Science Research
2015; 3(6): 304-313
Published online November 23, 2015 (http://www.sciencepublishinggroup.com/j/sr)
doi: 10.11648/j.sr.20150306.17
ISSN: 2329-0935 (Print); ISSN: 2329-0927 (Online)

Characterization of Sweet Pepper Genotypes by Using Morphological Traits

Md. Abdus Sattar[1], Md. Nazrul Islam[3], Md. Jahangir Hossain[2], Md. Shahidur Rashid Bhuiyan[4], Md. Ismail Hossain[3]

[1]Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research, Institute, Gazipur, Bangladesh
[2]Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[3]Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh
[4]Department of Genetics and Plant Breeding and Pro-Vice Chancellor, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

Email address:
sattar72@gmail.com (M. A. Sattar), nislam63@yahoo.com (N. Islam), dr.jahangir2011@yahoo.com (M. J. Hossain), ipbscfc2009@gmail.com (M. S. R. Bhuiyan), ismail_sau@yahoo.com (M. I. Hossain)

To cite this article:
Md. Abdus Sattar, Md. Nazrul Islam, Md. Jahangir Hossain, Md. Shahidur Rashid Bhuiyan, Md. Ismail Hossain. Characterization of Sweet Pepper Genotypes by Using Morphological Traits. *Science Research.* Vol. 3, No. 6, 2015, pp. 304-313. doi: 10.11648/j.sr.20150306.17

Abstract: Twenty one genotypes of sweet pepper representing different sources were evaluated in Olericulture Division, Horticulture Research Centre (HRC), BARI, Gazipur during 2012 to 2013. Wide variations were observed among the genotypes for the characters studied. Fruit set percent varied from as low as 63% in CA 018 to as high as 90.66% in CA 016. The longest fruit length was observed in fruits of CA 016 (16.20 cm) and the fruit of the genotype CA 015 (6.80 cm) was the shortest followed by the genotypes CA 019 (8.60 cm) and BARI Mistimorich-1 (8.70 cm). Maximum number of fruits plant^{-1} was observed in CA 016 (90) and minimum was in CA 018 (10). The highest fruit yield plant^{-1} was recorded in CA 016 (7.09 kg) and the lowest in CA 017 (0.5) and CA 003(0.52 kg). Fruits of CA 005 were the heaviest of all (178 g) while the genotype CA 017 produced fruits with minimum weight (23 g).

Keywords: Sweet Pepper (*Capsicum annuum* L.), Selection, Variation and Fruit Yield

1. Introduction

Sweet pepper (*Capsicum annuum* L.) is second most important solanaceous vegetable after tomato grown worldwide both as spice as well as vegetable crop. Due to its high cash value couple with consumption rate the annual trade of sweet pepper is approximately 17% of total spice trade in the world [1]. In India, it is believed that sweet pepper was introduction through the Portuguese in the 16th century [2]. Sweet pepper is grown in all over the Bangladesh and in most areas, some land races are cultivated. The yield of these land races is very low. But, these landraces are heterogeneous and serve as a reservoir of genetic variability for the plant breeder. During 1998-1999 to 2005-2006, the national average yield of sweet pepper was 0.89 ton/ha [3], which is much lower than India. Improving of chilli through developing high-yielding varieties with desirable qualities could reverse the existing trend of low productivity of this crop [4, 5]. In Bangladesh, no pure line has been developed through gene recombination and very few hybrid varieties have been developed by private seed companies. Significant variations on plant type, fruit type, fruit shape, fruit colour were found among the genotypes. But the yield is not up to mark as compared to other renowned sweet pepper cultivars. But in Bangladesh only one high yielding sweet pepper variety has been released by Bangladesh Agricultural Research Institute for cultivation. To meet the present ever increasing demand it is necessary to develop more high yielding varieties. Since there exists a considerable variability of this crop in Bangladesh, it is possible to develop high yielding varieties through breeding approaches like selection.

Presence of variability in a base population is very important for any improvement programme. For crop improvement it is necessary to collect the available genotypes through evaluation and identification and utilized them in breeding programme. Evaluation will provide their rapid, reliable and efficient means of information for their proper utilization. Collection, conservation and maintenance of genotypes are important to develop new varieties as mentioned by Kallo [6]. Again evaluation of genotypes of sweet pepper may lead to select suitable parental line for hybridization programme. Therefore, there is a need for conducting trial with different sweet pepper varieties and find out the varieties most suitable for Bangladesh.

2. Materials and Method

The experiment was conducted at the experimental farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh during winter season 2012-2013. Twenty one sweet pepper genotypes collected from local and exotic sources (Table 1), were chosen for this study. Only BARI Mistimorich-1, the only variety developed by BARI was used as check. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Thirty three days old healthy seedlings were transplanted in the experimental plots on 29 November 2012 in 3m x 1m plots at 50 x 40 cm spacing. Fertilizers and other cultivation practices were applied as per recommendation of the HRC. Data were recorded from 10 plants, randomly selected from the plot of each replication on plant height, number of branches per plant, days to first flower bud initiation, days to first anthesis, days to 50% flowering, number of fruits per plant, individual fruit weight, fruit length, fruit diameter, fruit yield per plant, total yield, number of seeds per fruit, fruit flash thickness, weight of 1000 seeds, dry matter per plant and leaf area index. The data were compiled and analyzed statistically by using MSTAT-C program. The mean comparison was done following the Duncan's Multiple Range Test (DMRT). Regression co-efficient analysis was done following the method described by Gomez and Gomez [7].

Table 1. *Accession number, source of collection and country of origin of collected sweet pepper genotypes.*

Serial no.	Accession number/variety	Source of collection	Country of origin
1.	CA 001	Personal contact	Japan
2.	CA 002	Personal contact	Japan
3.	CA 003	Personal contact	Thailand
4.	CA 004	Personal contact	Netherlands
5.	CA 005	Rajdhani Seed	Denmark
6.	CA 006	Rajdhani Seed	Denmark
7.	CA 007	Alauddin Seed	China
8.	CA 008	Alauddin Seed	China
9.	CA 009	Alauddin Seed	Japan
10.	CA 010	Pasha-pashi Seed	India
11.	CA 011	Pasha-pashi Seed	India
12.	CA 012	Pasha-pashi Seed	India
13.	CA 013	Manik Seed	Italy
14.	CA 014	Manik Seed	India
15.	CA 015	Manik Seed	Thailand
16.	CA 016	Krishibid Nursery	USA
17.	CA 017	Krishibid Nursery	USA
18.	CA 018	BARI	AVRDC
19.	CA 019	BARI	AVRDC
20.	CA 020	BARI	AVRDC
21.	BARI Mistimorich-1	BARI	AVRDC

3. Results and Discussion

3.1. Qualitative Growth Characters

Growth habit, leaf shape, leaf colour, leaf pubescence, fruit shape, fruit shape at pedicel attachment, fruit shape at blossom end, fruit pungency, fruit colour at intermediate stage, fruit set (Before harvesting), fruit colour at mature stage and seed colour in different genotypes of sweet pepper are presented in Table 2.

3.1.1. Growth Habit

Regarding growth habit of plants, the genotypes were categorized into 3 types *viz*. erect, intermediate and prostrate. Ten genotypes (CA 001, CA 002, CA 004, CA 008, CA 009, CA 010, CA 012, CA 013, CA 020 and BARI Mistimorich-1) exhibited intermediate type of growth habit, nine genotypes (CA 003, CA 005, CA 007, CA 011, CA 014, CA 015, CA 017, CA 018 and CA 019) exhibited erect type of growth and the rest two (CA 006 and CA 016) genotypes exhibited prostrate type of growth habit. Savita [8] found that the plants of 'Kunkur-3' variety exhibited open (prostrate) growth habit.

3.1.2. Leaf Shape

Based on leaf shape, the genotypes were classified into 3 *viz*. deltoid, ovate and lanceolate. Among 21 genotypes studied, deltoid leaf shape plants were observed in 6 genotypes (CA 001, CA 005, CA 006, CA 009, CA 013 and CA 018); 11 genotypes (CA 002, CA 004, CA 007, CA 008, CA 011, CA 012, CA014, CA 015, CA 019, CA 020 and BARI Mistimorich-1) were ovate and the rest 4 genotypes (CA 003, CA 010, CA 016 and CA 017) were lanceolate leaf shape type. Lankesh and Prakash [9] found that plants of 'Puri red' and 'Byadagidabbi' varieties were lanceolate and ovate shaped, respectively. The present observation corroborated with their findings.

3.1.3. Leaf Colour

Leaf colour of sweet pepper plants were classified into light green, green and dark green. Among the genotypes plants of 4 genotypes (CA 001, CA 003, CA 009 and CA 017) showed light green, 13 genotypes (CA 002, CA 004, CA 005, CA 007, CA 008, CA 010, CA 012, CA 013, CA 015, CA 018, CA 019, CA 020 and BARI Mistimorich-1) showed green and remaining 4 (CA 006, CA 011, CA 014 and CA 016) dark green type of leaf. Lankesh and Prakash [9] found that plants of 'Puri red' was light green and 'Byadagidabbi' was dark green in nature. The present observations are similar to their findings.

3.1.4. Foliage Density

Foliage densities of sweet pepper plants were classified into sparse, intermediate and dense. Among the genotypes plants of 6 genotypes (CA 001, CA 004, CA 006, CA015, CA 019 and CA 020) showed sparse; 6 genotypes (CA 003, CA 009, CA 013, CA 017, CA 018 and BARI Mistimorich-1) showed intermediate and remaining 9 genotypes (CA 002, CA 005, CA 007, CA 008, CA 010, CA 011, CA 012, CA 014 and CA 016) were dense type of foliage.

3.1.5. Fruit Shape

Based on fruit shape, the genotypes were classified into 6 *viz*. elongate, almost round, triangular, campanulate, blocky and cylindrical. Among the genotypes, 3 (CA 003, CA 016 and CA 017) were elongate type fruit shape; 5 (CA 001, CA 006, CA 007, CA 009 and CA 019) genotypes were triangular. Among the genotypes, 9 (CA 002, CA 004, CA 005, CA 011,CA 012, CA 014, CA 015, CA 020 and BARI Mistimorich-1) were blocky and plants of rest 4 genotypes (CA 008, CA 010, CA 013 and CA 019) were cylindrical.

Table 2. *Qualitative growth characters of sweet pepper plants and fruits.*

Genotypes	Growth habit	Leaf shape	Leaf colour	Foliage density	Fruit shape	**FS at ped. attah.
CA 001	Intermediate	Deltoid	Light green	Sparse	Triangular	Lobate
CA 002	Intermediate	Ovate	Green	Dense	Blocky	Lobate
CA 003	Erect	Lanceolate	Light green	Intermediate	Elongate	Obtuse
CA 004	Intermediate	Ovate	Green	Sparse	Blocky	Cordate
CA 005	Erect	Deltoid	Green	Dense	Blocky	Lobate
CA 006	Prostrate	Deltoid	Dark green	Sparse	Triangular	Cordate
CA 007	Erect	Ovate	Green	Dense	Triangular	Cordate
CA 008	Intermediate	Ovate	Green	Dense	Cylindrical	Truncate
CA 009	Intermediate	Deltoid	Light green	Intermediate	Triangular	Lobate
CA 010	Intermediate	Lanceolate	Green	Dense	Cylindrical	Lobate
CA 011	Erect	Ovate	Dark green	Dense	Blocky	Cordate
CA 012	Intermediate	Ovate	Green	Dense	Blocky	Lobate
CA 013	Intermediate	Deltoid	Green	Intermediate	Cylindrical	Cordate
CA 014	Erect	Ovate	Dark green	Dense	Blocky	Truncate
CA 015	Erect	Ovate	Green	Sparse	Blocky	Cordate
CA 016	Prostrate	Lanceolate	Dark green	Dense	Elongate	Truncate
CA 017	Erect	Lanceolate	Light green	Intermediate	Elongate	Acute
CA 018	Erect	Deltoid	Green	Intermediate	Cylindrical	Cordate
CA 019	Erect	Ovate	Green	Sparse	Triangular	Cordate
CA 020	Intermediate	Ovate	Green	Sparse	Blocky	Cordate
BM-1 *	Intermediate	Ovate	Green	Intermediate	Blocky	Cordate

* BM-1= BARI Mistimorich-1, ** FS at ped. attach= Fruit shape at pedicel attachment

Table 3. *Qualitative characters of fruits in sweet pepper.*

Genotypes	Fruit shape at blossom end	Fruit pungency	Fruit colour (intermediate stage)	Fruit set (Before harvest)	Fruit colour (mature stage)	Seed colour
CA 001	Sunken & pointed	Intermediate	Green	Intermediate	Dark red	Straw (deep yellow)
CA 002	Blunt	Intermediate	Green	Low	Red	Brown
CA 003	Pointed	Intermediate	Light green	Low	Red	Brown
CA 004	Blunted & sunken	Low	Deep green	Intermediate	Orange-yellow	Black
CA 005	Blunted & sunken	Not pungent (sweet)	Green	High	Dark red	Straw (deep yellow)
CA 006	Pointed	Low	Deep green	Low	Light red	Brown
CA 007	Sunken	Dense	Green	High	Red	Straw (deep yellow)
CA 008	Sunken	Dense	Green	Intermediate	Dark red	Black
CA 009	Sunken & pointed	Intermediate	Deep green	Low	Dark red	Black
CA 010	Sunken	Low	Green	High	Dark red	Straw (deep yellow)
CA 011	Sunken	Low	Deep green	High	Dark red	Straw (deep yellow)
CA 012	Sunken	Low	Green	High	Orange-yellow	Straw (deep yellow)
CA 013	Sunken & pointed	Low	Green	Intermediate	Red	Brown
CA 014	Sunken	Not pungent (sweet)	Deep green	High	Orange-yellow	Straw (deep yellow)
CA 015	Sunken	Intermediate	Green	Intermediate	Yellow	Brown
CA 016	Pointed	Low	Green	High	Red	Brown
CA 017	Pointed	High	Deep green	High	Dark green	Black
CA 018	Blunted & sunken	Not pungent (sweet)	Green	Low	Light red	Brown
CA 019	Pointed	Low	Deep green	Intermediate	Dark red	Straw (deep yellow)
CA 020	Sunken & pointed	Intermediate	Green	Intermediate	Dark red	Brown
BM-1 *	Blunted & sunken	Intermediate	Green	Intermediate	Dark red	Straw (deep yellow)

* BM-1= BARI Mistimorich-1

3.1.6. Fruit Shape at Pedicel Attachment

Regarding fruit shape at pedicel attachment, the genotypes were categorized into 5 types *viz*. acute, obtuse, truncate, cordate and lobate. One genotype (CA 017) exhibited acute type, one genotype (CA 003) exhibited obtuse type; 3 (CA 008, CA 014 and CA 016) genotypes exhibited truncate type; 10 genotypes (CA 004, CA 006, CA 007, CA 011, CA 013, CA 015, CA 018, CA 019, CA 020 and BARI Mistimorich-1)exhibited cordate type and plants of 6 genotypes (CA 001, CA 002, CA 005, CA 009, CA 010 and CA 012) exhibited lobate type. Lankesh and Prakash [9] found that plants of 'Puri red' were cordate and 'Byadagidabbi' was lobate type fruit shape at pedicel attachment. The present observations are similar to their findings.

3.1.7. Fruit Shape at Blossom End

Based on fruit shape at blossom end, the genotypes were classified into 5 *viz*. pointed, blunt, sunken, sunken and pointed and blunted and sunken. Among 21 genotypes studied, pointed fruit shape at blossom end plants were observed in 5 genotypes (CA 003, CA 006, CA 016, CA 017 and CA 019); 1 genotype (CA 002) was blunt; 7 genotypes (CA 007, CA 008, CA 010, CA 011, CA 012, CA 014 and CA 015) were sunken; 4 genotypes (CA 001, CA 009, CA 013 and CA 020) were sunken and pointed and rest 4 genotypes (CA 004, CA 005, CA 018 and BARI Mistimorich-1). Lankesh and Prakash [9] found that plants of 'Puri red' and 'Byadagidabbi' varieties were pointed and sunken fruit shaped at blossom end, respectively. The present observation corroborated with their findings.

3.1.8. Fruit Pungency

Regarding fruit pungency, the genotypes were categorized into 4 types *viz*. not pungent i.e. sweet, low, intermediate and high. 3 genotypes (CA 005, CA 014 and CA 018) exhibited not pungent, 8 genotypes (CA 004, CA 006, CA 0010, CA 011, CA 012, CA 013, CA 016 and CA 019) exhibited low; 7 genotypes (CA 001, CA 002, CA 003, CA 009, CA 015, CA 020 and BARI Mistimorich-1) exhibited intermediate type and rest of 1 genotype (CA 017) exhibited highly pungent. Lankesh and Prakash [9] found that plants of 'Puri red' were low and 'Byadagidabbi' was intermediate type fruit pungency. The present observation is similar to their findings.

3.1.9. Fruit Colour at Intermediate Stage

Based on fruit colour at intermediate stage, the genotypes were classified into 3 *viz*. green, light green and deep green. Among 21 genotypes studied, green fruit colour were observed in 13 genotypes (CA 001, CA 002, CA 005, CA 007 CA 008, CA 010, CA 012, CA 013, CA 015, CA 016, CA 018, CA 020 and BARI Mistimorich-1); 1 genotype (CA 003) was light green and rest of 7 genotypes (CA 004, CA 006, CA 009, CA 011, CA 014, CA 017 and CA 019) were deep green. Lankesh and Prakash [9] found that plants of 'Puri red' and 'Byadagidabbi' varieties were deep green and green, respectively. The present observations are similar to their findings.

3.1.10. Fruit Set (Recorded Before Harvest)

Regarding fruit set, the genotypes were categorized into 3 types *viz*. low, intermediate and high. 5 genotypes (CA 002, CA 003, CA 006, CA 009 and CA 018) exhibited low fruit set, 8 genotypes (CA 001, CA 004, CA 008, CA 0013, CA 015, CA 019, CA 020 and BARI Mistimorich-1) exhibited intermediate and rest of 8 genotypes (CA 005, CA 007, CA 010, CA 011, CA 012, CA 014, CA 016 and CA 017) exhibited high.

3.1.11. Fruit Colour at Mature Stage

Regarding fruit colour at mature stage, the genotypes were categorized into 5 types *viz*. dark red, red, orange yellow, light red and yellow. Among 21 genotypes studied, dark red colour were observed in 10 genotypes (CA 001, CA 005, CA 008, CA 009, CA 010, CA 011, CA 017, CA 019, CA 020 and BARI Mistimorich-1); 5 genotypes (CA 002, CA 003, CA 007, CA 013 and CA 016) were red; 3 genotypes (CA 004,CA 012 and CA 014) were orange-yellow; 2 genotypes (CA 006 and CA 018) and rest of 1 genotype (CA 015) was yellow fruit at mature stage. Lankesh and Prakash [9] found that plants of 'Puri red' and 'Byadagidabbi' varieties were dark red and red, respectively. The present observations are similar to their findings.

3.1.12. Seed Colour

Based on seed colour, the genotypes were classified into 3 *viz*. straw (deep yellow), brown and black. Among 21 genotypes studied, straw (deep yellow) seed colour were observed in 9 genotypes (CA 001, CA 005, CA 007, CA 010, CA 011, CA 012, CA 014,CA 019 and BARI Mistimorich-1); 8 genotypes (CA 002, CA 003, CA 006, CA 013, CA 015, CA 016, CA 018 and CA 020) were brown and rest of 4 genotypes (CA 004, CA 008, CA 009, CA and CA 017) were black.

3.2. Quantitative Growth Characters of Sweet Pepper Plants

3.2.1 Plant Height at 120 DAT (cm)

Significant variation was reflected among the genotypes in case of plant height at 120 days after transplanting. The tallest plants were produced by the genotypes CA 003 (117.80 cm) and the lowest plant height was recorded in the genotype CA 017 (74.96 cm) (Table 4). There were no remarkable variation among the plant height of CA 005 (85.17 cm), CA 010 (83.80 cm), CA 011 (85.76 cm), CA 016 (84.15 cm) and CA 020 (84.28 cm). It is about 25% of the total genotypes. Near about 50% of the genotypes produced plants the heights of which ranged from 78.65 cm to 81.74 cm and they are statistically identical with each other.

Table 4. *Plant height, branches per plant, fresh plant weight, dry matter per plant and LAI of 21 sweet pepper genotypes.*

Genotype	Plant height (cm) at 120 DAT	Branches plant^{-1} at 120 DAT	Fresh plant weight (kg)	Dry matter plant^{-1} (g)	LAI
CA 001	81.74 d	32.22 o	1.61jk	268.2jk	4.48 g
CA 002	78.96 f	34.16 n	1.56 lm	263.5 k	4.29 i
CA 003	117.8 a	30.27 p	1.40 p	255.9 l	4.09 k
CA 004	77.92 g	35.20 m	1.47 o	245.1 m	3.99 l
CA 005	85.17 b	39.14 i	2.35 c	391.8 c	5.69 c
CA 006	76.12 h	36.25 l	1.76 h	293.8 h	4.21 j
CA 007	79.85 e	40.87 g	2.23 d	371.8 d	5.78 b
CA 008	80.08 e	37.18 k	1.42 p	236.8 n	4.48 g
CA 009	78.92 f	34.80 m	1.53mn	254.4 l	4.56 f
CA 010	83.80 c	42.19 f	2.45 b	408.4 b	5.09 e
CA 011	85.76 b	43.21 e	1.87 f	311.8 f	5.24 d
CA 012	78.65 fg	44.27 d	2.22 d	369.6 d	5.89 a
CA 013	77.84 g	38.18 j	1.76 h	293.4 h	3.92 m
CA 014	81.29 d	45.25 c	1.85 f	308.4 f	5.09 e
CA 015	80.28 e	43.00 e	1.69 i	281.7 i	3.59 p
CA 016	84.15 c	47.54 a	2.68 a	447.8 a	5.90 a
CA 017	74.96 j	41.26 g	1.64 j	273.4 j	4.39 h
CA 018	75.09 ij	39.88 h	1.59 kl	264.4 k	3.84 n
CA 019	75.87 hi	38.97 i	1.49 no	248.5 m	3.75 o
CA 020	84.28 c	44.28 d	2.04 e	340.1 e	5.08 e
BARI Mistimorich-1	80.12 e	46.08 b	1.80 g	300.1 g	4.39 h
Level of significance	**	**	**	**	**
CV %	4.80	4.90	10.23	10.86	6.32

** = Significant at 1 % level of probability

In a column, means followed by common letters are not significantly different from each other at 1 % level of probability by DMRT

The variation in plant height was might be due to the genetic makeup. The plant height of the plants in the present investigation was partially similar with findings of Valsikova [10], and Ado *et al.* [11]. Olufolaji and Makinde [12] obtained significant variation in plant height of bell pepper plants trialed in Nigeria, which varied from 36.80 to 90.20 cm at final harvest.

3.2.2. Branches Plant^{-1} at 120 DAT

Significant variation was reflected among the genotypes in case of branches plant^{-1} at 120 days after transplanting. Maximum branches plant^{-1} were produced by the genotypes CA 016 (47.54) and minimum branches plant^{-1} was recorded in the genotype CA 003 (30.27) (Table 4). There were no remarkable variation among the branches plant^{-1} of CA 008 (37.18), CA 013 (38.18), CA 018 (39.88) and CA 019 (38.97). It is about 30% of the total genotypes. Near about 40% of the genotypes CA 010 (42.19), CA 011 (43.21), CA 012 (44.27), CA 014 (45.25), CA 015 (43.00) and CA 020 (44.28) produced the branches plant^{-1} of which ranged from 42.19 to 45.25 and they are statistically identical with each other. The variation in branches plant^{-1} was might be due to the genetic makeup. The branches plant^{-1} of the plants in the present investigation was partially similar with findings of Valsikova [10], and Ado *et al.* [11]. Olufolaji and Makinde [12] obtained significant variation in branches plant^{-1} of bell pepper plants trialed in Nigeria, which varied from 20.89 to 35.17 at final harvest.

3.2.3. Fresh Plant Weight

Signification variation in respect of fresh plant weight of sweet pepper at final harvest was revealed due to the influence of different genotypes. The value for this parameter varied from 2.68 g to 1.40 g (Table 4). Fresh weight was the highest (2.68 g) in CA 016 which was statistically identical to CA 010 (2.45 g) while it was the lowest (1.40 g) in CA 003.

3.2.4. Dry Matter Plant^{-1}

Regarding dry matter plant^{-1} of sweet pepper at final harvest, significant variation was observed due to the influence of different genotypes. From table 4, it can be revealed that the highest accumulation dry matter plant^{-1} (447.80 g) was observed in CA 016 which was statistically similar to CA 010 (408.40 g). On the contrary, the lowest dry matter plant^{-1} (236.80 g) was in CA 008, followed by CA 004 and CA 019.

3.2.5. Leaf Area Index (LAI)

Leaf Area Index (LAI) is an important indicator influencing the yield. Leaf area index of sweet pepper at final harvest was found to be influenced significantly by different genotypes, the result of which is presented in table 4. From the table, it can be revealed that the height value of leaf area index was observed in CA 016 (5.90) which was statistically similar to CA 007 (5.78). On the contrary, the lowest value of leaf area index was observed in CA 015 (3.59) which was statistically similar to CA 019 (3.75).

3.2.6. Days to First Flower Bud Initiation (DAT)

The genotypes statistically differed from each other as to the requirement of days to first flower bud initiation (Table 5). Minimum days were required by CA 013 (11.19 DAT), CA 018 (11.96) and CA 004 (11.97). It had been observed that 15, out of 21 genotypes took 12-14 days to first flower bud initiation and this ranged is the lowest. The genotypes CA 007 and CA 008 took 15 days i.e. the former genotypes differed from the later by 3 days. In respect of days to first flower bud initiation CA 016 took maximum of 19 days.

Table 5. *1st flower bud initiation, 1st anthesis, days to 50% flowering, % fruit set, fruit length and fruit diameter of 21 of sweet pepper genotypes.*

Genotype	1st flower bud initiation (DAT)	1st anthesis (DAT)	Day to 50% flowering	% fruit set	Fruit length (cm)	Fruit diameter (cm)
CA 001	12.68 jkl	31.98 j	39.67 m	80.34 f	12.1 d	6.2 g
CA 002	13.56 g	32.34 fg	42.34 j	79.00 g	12.3 c	5.9 h
CA 003	13.34 h	32.19 hi	40.18 l	75.64 i	9.3 m	4.2 k
CA 004	11.97 m	33.16 d	44.75 f	78.12 h	9.3 m	4.9 j
CA 005	14.67 d	33.67 c	39.08 n	83.70 bc	9.0 n	7.1 b
CA 006	13.00 i	32.00 j	43.75 h	74.54 j	12.3 c	5.8 h
CA 007	15.46 b	34.08 b	39.00 n	81.69 de	10.0 j	6.2 g
CA 008	15.08 c	31.98 j	46.36 e	70.57 l	11.8 e	6.8 d
CA 009	12.82 j	32.07 ij	47.65 c	75.28 i	9.7 k	7.0 bc
CA 010	13.64 g	33.08 d	42.09 j	81.24 e	12.5 b	7.7 a
CA 011	12.59 l	33.18 d	41.48 k	82.16 d	11.0 g	7.1 b
CA 012	14.08 e	31.06 k	40.37 l	83.16 c	10.3 i	6.9 c
CA 013	11.19 n	32.44 f	46.42 e	69.18 m	11.8 e	5.9 h
CA 014	12.74 jk	30.54 l	38.84 n	81.33 e	9.5 l	7.0 bc
CA 015	14.18 e	33.67 c	42.67 i	70.28 l	6.8 p	5.0 i
CA 016	19.12 a	37.49 a	49.76 a	90.66 a	16.2 a	6.4 f
CA 017	12.67 kl	31.08 k	47.27 d	72.54 k	11.2 f	2.9 l
CA 018	11.96 m	33.17 d	46.55 e	63.47 n	11.3 f	6.2 g
CA 019	13.87 f	32.28 gh	42.67 i	72.68 k	8.6 o	6.2 g
CA 020	14.09 e	32.16 hi	44.09 g	84.26 b	10.7 h	6.5 e
BARI Mistimorich-1	13.67 g	32.65 e	48.12 b	81.29 e	8.7 o	6.9 c
Level of sig.	**	**	**	**	**	**
CV %	5.56	10.65	8.35	5.36	2.42	4.75

** = Significant at 1 % level of probability

In a column, means followed by common letters are not significantly different from each other at 1 % level of probability by DMRT

3.3. Yield and Yield Contributing Characters

3.3.1. Fruit Length (cm)

The difference in fruit length (cm) among the genotypes was observed to be statistically significant. The longest length was observed in fruits of CA 016 (16.20 cm) and is completely different from the other genotypes (Table 5). On the other hand, the fruit of the genotype CA 015 (6.80 cm) was the shortest followed by the genotypes CA 019 (8.60 cm) and BARI Mistimorich-1 (8.70 cm). Wide variability in respect of fruit length (cm) was exhibited among the genotypes and differed almost from genotype to genotype. Fruit length of bell pepper varied from 21 mm to 90 mm as was found by Olufolaji and Makinde [12]. Fruit length of 8 sweet pepper genotypes ranged from 56 mm 91 mm when performance trial was done at KamphaengSaen, Nakhon, Thailand [13].

3.3.2. Fruit Diameter (cm)

There had an appreciable variation among the genotypes under study pertaining to the fruit diameter. It varied from 2.90 cm to 7.71 cm (Table 5). The genotype CA 010 had the widest diameter and it did not differ from the other two genotypes *viz.* CA 005 (7.10 cm) and CA 011 (7.10 cm). The fruit diameters of CA 009, CA 014, CA 012 and BARI Mistimorich-1 were found not to vary from each other. The genotype CA 017 showed the lowest fruit diameter and it was also found to be solely different from the rest 20 genotypes. Four genotypes CA 001, CA 007, CA 018 and CA 019 produced fruits with same diameter 6.20 cm. In all the genotypes it was evident that the diameter of fruit did not exceed the length of the fruit. Olufolaji and Makinde [12] found fruit diameter of bell pepper ranging from 20 mm to 40 mm; the lowest being nearer to CA 017 and the highest to the CA 003 of the present investigation.

3.3.3. Number of Fruits Plant^{-1}

Contribution of yield requires the study of the yield attributes of twenty one sweet pepper genotype and number of fruits plant-1 is one of the precious parameter which determines the yield and it was recorded as such. There were significant influences of the number of fruits plant-1 (Fig. 3). The variation was found wide starting from as low as 10 plant-1 in CA 018 and CA 015 to as high as 90 in number in CA 016. The number of fruits produced plant-1 of the genotype CA 020 (44) ranked the second among the twenty one followed by the entry CA007 (36), CA 012 (36) and CA 010 (35). But interesting results were reflected pertaining to the fruits produced plant-1 is that among seven genotypes produced tremendously lower number of fruits and there had not have remarkable variation among the seven when statistical mean separation was performed. It ranged from only 11 to 15 i.e. the highest and the lowest number differed by only 4. Three genotypes out of 21 produced fruits which varied from 21.93 to 22.29 in number i.e. the highest and lowest number differed by only 0.35. Depestre and Gomez [1] recorded 10.50 to 18.38 numbers of fruits plant^{-1} in Cuba during off-season whereas; Olufolaji and Makinde [12] reported highest variability among the bell pepper germplasm. The number being varied from 20 to 124. But Rylski and Spigelman [14] obtained only around 8.5 in bell per genotype 'Maor" on an average. Contrasting to this, Hegde [15] recorded only 6.8 to 7.7 numbers of fruits plant^{-1} under different moisture levels at Bangalore in India when the variety used was 'California Wonder'.

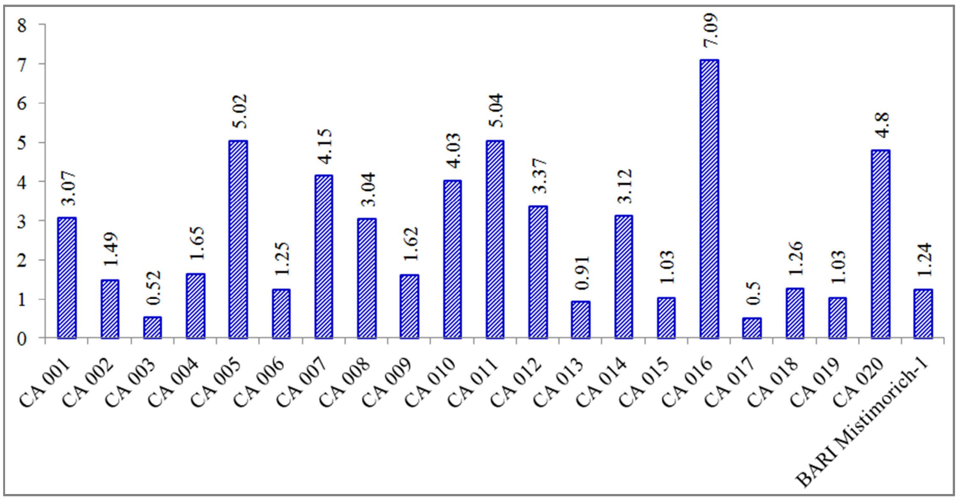

Fig. 1. *Fruit yield plant^{-1} (kg) of different sweet pepper genotypes.*

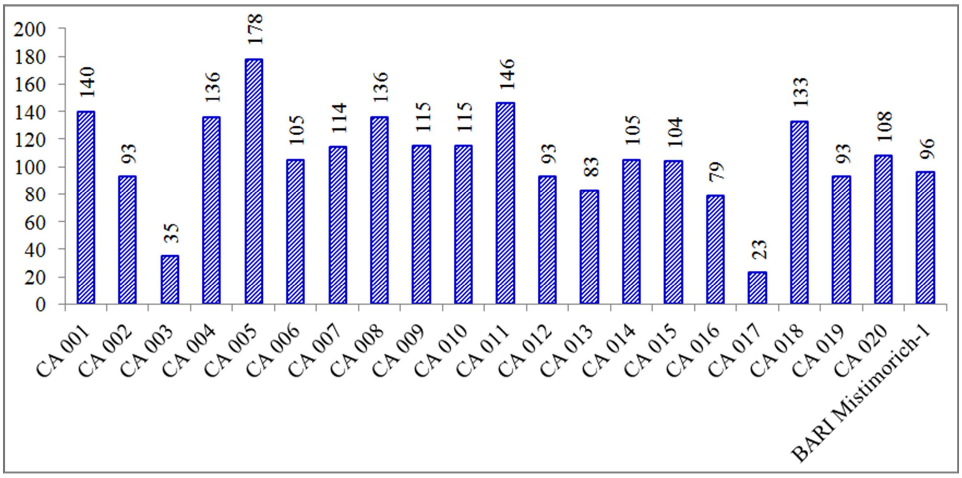

Fig. 2. *Individual fruit weight (g) of different sweet pepper genotypes.*

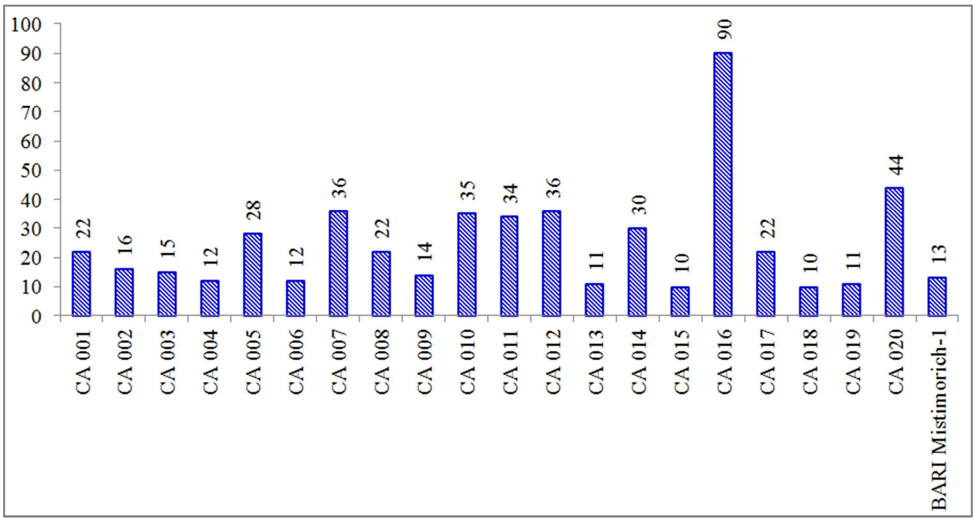

Fig. 3. *Number of fruits plant^{-1} of different sweet pepper genotypes.*

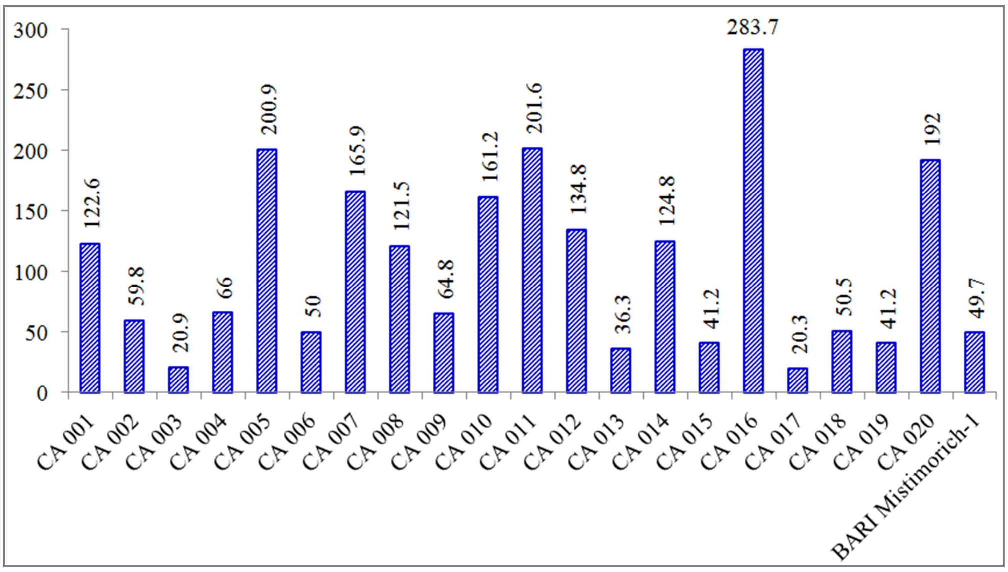

Fig. 4. *Fruit yield (t ha^{-1}) of different sweet pepper genotypes.*

3.3.4. Fruits Yield Plant^{-1}

Yield plant^{-1} is one of the important determiners to assess the yield potentiality of the particular variety concerned and therefore, this parameter was studied in the present investigation. Yield plant^{-1} was recorded in kilogram and it was found to vary significantly among the investigated genotypes.

Fruit yield plant^{-1} varied from 0.52 to 7.09 kg. The highest yield was recorded in CA 016 and the lowest in CA 017 and CA 003 (Fig. 1). The difference in plant^{-1} yield was not found to be significant among CA 013 (0.91 kg), CA 019 (1.03 kg) and CA 015 (1.03 kg); among CA 002 (1.49 kg), CA 009 (1.62 kg) and CA 004 (1.65 kg); among BARI Mistimorich-1 (1.24 kg), CA 006 (1.25 kg) and CA 018 (1.26 kg). The second highest yielder genotype was CA 011 (5.04 kg) that was statistically similar to the genotype CA 020 (4.8 kg). The higher yield of CA 016, CA 011 and CA 020 were due to the individual fruit weight. The higher number of fruits plant^{-1} was produced by CA 016, CA 005, CA 020 and CA 010 at the same time their individual fruit weight were very high which consequently contributed to the higher yield of the genotypes CA 005, CA 020 and CA 010 except CA 106. Aliyu and Olarewaju [16] found plant^{-1} yield of different sweet pepper accessions ranging from 21.00 g to 123.31 g in Nigeria whereas, Anand and Deshpande [17] recorded 182.6 g in 2005 and 157.9 g in 2006 mean fruit yield plant^{-1} during summer season in South Indian when 16 genotypes were trailed. Olufolaji and Makinde [12] obtained comparatively higher plant^{-1} yield against the present investigation which varied from 299.2 g to 360 g. Meanwhile, Depestre and Gomez [18] reported higher yield compared to Olufolaji and Makinde [12] in India which ranged from as low as 300.00 g in HD-12 to as high as 400 g in HD-60. But none found plant^{-1} yield more than 500 g as obtained in the present study indicating a bright possibility of growing sweet pepper under the agro-climatic condition of Bangladesh.

3.3.5. Individual Fruits Weight (g)

Whenever, the mean single fruit weight was taken from the five fruits produced at different nodes of each of the genotype, it could be easily seen a significant variation among the genotypes as evident in Fig. 2. Fruits of CA 005 were the heaviest of all (178 g) while the genotype CA 017 produced fruits with minimum weight (23 g). The fruits of CA 016 were completely different from the rest 20 genotypes when single fruit weight was recorded only 79 g. Individual fruit weight of three genotypes *viz*. CA 006, CA 014 and CA 015 could not be detected to be statistically diversified. Further, statistically similar mean fruit weight was also evident among CA 007, CA 009 and CA 010 with 114 g, 115 g and 115 g, respectively. The other three genotypes namely CA 001, CA 003 and CA 016 were completely different from the rest nine genotypes when single fruit weight was considered while the genotype CA 002 showed statistically identical weight with that of CA 012.

During off-season in Cuba when the average temperature was 28^{0}C, some sweet pepper genotypes produced fruits in the field where the mean individual fruit weight ranged from 24.78 g to 136.12 g [18]. The mean fruit weight of CA 002, CA 003, CA 004, CA 006, CA 007, CA 009, CA 010, CA 012, CA 013, CA 014, CA 015, CA 016, CA 017, CA 018, CA 019, CA 020 and BARI Mistimorich-1 were within the range of what they found. The low fruit weight of bell pepper under different moisture regimes was also observed by Hedge [15] at Bangalore in India. In South India, during summer season the average fruit weight varied from 27.9 g to 90.5 g [17]. On the other hand, Rylski and Spigelman [14] observed mean weight higher than 100 g under different shading situations. Further, Bakker [19] recorded mean fruit weight of sweet pepper ranging from 119.7 g to 131.9 g under different humidity treatments.

3.3.6. Fruit Yield (t ha^{-1})

The performance of the twenty one genotypes was accomplished under the agro-climatic and edaphic conditions of Bangladesh especially in the field of Horticulture Research Centre of the Bangladesh Agricultural Research Institute, Gazipur and the ultimate goal of the performance trial was to estimate the yield potentialities of the genotypes. Fruit yield (t ha^{-1}) of the genotypes varied remarkably (Fig. 4). It ranged from 20.3 t ha^{-1} in CA 003 to 283.7 t ha^{-1} in CA 016. The second highest yield was calculated in CA 005 (200.9 t ha^{-1}) and CA 011 (201.6 t ha^{-1}) followed by the genotypes CA 020 (192 t ha^{-1}). The intermediate yields were in CA 007 (165.9 t ha^{-1}), CA 010 (161.2 t ha^{-1}) and CA 012 (134.8 t ha^{-1}). Hernandez [20] observed *Capsicum annuum* yield (t ha^{-1}) to be ranged from 6.27 to 17.06 ton but Hedge [15] found sweet pepper yield varied from 17.54 t ha^{-1} to 25.97 t ha^{-1} at different moisture levels and 17.63 t ha^{-1} to 28.96 t ha^{-1} at different nitrogen level in India.

3.3.7. Marketable Fruits Yield ha^{-1}

Harvested fruit that was higher than 60 g in weight was considered as marketable fruit. Marketable fruit yield ha^{-1} is one of the important determiners to assess the yield potentiality of the particular variety concerned and therefore, this parameter was studied in the present investigation. Marketable fruit yield ha^{-1} was recorded in gram and it was found to vary significantly among the investigated genotypes.

Table 6. *Marketable yield, cull yield, seeds fruit^{-1} and 1000 seed weight of 21 sweet pepper genotypes.*

Genotype	Marketable yield (t ha^{-1})	Cull yield (t ha^{-1})	Number of seeds $fruit^{-1}$	1000 Seed weight (g)
CA 001	118.80 f	3.77 f	56.13 l	8.85 a
CA 002	59.62 g	3.14 g	74.63 jk	5.55 l
CA 003	20.60 j	0.27 i	33.07 n	5.23 m
CA 004	64.03 g	1.98 h	183.10 a	8.10 d
CA 005	195.80 b	5.08 de	109.20 g	6.82 i
CA 006	49.77 h	0.27 i	86.97 i	6.53 j
CA 007	161.90 d	3.96 f	71.56 k	8.43 c
CA 008	117.40 f	4.10 f	150.10 b	8.94 a
CA 009	61.06 g	3.78 f	54.91 l	8.73 b
CA 010	157.20 d	4.03 f	77.19 j	8.07 d
CA 011	195.00 b	5.93 c	99.18 h	7.71 e
CA 012	130.10 e	4.71 e	154.20 b	8.02 d
CA 013	33.48 i	3.07 g	115.20 f	7.10 h
CA 014	119.30 f	5.48 cd	185.10 a	8.11 d
CA 015	33.98 i	7.24 b	55.47 l	7.71 e
CA 016	271.80 a	11.91a	125.10 e	7.21 g
CA 017	18.32 j	1.79 h	26.74 o	5.67 k
CA 018	46.68 h	3.78 f	95.61 h	7.47 f
CA 019	36.12 i	5.07 de	50.76 m	7.41 f
CA 020	184.40 c	7.65 b	145.50 c	7.04 h
BARI Mistimorich-1	44.09 h	5.56 cd	136.10 d	7.76 e
Level of significance	**	**	**	**
CV %	4.25	5.67	4.98	4.13

** = Significant at 1 % level of probability

In a column, means followed by common letters are not significantly different from each other at 1 % level of probability by DMRT

Marketable fruit yield varied from 18.32 ton ha^{-1} to 271 ton ha^{-1} (Table 6). The highest yield was recorded in CA 016 and lowest in CA 017 and CA 003. The second highest marketable yielder genotypes were CA 005 (195.80 t ha^{-1}) CA 011 (195 t ha^{-1}). The higher marketable yield of CA 016, CA 005 and CA 011 were due to the higher number of fruits and individual fruit weight.

3.3.8. Cull Fruits Yield ha^{-1}

Fruit that was lower than 60 g in weight was considered as cull fruit. Statistical variability was exhibited regarding cull fruits yield ha^{-1} of twenty one sweet pepper genotypes (Table 6). It varied from 0.27 ton ha^{-1} to 11.91 ton ha^{-1}. The highest cull yield was recorded in CA 016 and the lowest in CA 003 and CA 006. The second highest cull yield ha^{-1} was calculated in CA 015 (7.65 t ha^{-1}) and CA 020 (7.65 t ha^{-1}) followed by the genotypes CA 011 (5.93 t ha^{-1}), BARI Mistimorich-1 (5.56 t ha^{-1}), CA 014 (5.48 t ha^{-1}), CA 005 (5.08 t ha^{-1}) and CA 019 (5.07 t ha^{-1}).

3.3.9. Number of Seeds $Fruit^{-1}$

The number of seeds produced $fruit^{-1}$ was counted to see the seed production potentialities of the sweet pepper genotypes under study. They showed wide variation regarding the number of seeds produced $fruit^{-1}$ (Table 6). In respect of seed production potentiality the genotype CA 014 topped the list producing around 185 seeds $fruit^{-1}$ while CA 004 produced 183 and these two genotypes were lettered as ‘a’ indicating no significant difference between the two. The second highest number of seeds $fruit^{-1}$ produced by the genotypes CA 012 (154.20) and CA 008 (150.10) which were not statistically significant. Five genotypes *viz*. CA 005, CA 013, CA 016, CA 020 and BARI Mistimorich-1 produced fruits with mean seed number more than 100 fruit^{-1} but less than 150. About 29 % genotypes produced fruits with mean seed number more than 70 but < 100. Only CA 003 and CA 017 had shown poor performance as regards the production of seeds fruit^{-1} through numerical values of 33.07 and 26.74, respectively. Rylski and Spigelman [14] observed the number of seeds fruit^{-1} to be 149 in open field conditions using the variety 'Maor'. Pressman *et al.* [21] found seeds fruit^{-1} upto 162 in number in the variety Mazurka of sweet pepper when three lines pollination were done and 319 seeds fruit^{-1} under the same pollination pattern. Rylski and Spigelman [14] found 244 to 304 seeds fruit^{-1} under different shading percentages. On the contrary, Bakker [19] observed the number of seeds fruit^{-1} varied from 79.2 to 119.2 at different day/night temperature conditions. Sanchez *et al.* [22] found maximum 458 seeds fruit^{-1} when 60 cm plant to plant spacing was followed in bell pepper.

3.3.10. 1000 Seed Weight (g)

Significant variation among the genotypes was observed for 1000 seed weight presented in Table 6. The ranges of 1000 seed weight varied from 5.23 g to 8.94 g. Maximum weight was recorded in CA 008 and the lowest in CA 003. Higher seed weight during winter was accounted might be due to increased synthesis of plant hormones along with other favorable factors for seed formation under optimum temperature.

4. Conclusion

The genotypes of sweet pepper showed variation in morphological as well as quantitative traits. On the basis of yield, fruit quality and fruit colour, the genotypes CA 005, CA 007, CA 010, CA 011, CA 012, CA 014, CA 016 and CA 020 were found to be promising under Bangladesh condition. Considering yield performance and physio-morphological characters, the genotypes CA 005, CA 007, CA 010, CA 011, CA 012, CA 014, CA 016 and CA 020 may be considered better parents for future hybridization programme.

Acknowledgement

The work has been carried out in Ph.D. programme under the financial support of Bangladesh Agricultural Research Institute (BARI), Government of Bangladesh for professional fellowship through IQHDP programme.

References

[1] Ahmed J, Shivhare U S, Raghavan GSV. (2000). Rheological characteristics and kinetics of color degradations of green chili puree. J Food Eng 44(2): 239-244.

[2] Singh PK, Dasgupta SK, Tripathi SK. 2004. Hybrid vegetable development. International book distribution co. Lucknow, India.

[3] BBS (Bangladesh Bureau of Statistics). (2007). Statistical year book 2006. Bangladesh bureau of statistics, Ministry of Planning, GOB. Dhaka, Bangladesh. ISBN 984-508-814-7.

[4] Verma SK, Singh RK, Arya RR. (2004). Genetic variability and correlation studies in chillies. Progressive Hort 36: 113-117.

[5] Sreelathakumary I, Rajamony L. (2002). Variability, heritability and correlation studies in chilli (*Capsicum* spp.) under shade. Indian J Hort 59: 77-83.

[6] Kallo S. (1988). Vegetable breeding. Vol. III, CRC Press Inc. Florida, USA Chapter I. 1-40.

[7] Gomez KA, Gomez AA. 1984. Statistical procedure for agricultural research. (2nd ed.). John Wiley and Sons, Inc. Singapore 150-324.

[8] Savita M, Mantri M. (2009). "Kunkur-3" a new sweet pepper cultivar from Plant Research International. Acta Hortic 358(1): 153-157.

[9] Lankesh K R, Prakash PV. (2008). Sweet pepper cultivar 'Puri red' and 'Byadagi dabbi'. Vedecke-Prace- Ovocnarske 18(2): 169-174.

[10] Valsikova M. (2009). Czechoslovak sweet pepper cultivars. Capsicum News letter 8-9: 20-21.

[11] Ado SG, Samarawira I, Olarewaju JD. (2007). Evaluation of local accessions of pepper (*Capsicum annuum* L.) Atn Samaru, Nigeria. Capsicum Newsletter 18(2): 17-18.

[12] Olufolaji AO, Makinde M J. (2004). Assessment of the Vegetative, reproductive characters and fruit production pattern of pepper cultivars (*Capsicum* spp). Capsicum and Eggplant Newsletter 13: 54-57.

[13] Anonymous. (1998). Pepper Physiology: Growth and partitioning of dry matter. Progress Rept. Asian Vegetable Research and Development Center 11: 88-97.

[14] Rylski I, Spigelman M. 1996. Use of shading to control the time of harvest of red-ripe pepper fruits during the winter season in a high-radiation dessert climate. Scientia Hort 29:37-45.

[15] Hegde DM. (1998). Irrigation and nitrogen requirement of bell pepper (*Capsicum annuum* L). Indian J. Agril. Sci 58(9): 668-672.

[16] Aliyu L, Olarewaju JD. (2004). Variation in morphological and agronomic characters in sweet pepper (*Capsicum annuum* L.). Capsicum and Eggplant Newsletter 13: 52-53.

[17] Anand N, Deshpande AA. (2006). Breeding bell peppers for summer. Capsicum Newsletter 5: 29-30.

[18] Depestre T, Gomez O. (2005). New sweet pepper cultivars for Cuban off season production. Capsicum and Eggplant Newsletter 14: 47-49.

[19] Bakker JC. (1998). The effect of air humidity on flowering, fruit set, seed set and fruit growth and yield of sweet pepper. Netherlands J. Agril. Sci 36(2): 201-208.

[20] Hernandez JH. (2005). Yield performance Jalapeno pepper cultivars (*Capsicum annuum* L.). Capsicum and Eggplant Newsletter 19: 86-90.

[21] Pressman E, Moshkovitch H, Rosenfeld K B, Aloni B. (2008). Influence of low night temperatures on sweet pepper flower quality and the effect of repeated pollination, with viable pollen, on fruit setting. J. Hort. Sci. and Biotech 48(4): 238-244.

[22] Sanchez VM, Sundstrom FJ, Mc Clure GN, Lang NS. (2003). Fruit maturity, storage and postharvest maturation treatments affect bell pepper (*Capsicum annuum* L.) seed quality. Sci. Hortic 54: 191-201.