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MORPHOGENETIC DIVERGENCE IN SWEET PEPPER (*Capsicum annuum* L.) GENOTYPES

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ABSTRACT

Sweet pepper is one of the most important vegetable crops and its demand is increasing day by day in Bangladesh indicating need for varietal improvement program. Eleven sweet pepper genotypes from native and exotic sources were characterized for twenty-five morphological traits using vegetative and reproductive appearances at Bangladesh Institute of Nuclear Agriculture, Mymensingh, from November 2021 to March 2022. Noticeable variation was observed among twenty-five qualitative traits (25) studied. Nineteen (19) traits showed undisputable variation. Higher number (9 genotypes) of light purple, purple and dark purple color at node indicated high amount of anthocyanin content. Leaf shape is used as genotypes identifier at vegetative stage and three types of leaves were found with dark green color (6 genotypes) that is highly correlates with yield. In case of flower, 100% white color corolla indicates higher number of fruit set. Entire genotypes exhibited one or more exclusive characters especially fruit shape and color which could be used as important breeding materials. CKN-1 and CKN-8 had the highest yield per plant (367.6 and 362.04 grams, respectively), making them potentially good for cultivation, whereas plant height, fruit number, weight, length, and diameter varied among the selected genotypes. A positive Correlation was observed among the traits and genetic distance value ranged from 0.17 to 0.68 among the selected genotypes. However, selection of genotypes with desirable morphological characteristics can be used for their exploitation of future research program.

Keywords: Capsicum, Fruit color, Genetic dissimilarity, Morphological characterization, Sweet pepper.

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INTRODUCTION

Sweet pepper or Bell pepper is a cultivar group of the species *Capsicum annuum* L. an important vegetable crop, grown worldwide for its delicate taste, pleasant flavour and color. Capsicum is a genus of flowering plants in the nightshade family Solanaceae. Though the genus Capsicum contains about 20 species, till now only five domesticated species viz. *C. annum, C. frutescens, C. chinense, C. baccatum* and *C. pubescens* are recognized (Negi et al., 2018). All cultivated species of sweet pepper have 2n=24 chromosomes (Greenleaf, 1986). As a food, sweet pepper has high nutritive value as it contains 175 mg ascorbic acid, 870 I.U. vitamin A, 1.29 mg protein, 0.06mg thiamine, 0.03mg riboflavin, 0.55mg niacin and 11mg calcium per 100g edible fruit (Joshi, and. Singh, 1975). Peppers are also well known for its high content in bioactive compounds and strong antioxidant properties including neutral phenolic compounds or flavonoids called quercetin, luteolin, and capsaicinoids (Chavez-Mendoza et al., 2015). The nutritional status of Bangladeshi people is a matter of great concern as more than half of the populations have been suffering from malnutrition (Ferdousi et al., 2020). Thus, consumption of sweet pepper can relieve the suffering from malnutrition of Bangladeshi people to some extent, because they provide more vitamin, minerals, protein, and strong antioxidant properties.

Sweet pepper has been grown in Bangladesh for nearly two decades and it is a small scale cultivated vegetable in Bangladesh. Though it has a good economic importance, but growers are not able to produce good quality Capsicum with high productivity in Bangladesh (Akter et al., 2017). In Bangladesh only two open pollinated sweet pepper varieties i.e., BARI Mistimarich 1 and BARI Mistimarich 2 has been released by Bangladesh Agricultural Research Institute (BARI, 2019) for cultivation. Most of the seeds used for cultivation in Bangladesh are imported (Mahmud et al., 2017). Development of high yielding varieties with good quality through the advance breeding methods is essential to meet the farmers as well as market demand.

Germplasm is referred to as a set of genotypes that can be conserved or used (Taylor and Tuia, 2008). Bangladesh is not self-sufficient in sweet pepper germplasm to fulfill its requirements and mostly depends on alien sources. Collection of diverse germplasm and their systematic evaluation assume considerable importance in any crop improvement program (Gogoi and Gautam, 2002). Less genetic diversity means less opportunity for the development and growth and innovation required to boost agriculture (Taylor and Tuia, 2008). Evaluation of the potentialities of the indigenous and exotic germplasm is essential because promise for further improvement program depends on the genetic diversity of the crop (Sreenivas et al., 2019).

Morphological characterization based on qualitative traits of crops is a very crucial and essential first step in any crop improvement and breeding program (Joshi et al., 2020). The immense phenotypic diversity has helped to develop a high yielding variety and morphological or phenotypic characterization is considered as the important step in the description and classification of germplasm (Luitel et al., 2018). Meanwhile, studies on morphological characterization of the collected genotypes have been widely used for the assessment of genetic diversity, breeding value and yield potential of the crop (Salim et al., 2020).

Genetic cataloguing based on standard descriptors helps to easily describe the morphological features of a genotype and thus helps exchange of information about new genotypes. Therefore, the present investigation was undertaken to characterize collected native and alien sweet pepper germplasm based on their morphological traits as well as to identify promising genotypes and traits which can be used in future research program.

MATERIALS AND METHODS

The experiment was conducted at the Research Field of BINA HQ, Mymensingh, Bangladesh during November 2021 to March 2022. Eleven (11) sweet pepper genotypes were collected from native and exotic sources used in this study and displayed in Table 1. The experiment was carried out in plastic pots. A total of 165 (11×15) pots were prepared. Each pot size was 10L and hosted one plant. Seeds were soaked in water for 24 hours in order to facilitate germination and subsequently sown on plastic trays in lines. Sowing of seeds on the tray was done at a depth of one centimeter for easy emergence. Sowing was done on 17 November 2021. Six to seven days were required to start germination. When the seedlings attained 3 leaf stages, they were transferred under the polyethylene shade covering with fine net to prevent from scorching sunlight as well as unexpected storm or heavy rainfall and insect infestation. The seedlings were watered thoroughly every day as per on the requirement. Thirty-six days old seedlings were transplanted on 22 December, 2021, in well prepared experimental pots comprising of soil, compost and sand (3:1:1). One teaspoon of urea, half teaspoon of MoP and gypsum were applied 25 and 50 days after transplanting of seedlings in the pots.

Table 1. List of Sweet pepper genotypes used in this study

Sl. No.	Sweet pepper genotypes ID used in this study	Source organization of collection
1	CKN-1	AVRDC, Taiwan
2	CKN-2	AVRDC, Taiwan
3	CKN-3	AVRDC, Taiwan
4	CKN-6	AVRDC, Taiwan
5	CKN-7	AVRDC, Taiwan
6	CKN-8	AVRDC, Taiwan
7	CKN-9	AVRDC, Taiwan
8	CKN-10	AVRDC, Taiwan
9	CKN-11	AVRDC, Taiwan
10	CKN-12	BARI, Gazipur
11	CKN-13	BARI, Gazipur

During the crop cycle, appropriate intercultural operations were performed for proper plant growth and development, such as irrigation at different growth stages, weeding, soil mulching and staking as and when needed. Different types of insect infestation were occurred during the experimental period such as mites, aphids, and yellow strip armyworm. To control these karishma (Azoxystrobin + Cyproconazole), zero mite (Abamectin + Propargite) and mukti (Imidacloprid) @ 1ml/lL of water were sprayed at 7 days of interval.

Data Collection: Observations of different characters were recorded from eleven sweet pepper genotypes at specified stages of crop growth period when the characters under study had full expression. Five plants from each genotype were randomly selected and tagged for recording the observations. The data was taken in the form of descriptor of IPGRI, AVRDC and CATIE (1995) for the crop capsicum (*Capsicum spp*.). All the plant and leaf characters were observed when plants were attained at full mature stage and leaf pubescence on the younger stage. Fruit parameters were recorded by observing 10 fruits from different plants on mature fruits in the first harvest unless specified. However, Morphological data was analyzed by STATISTIX 10. Meanwhile, correlation and genetic dissimilarity study was done by Past 4.10 software.

RESULTS AND DISCUSSION

Morphological characterization

Data from 11 sweet pepper genotypes were recorded on the basis of “Descriptors for *Capsicum spp*. (*Capsicum annuum* L.)” (IPGRI, AVRDC and CATIE,1995)

Plant growth characteristics

Diverse variation was found regarding eleven morphological traits of capsicum observed at appropriate stage of each genotype and displayed in Table 2. Two types of stem color were observed such as, dominant green (7 genotypes) and green with purple streak (4 genotypes). Most of the genotypes (10) exhibited cylindrical or round stem shape with strong intensity of anthocyanin coloration i.e., light purple color on nodes (5 genotypes) while angled stem shape was found in case of one genotype as well as equally two genotypes showed green and purple color at nodes. Purple color or purple color streak on pepper plants indicates the presence of high amount of anthocyanin content, which is an effective antioxidant for human body (Moon and Shibamoto, 2009). Plant growth habit was characterized as prostate, intermediate and erect, where intermediate (8 genotypes) was found dominant compared to prostate (3 genotypes). The branching habit was intermediate in all the genotypes except one sparse and only two genotypes were dense.

Leaf characteristics

Leaf shape was mainly lanceolate (5 genotypes); some genotypes had deltoid (3) and ovate (3) shape leaves. Through a study (Joshi et al., 2020) it is investigated that dark green leaf color more frequent (54.54%) while green color was less frequent (45.46%) in *C. annuum* L. genotypes. In the present investigation dark green leaf color was more (6 genotypes) than green (4 genotypes) and light green (1 genotype) color. The dark green color of leaves is generally due to presence of high chlorophyll content in the leaves which ultimately leads to increased yield. Hence, it becomes a good criterion for selection of elite cultivars group (Pachiyappan and Saravannan, 2016). All the genotypes in the present study had entire leaf margin but leaf pubescence was sparse (4 genotypes), intermediate (3 genotypes) and dense (4 genotypes). The leaf density was equally dense (5 genotypes) and intermediate (5 genotypes) as well as sparse in case of one genotype.

Characterization of reproductive plant parts

The most important advances obtained in the genetic improvement of plants are associated with the knowledge of their reproductive system (Pena-Yam et al., 2019) and thirteen morphological traits of reproductive organ of sweet pepper genotypes are arrayed in Table 3. Flower position highly influences the degree and mode of pollination (Joshi et al., 2020). All of the germplasm showed intermediate flower position and were found having attractive white corolla color which is a desirable trait as it helps in attracting pollinators during the pollination process (Rahman et al., 2017).

Table 2. Different plant growth characteristics of sweet pepper genotypes

Genotypes	Stem color	Nodal antho-cyanin	Stem shape	Stem pube-scence	Plant growth habit	Branc-hing habit	Leaf density	Leaf color	Leaf shape	Lamina margin	Leaf pube-scence
CKN-1	Green with purple streak	Dark purple	Cylindrical	Dense	Prostrate	Sparse	Intermediate	Green	Ovate	Entire	Sparse
CKN-2	Green with purple streak	Dark purple	Cylindrical	Sparse	Intermediate	Intermediate	Intermediate	Dark green	Lanceolate	Entire	Dense
CKN-3	Green	Light purple	Cylindrical	Intermediate	Intermediate	Intermediate	Sparse	Green	Lanceolate	Entire	Intermediate
CKN-6	Green	Light purple	Cylindrical	Intermediate	Intermediate	Intermediate	Intermediate	Green	Lanceolate	Entire	Dense
CKN-7	Green	Light purple	Cylindrical	Sparse	Intermediate	Dense	Dense	Dark green	Ovate	Entire	Dense
CKN-8	Green with purple streak	Light purple	Cylindrical	Sparse	Intermediate	Intermediate	Dense	Green	Lanceolate	Entire	Intermediate
CKN-9	Green	purple	Cylindrical	Intermediate	Prostrate	Intermediate	Dense	Dark green	Deltoid	Entire	Dense
CKN-10	Green	purple	Angled	Sparse	Intermediate	Intermediate	Intermediate	Dark green	Ovate	Entire	Sparse
CKN-11	Green with purple streak	Light purple	Cylindrical	Sparse	Intermediate	Dense	Dense	Dark green	Lanceolate	Entire	Intermediate
CKN-12	Green	Green	Cylindrical	Intermediate	Intermediate	Intermediate	Dense	Light green	Deltoid	Entire	Sparse
CKN-13	Green	Green	Cylindrical	Dense	Prostrate	Intermediate	Intermediate	Dark green	Deltoid	Entire	Sparse

Fruit color of sweet pepper genotypes at different stages is one of the most desirable traits for selecting a suitable inbred line. Attractive fruit color, lesser fruit pubescence and smooth fruit texture are the factors which determine consumer acceptability of the product. Hence, these traits become good selection criterion for a breeder (Joshi et al., 2020). In the present study it was found that fruit color at intermediate stage was green (8 genotypes) and more prominent than lemon green and deep green. Diversified fruit color was observed at mature stage such as Lemon yellow, Orange yellow, Orange, Red, Dark red and Red with purple tint. Among these, red color (4 genotypes) was more dominant (Table 3). Wider variation was found for fruit shape (Fig.1). As per consumer's preference blocky fruits are more preferable and higher number of blocky fruits were observed (6 genotypes) than triangular (4 genotypes) and elongate (1 genotype) shape. Fruits are categorized into four categories based on fruit shape at blossom end as like sunken (5 genotypes), pointed (3 genotypes), blunt (2 genotypes) as well as sunken and pointed (1 genotype). Fruit shape at pedicel attachment was found obtuse (1 genotype), cordate (3 genotypes) and lobate (7 genotypes). Blocky fruit shape, lobate pedicel attachment, sunken blossom end, pendent fruit position and dark green fruit color at maturity are desirable attributes (Sharma et al., 2017). Perfect fruit shape, size and color along with mild taste are the main quality parameters that make the task of developing new genotypes/variety/ hybrids very sticking (Sharma et al., 2020). All the genotypes were devoid of blossom end fruit appendages except CKN- 8 and CKN- 11. As most of the genotypes were blocky, so intermediate corrugation (5 genotypes) found dominant over slightly corrugated (4 genotypes) and corrugated (2 genotypes) at cross section. All the genotypes had straw color seed and most of the genotypes (6 genotypes) contained more than fifty (>50) seeds which were measured from ten fruits in each replication and the average was considered to the number of seed per fruits.

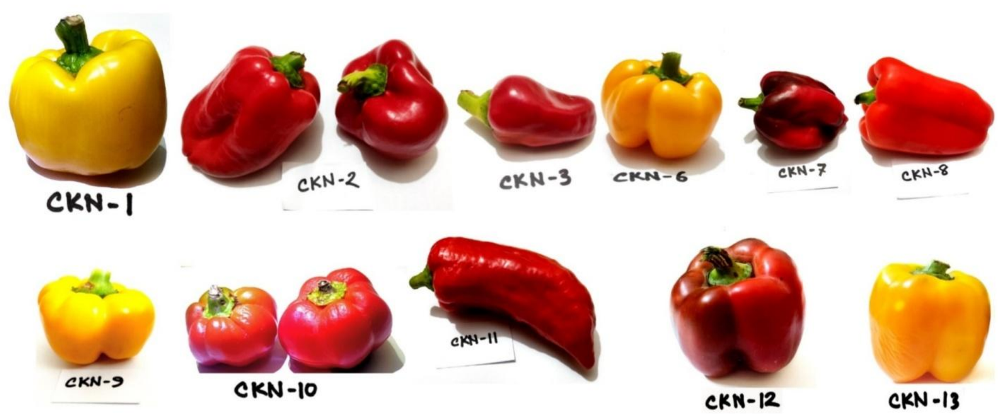

Figure 1. Variation in fruit color, shape and size of eleven genotypes of *Capsicum annuum* L. at mature stage.

Table 3. Morphological characterization of reproductive plant parts of sweet pepper genotypes

Genotypes	Flower position	Corolla color	Fruit set	Fruit color at interm-ediate stage	Fruit color at mature stage	Fruit shape	Fruit shape at blossom end	Fruit shape at pedicel attachment	Fruit blossom end appendage	Fruit surface	Fruit cross sectional corrugation	Seed color	No. of seeds per fruit
CKN-1	Intermediate	White	Intermediate	Lemon green	Lemon yellow	Blocky	Sunken	Lobate	Absent	Smooth	Slightly corrugated	Straw (Deep yellow)	>50
CKN-2	Intermediate	White	High	Green	Dark red	Blocky	Sunken and pointed	Lobate	Absent	Smooth	Intermediate	Straw (Deep yellow)	>50
CKN-3	Intermediate	White	Low	Green	Red	Elongate	Pointed	Obtuse	Absent	Semi-wrinkled	Slightly corrugated	Straw (Deep yellow)	<20
CKN-6	Intermediate	White	Low	Green	Orange	Triangular	Blunt	Lobate	Absent	Semi-wrinkled	Intermediate	Straw (Deep yellow)	20-50
CKN-7	Intermediate	White	Intermediate	Deep green	Red with purple tint	Triangular	Pointed	Cordate	Absent	Semi-wrinkled	Corrugated	Straw (Deep yellow)	20-50
CKN-8	Intermediate	White	High	Green	Red	Triangular	Blunt	Cordate	Present	Smooth	Slightly corrugated	Straw (Deep yellow)	>50
CKN-9	Intermediate	White	Intermediate	Deep green	Orange yellow	Blocky	Sunken	Lobate	Absent	Smooth	Intermediate	Straw (Deep yellow)	20-50
CKN-10	Intermediate	White	Low	Green	Red	Blocky	Sunken	Lobate	Absent	Smooth	Intermediate	Straw (Deep yellow)	20-50
CKN-11	Intermediate	White	Intermediate	Green	Red	Triangular	Pointed	Cordate	Present	Semi-wrinkled	Slightly corrugated	Straw (Deep yellow)	>50
CKN-12	Intermediate	White	Intermediate	Green	Dark red	Blocky	Sunken	Lobate	Absent	Smooth	Corrugated	Straw (Deep yellow)	>50
CKN-13	Intermediate	White	Intermediate	Green	Orange	Blocky	Sunken	Lobate	Absent	Smooth	Intermediate	Straw (Deep yellow)	>50

Correlation among the selected traits of the genotypes

Table 4 presents yield contributing characteristics of sweet pepper genotypes, including plant height, number of fruits per plant, fruit weight, fruit length, fruit diameter, and yield per plant. This data is important for plant breeders and farmers looking to improve crop yield and quality. The data shows that CKN-8 had the highest yield per plant with 362.04 g, followed by CKN-1 with 367.6 g. CKN-10 had the lowest yield per plant with only 118.92 g. Therefore, CKN-8 and CKN-1 are potentially good genotypes for cultivation due to their high yield. Plant height ranged from 30.1 cm to 53.5 cm, with CKN-6 being the tallest genotype and CKN-10 being the shortest. The number of fruits per plant ranged from 2 to 7, with CKN-2 having the highest number of fruits per plant and CKN-3 having the lowest. Fruit weight ranged from 14.16 g to 76.22 g, with CKN-11 having the heaviest fruit and CKN-3 having the lightest. Fruit length ranged from 5.1 cm to 12.1 cm, with CKN-11 having the longest fruit and CKN-6 having the shortest. Fruit diameter ranged from 1.2 cm to 6.4 cm, with CKN-1 having the widest fruit and CKN-3 having the narrowest.

Correlation study indicated that there was a significant positive correlation among fruit length, fruit weight and yield per plant (Table 4). There were also positive correlation between fruit diameter and fruit weight along with no. of fruit per plant and yield per plant. But plant height had a negative correlation with fruit weight and yield per plant (Fig. 2).

Table 4. Yield contributing characters of sweet pepper genotypes

Genotype	Plant height (cm)	No. of fruits/plant	Fruit wt. (gm)	Fruit length (cm)	Fruit diameter (cm)	Yield/plant (gm)
CKN-1	38.5bc	5ab	73.52ab	7.5cd	6.4a	367.6a
CKN-2	50.9a	7a	38.45d	9.1b	4.2d	269.15bc
CKN-3	41.2b	2 c	14.16 e	5.3 g	1.2 e	28.32 f
CKN-6	53.5a	3 bc	34.36 d	5.7 fg	4.5 bd	103.08 e
CKN-7	51.6a	5 ab	43.76 d	7.9 c	5.0 bcd	218.8 cd
CKN-8	33.4de	6 ab	60.34 bc	9.3 b	4.2 d	362.04 a
CKN-9	36.6bcd	4 bc	39.6 d	5.2 g	5.0 bcd	158.4 de
CKN-10	30.1e	3 bc	39.64 d	5.1 g	5.3 b	118.92 e
CKN-11	34.9cd	4 bc	76.22 a	12.1a	4.3 cd	304.88 ab
CKN-12	34.3cde	5 ab	72.94 ab	6.8 de	6.3 a	364.7 a
CKN-13	37.8bcd	4 bc	49.34 cd	6.5 ef	5.2 bc	197.36 d
CV (%)	6.93	21.15	18.83	7.23	12.24	17.28
$LSD_{0.05}$	4.72	2.97	15.71	0.89	0.97	66.306

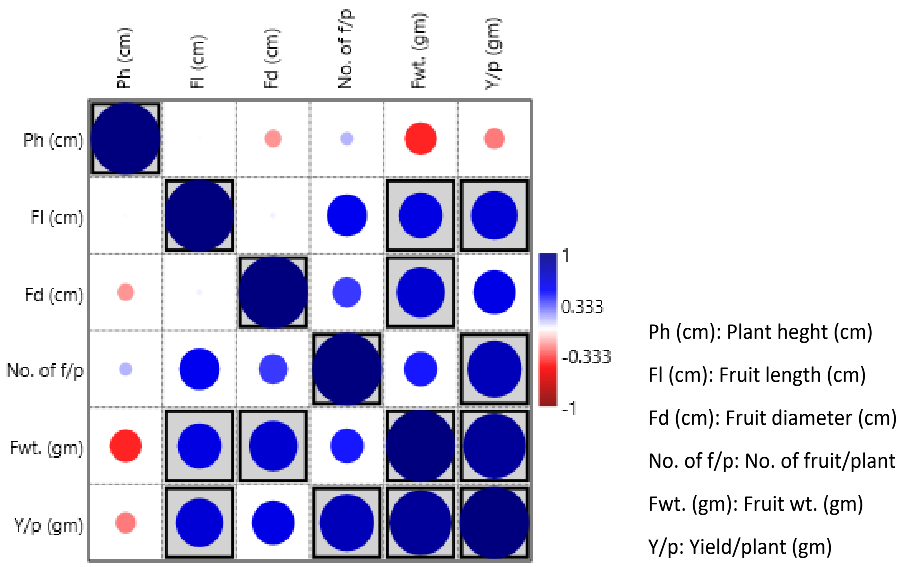

Figure 2. Correlation among the studied traits of the selected Capsicum genotypes.

Genetic dissimilarity analysis

Green colored point showed lowest genetic dissimilar pair while red colored point indicated maximum genetic dissimilarity. In Gower's matrix the genotype CKN-3 was found to be the most dissimilar accession with others followed by CKN-11, CKN-12. The genotype CKN-13 showed higher amount of similarity with another genotypes followed by CKN-9, CKN-7 and CKN-6 (Fig. 3). In this study, genetic distance among eleven sweet pepper genotypes ranged from 0.17 to 0.68.

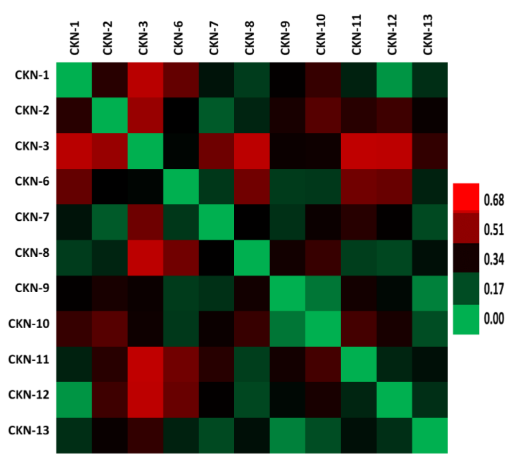

Figure 3. Dissimilarity matrix showing the genetic distances among the genotypes.

CONCLUSION

Based on the above discussion it can be concluded that a distinct morphological variation was observed among eleven sweet pepper genotypes. Among different morphological traits studied, a higher frequency was observed for plant height, nodal anthocyanin, dark green leaves, intermediate branching habit and flower position, blocky fruit shape, green and red color fruit, sunken blossom end shape, fruit length and diameter, fruit weight, yield etc. indicating fitness of genotypes. Finally, the study suggested that the genotypes such as CKN- 1, CKN- 2 and CKN- 8 exhibited desirable characters in various aspects which can be selected for further research programs.

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