickness (mm)	2.180	2.840	1.575
4.	Placenta length (cm)	1.633	1.740	0.625
5.	Placenta width (cm)	1.500	1.875	0.725
6.	Total soluble solids (°Brix)	9.210	21.705	10.800
7.	Fruit to seed ratio	1.945	2.662	1.670
8.	Seed number	82.100	36.950	81.750
9.	Total capsaicinoids (SHU)	255.709	1758.07	279.225

4. CONCLUSIONS

A significant diversity in fruit quality traits was evident among the twenty-two studied *Capsicum* genotypes, which were sources from diverse eco-geographical regions within the country and interestingly, there was no correlation between their genetic diversity and geographical origins. Total capsaicinoids content was the most significant primary contributor to genetic divergence, followed by fruit length, fruit width, placenta width and seed number. Additionally, it was revealed that genotypes belonging to clusters I and II exhibited promising economic traits, indicating their suitability for inclusion in efforts to genetically improve *Capsicum* varieties.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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