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Genotypic and Seasonal Variation in Plant Development and Yield Attributes in Tomato (*Lycopersicon esculentum* Mill.) Cultivars

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Abstract: Morphological attributes and yield of eight genotypes of tomato namely, J-5, Binatomato-5, BARItomato-7, CLN-2026, CLN-2366, CLN-2413, CLN-2418 and CLN-2443 were studied over three seasons. Effects of seasonal and genotypic variations and their combination on plant height, number of primary branches per plant, number of flower clusters per plant, number of fruit clusters per plant, number of fruits per plant, individual fruit weight, fruit yield were significant. Fruit yield and almost all the morphological attributes of tomato genotypes were at peak in winter followed by pre-winter and summer season. Over three seasons, the genotype CLN-2413 produced the highest fruit yield followed by BARI tomato-7 producing the tallest plants with maximum number of primary branches and the highest number of fruits per plant. The genotypes Binatomato-5, CLN-2026 and CLN-2418 ranked 3rd and CLN-2366 and CLN-2443 ranked 4th with respect to yield performance. The genotype J-5 produced the lowest number of fruits per plant and fruit yield. In winter, fruits number and yield were highest in CLN-2413 while BARI tomato-7 carried the statistically same rank.

Key words: Tomato, yield, yield attributes, growing season

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to family Solanaceae and genus *Solanum* is one of the most important vegetables after potato (*Solanum tuberosum* L.) and sweet potato (*Ipomoea batatus* L.) in the world and in Bangladesh (Food and Agriculture Organization, 2005). Moreover, it is top listed in canned vegetables. A large number of tomato varieties grow in Bangladesh however, most of them lost their potential due to genetic deterioration, diseases and insect infestations. In order to increase tomato production in Bangladesh, it is essential to identify cultivars capable of year-round production with higher yield and resistance to pests. There exists a few high yielding and disease and insect resistant varieties but these do not perform better throughout the year because of photo-sensitiveness and less adaptability (Hannan *et al*., 2007).

Tomato is cultivated in all parts of Bangladesh and is adaptable to wide range of soil and climate (Ahmed *et al*., 1986). Tomato is a highly perishable fruit and rapidly deteriorates after ripening. Nutritive value of the fruit is an important aspect of quality in tomato. Concerning food value, it is very rich because of higher contents of vitamin A, B and C including calcium, iron and other minerals (Bose and Som, 1990). It is a nutritious and delicious vegetable used in salad, soups and processes into stable products like ketchup, sauce, pickles paste, chutney and juice. Lycopene in tomato is a powerful antioxidant and reduces the risk of prostate cancer (Hossain *et al*., 2004).

Tomatoes are grown during winter (November to April) in Bangladesh during winter, when rainfall is scarce and about 250 mm of soil moisture is exhausted by evapotranspiration. Tomato requires day temperature of 21-28°C and moderately cool night temperature of 15-20°C for proper fruit setting (Grubben, 1977). Temperature (both day and night), humidity, rainfall and light intensity are the basic limiting factors in tomato production (Adams *et al*., 2001). High daytime temperature and night temperatures above 32 and 21°C, respectively, limit fruit set due to impaired physiological process in the pistil leading to floral or fruit abscission (Mohanty, 2002; Pearce *et al*., 1993). Different countries released much more varieties of tomato compared to Bangladesh by conducting more research while limited research work on tomato has been conducted in Bangladesh and hence number varieties is also limited.

Average yield of tomato in Bangladesh in 2002-2003 was 6.46 t ha^{-1} in Bangladesh (BBS, 2005), while it was

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69.41 t ha^{-1} in USA, 59.26 t ha^{-1} in Japan, 26.13 t ha^{-1} in China, 14.27 t ha^{-1} in India and 13.25 t ha^{-1} in Indonesia (FAO, 2005). In Bangladesh, tomato has great demand throughout the year especially from September to October, but its production is mainly concentrated during the winter season. To meet demand, it is highly important to increase the yield of tomato per unit area of land. Increase in production depends on many factors, such as use of improved varieties, proper management and awareness about improved production technologies. We believe that different types of techniques, such as nuclear techniques, fertilizer management, proper spacing, applying plant growth regulators, synthetic mulching, natural mulching and conventional breeding methods may improve yield and quality under existing environmental conditions. Therefore, the eight tomato genotypes (2 varieties and 6 exotic lines) were used in this experiment to evaluate some morphological attributes and yield of tomato genotypes; in order to select the better genotypes of tomato with respect to yield performance.

MATERIALS AND METHODS

The experiment was carried out at the experimental field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during July 2006 to June 2007. The experimental site is located in the sub-tropical zone at 24°75'N latitude and 90°50'E longitude, 18 m altitude, characterized by heavy rainfall, high humidity, high temperature and relatively long days during June to September and scanty rainfall associated with moderately low temperature, low humidity and short days during winter season. The soil is a silty loam in texture having the pH value 6.5. The land was ploughed and well pulverized by a power tiller and subsequent laddering. Manure and fertilizers were used at 10 tone of composted cowdung, 100 kg N (as urea), 50 kg P (as triple super phosphate) and 125 kg K (as muriate of potash) per hectare. Total amount of cowdung and triple super phosphate and half of urea and muriate of potash were applied during land preparation. The remaining half of urea and muriate of potash were applied 30 and 50 Days after Transplanting (DAT) in two equal splits.

The experiment was set in a randomized complete block design with three replications. The experiment was composed of eight tomato genotypes, J-5, Binatomato-5, BARItomato-7, CLN-2026, CLN-2366, CLN-2413, CLN-2418 and CLN-2443. Seedlings were raised in pots. Thirty-day-old seedlings were transplanted onto the experimental plot in the afternoon of 31 July for pre winter, 4 November for winter 2006 and 4 March 2007 for summer season, respectively. Gap filling was done within a week with, the healthy seedlings of same genotypes previously planted in the border area. Weeding and mulching were accomplished as necessary. Seedlings were watered daily in the morning until 20 Days After Planting (DAP). This watering for any of the seasons and the following the irrigation treatments till harvest. Plants were supported by sticks. White flies were controlled with Dimecron 50 EC in 2 ml L^{-1} water at 15 days interval. Precautionary measures against disease infestation, especially late blight was done biweekly by spraying Dithane M-45 in 2 g L^{-1} of water.

Data were collected from 10 randomly selected plants in each plot. Data of plant height, number of primary branches, number of flower clusters, number of fruit clusters, number of fruits per plant, individual fruit weight, fruit yield (kg plant^{-1}) and fruit yield (t ha^{-1}) were compiled and analyzed statistically following factorial experiment over season with MSTAT-C software. Differences among the genotypes and treatment means were compared by Duncan's new multiple range test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: Plant height differed significantly between seasons (Table 1). Plants grew taller in winter compared to other seasons which did not show variation in plant height. The tallest plant (109.4 cm) was obtained from the genotype BARItomato-7, which was statistically similar to Binatomato-5. In contrast, the shortest plant (86.2 cm) was observed in genotype CLN-2443. Present results are in agreement with earlier reports of genotypic variations with regard to plant height by Mehta and Asati (2008) and Singh *et al.* (2002a, b).

The effects of the interaction between seasons and genotypes were significant on the plant height (Table 2). The tallest plant (113.3 cm) was obtained from BARItomato-7 and Binatomato-5 in winter. The shortest

Table 1: Morphological attributes of tomato genotypes over seasons

Treatments	Plant height (cm)	Primary branches	Flower clusters	Fruit clusters
		(No. plant^{-1})		
Season				
Pre-winter	96.5b	5.1ab	14.2b	9.6b
Winter	98.3a	5.5a	15.6a	10.4a
Summer	94.9b	4.8b	13.0c	8.6c
Genotype				
J-5	98.1b	4.2d	11.0e	8.6bcd
BINA tomato-5	107.4a	7.2a	14.2c	8.2cd
BARI tomato-7	109.4a	7.3a	16.4b	8.8bc
CLN-2026	90.4cd	3.4d	14.2c	7.3e
CLN-2366	100.1b	6.3b	23.4a	17.2a
CLN-2413	88.8de	5.2c	12.6d	7.8de
CLN-2418	92.2c	3.6d	10.1e	9.1b
CLN-2443	86.2f	4.1d	12.3d	9.3b

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Table 2: Morphological attributes based on interaction between seasons and tomato genotypes

Seasons× genotypes	Plant height (cm)	Primary branches	Flower clusters	Fruit clusters
		----------------(No. plant^{-1})----------------		
S_1V_1	96.6def	4.3fgh	11.0j-m	8.6c-g
S_1V_2	106.0bc	7.0abc	14.0e-i	8.3d-h
S_1V_3	109.0ab	7.3ab	16.3de	8.6c-g
S_1V_4	90.0g-j	3.3h	14.0e-i	7.0hi
S_1V_5	100.6d	6.3bcd	23.3b	18.3a
S_1V_6	90.0g-j	5.0d-g	12.6g-k	7.6f-i
S_1V_7	93.0fgh	3.6gh	10.0 lm	9.0c-f
S_1V_8	86.6ij	4.3fgh	12.3h-l	9.3cde
S_2V_1	100.3d	4.3fgh	11.6i-m	9.3cde
S_2V_2	110.0ab	8.0a	15.3def	9.0c-f
S_2V_3	113.3a	8.0a	17.6cd	10.0c
S_2V_4	91.0ghi	3.6gh	15.0efg	8.3d
S_2V_5	101.3cd	7.0abc	27.6a	19.0a
S_2V_6	89.0hij	6.0b-e	14.3e-h	8.3d-h
S_2V_7	95.0efg	3.6gh	10.6klm	9.6cd
S_2V_8	87.0ij	4.0gh	12.6g-k	10.0c
S_3V_1	97.3def	4.0gh	10.3klm	8.0e-i
S_3V_2	106.3bc	6.6abc	13.3f-j	7.3ghi
S_3V_3	106.0bc	6.6abc	15.3def	8.0e-i
S_3V_4	90.3g-j	3.3h	13.6f-i	6.6i
S_3V_5	98.3de	5.6c-f	19.3c	14.3b
S_3V_6	87.6hij	4.6e-h	11.0j-m	7.6f-i
S_3V_7	88.6hij	3.6gh	9.6m	8.6c-g
S_3V_8	85.0j	4.0gh	12.0h-m	8.6c-g

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. S_1: Pre winter, S_2: Winter, S_3: Summer, V_1: J-5, V_2: Binatomato-5, V_3: BARItomato-7, V_4: CLN-2026, V_5: CLN-2366, V_6: CLN-2413, V_7: CLN-2418, V_8: CLN-2443

plant (85.0 cm) was obtained from CLN-2443 in summer, which was statistically similar to CLN-2026, CLN-2413, CLN-2443 in pre-winter, CLN-2413, CLN-2443 in winter, CLN-2026, CLN-2413 and CLN-2418 in summer.

Number of primary branches: There was significant variation in the number of primary branches per plant among the seasons (Table 1). The highest number of primary branches per plant (5.5) was observed in winter followed by pre-winter season and the lowest number was found in summer season. Number of primary branches showed significant variation among the tomato genotypes (Table 1). The highest number of primary branches per plant (7.3) was observed in BARItomato-7, which was statistically similar to Binatomato-5. The lowest number of primary branches per plant (3.4) was observed in CLN-2026, which was identical to J-5, CLN-2418 and CLN-2443. The above results of variability in branching were in full agreement with the earlier workers (Dutta *et al*., 1995; Ghosh *et al*., 1995). Difference in number of branching in the genotypes may be due to its genetic potential.

The interaction effects of seasons and genotypes were significant on the number of primary branches per plant (Table 2). The highest number of primary branches per plant (8.0) was obtained from BARItomato-7 and Binatomato-5 in winter, which was statistically similar to Binatomato-5 and BARItomato-7 in pre-winter, CLN-2366 in winter, Binatomato-5 and BARItomato-7 in summer. Both BARItomato-7 and Binatomato-5 performed well in producing primary branches in all three seasons. The lowest number of primary branches per plant (3.3) was obtained from CLN-2026 in pre-winter and CLN-2026 in summer, which was statistically similar to J-5, CLN-2418 and CLN-2443 in pre-winter, J-5, CLN-2026, CLN-2418 and CLN-2443 in winter, J-5, CLN-2413, CLN-2418 and CLN-2443 in summer. The present results are in confirmation with that of Bhangu and Singh (1993) and Ramezan *et al*. (2009) where they reported significant genotypic variations in primary branches of tomato.

Number of flower clusters: The number of flower clusters per plant showed significant variation among seasons (Table 1). The highest number of flower cluster per plant (15.6) occurred in winter season followed by pre-winter. Number of flower clusters per plant (13.0) was the lowest in summer season. Genotypic variation for the number of flower clusters per plant was significant (Table 1). The highest number of flower clusters per plant (23.4) was found in CLN-2366 while the lowest (10.1) were noticed in CLN-2418. Although, the tallest plant and highest number of primary branches per plant were observed in BARItomato-7 but the highest number of flower cluster per plant was found in CLN-2366. The variation in number of flower clusters per plant was possibly due to different genetic make up of the tomato genotypes.

The interaction effects of seasons and genotypes were significant on the number of flower clusters per plant (Table 2). The highest number of flower clusters per plant (27.6) was obtained from CLN-2366 in winter. The lowest number of flower clusters per plant (9.6) was obtained from CLN-2418 in summer, which was statistically similar to J-5 and CLN-2418, J-5 and CLN-2418 in winter, J-5, CLN-2413 and CLN-2443 in summer.

Number of fruit clusters: Seasonal variation in the number of fruit clusters per plant was significant (Table 1). The highest number of fruit clusters per plant (10.4) was observed in winter followed by pre-winter season. The lowest number of fruit clusters per plant (8.6) was recorded in summer season. A marked variation in the number of fruit cluster per plant was observed in different tomato genotypes (Table 1). The highest number of fruit cluster per plant (17.2) was found in CLN-2366, which was statistically different from other genotypes. The lowest number of fruit cluster per plant (7.3) was found in CLN-2026, which was statistically similar to CLN-2413. The result is consistent with the results of Singh *et al*. (2002a, b) and Saeed *et al*. (1999).

The interaction effects of seasons and genotypes were significant on the number of fruit clusters per plant (Table 2). The highest number of fruit clusters per plant (19.0) was obtained from CLN-2366 in winter, which was statistically similar to CLN-2366 in pre-winter. The lowest number of fruit cluster per plant (6.6) was obtained from CLN-2026 in summer, which was statistically similar to CLN-2026 and CLN-2413 in pre-winter, J-5, Binatomato-5, BARItomato-7 and CLN-2413 in summer.

Number of fruits: The number of fruits per plant showed significant variations among the seasons (Table 3). The highest number of fruits per plant (27.6) was found in winter season. The lowest number of fruits per plant (15.3) was found in summer season. Highest fruit setting in winter season might be due to prevailing moderately cool night temperature (15-20°C) (Mehdi *et al.*, 2008). The number of fruits per plant showed significant variation among the genotypes (Table 3). The highest number of fruits per plant (30.6) was found in CLN-2413, which was statistically similar to BARI tomato-7. The lowest number of fruits per plant (12.7) was found in J-5. The variation in number of fruits per plant was genotype dependent. Significant genetical variations in number of fruits per plant over seasons have also been reported by Bhutani *et al.* (1989) and Islam and Khan (1991).

The effects of the interaction between seasons and genotypes were significant on the number of fruit per plant (Table 4). The highest number of fruits per plant (40.3) was obtained from CLN-2413 in winter, which was statistically similar to Binatomato-5 and BARItomato-7 in winter. In contrast, the lowest number of fruits per plant (9.6) was obtained from J-5 in summer and pre-winter; CLN-2026 and CLN-2418 in summer.

Individual fruit weight: The weight of individual fruit showed significant variation in different seasons (Table 3). The highest individual fruit weight (53.7 g) occurred in winter season. The lowest individual fruit weight (39.2) occurred in summer season. The individual fruit weight varied significantly among the genotypes (Table 3). The heaviest fruit (58.8 g) was found in CLN-2418. In contrast, the lightest fruit (38.8 g) was found in Binatomato-5, which was statistically similar to CLN-2366. The variation in individual fruit weight of different genotypes might be due to their different genotypic characters. Reports on seasonal variation in fruit weight by Ajlouni *et al.* (1996) and Hussain *et al.* (2001) also supports our findings.

The interaction effects of seasons and genotypes were significant on the individual fruit weight (Table 4). The highest individual fruit weight (66.3 g) was obtained from CLN-2418 in winter. The lowest individual fruit weight (30.0 g) was obtained from Binatomato-5 in summer, which was statistically similar to BARItomato-7 and CLN-2026 in summer.

Table 3: Yield and yield attributes of tomato genotypes over seasons

Treatment	Fruits (No. plant^{-1})	Individual fruit weight (g)	Fruit yield (kg plant^{-1})	Yield (t ha^{-1})
Seasons				
Pre-winter	21.8b	46.3b	1.00b	37.5b
Winter	27.6a	53.7a	1.49a	56.1a
Summer	15.3c	39.2c	0.59c	22.2c
Genotypes				
J-5	12.7e	43.6cd	0.56e	21.1e
BINA tomato-5	26.8b	38.8e	1.11c	41.6c
BARI tomato-7	30.4a	45.4c	1.44b	54.1b
CLN-2026	20.2c	45.7c	0.97c	36.4c
CLN-2366	18.4cd	41.7de	0.79d	29.6d
CLN-2413	30.6a	50.6b	1.59a	59.8a
CLN-2418	16.3d	58.8a	0.97c	36.3c
CLN-2443	17.1d	46.4c	0.79d	29.8d

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Table 4: Yield attributes based on the interaction between seasons and tomato genotypes

Seasons × genotypes	Fruits (No. plant^{-1})	Individual fruit weight (g)	Fruit yield (kg plant^{-1})	Yield (t ha^{-1})
S_1V_1	11.0kl	43.3ef	0.47jk	17.8jk
S_1V_2	27.3de	37.3gh	1.01efg	38.0fgh
S_1V_3	29.6cd	43.6ef	1.29d	48.6de
S_1V_4	19.3fgh	49.6de	0.95e-h	35.6f-i
S_1V_5	18.6ghi	41.6fg	0.77ghi	29.1hi
S_1V_6	34.0bc	49.6de	1.68bc	63.0bc
S_1V_7	17.0hij	58.3b	0.99efg	37.2fgh
S_1V_8	17.6g-j	47.0def	0.83ghi	31.1hi
S_2V_1	17.6g-j	46.3def	0.81ghi	30.7hi
S_2V_2	36.6ab	49.3de	1.81b	68.1b
S_2V_3	39.0a	58.6b	2.26a	84.9a
S_2V_4	27.0de	57.0bc	1.53c	57.4cd
S_2V_5	24.0ef	46.3def	1.11def	41.9efg
S_2V_6	40.3a	57.6bc	2.31a	86.9a
S_2V_7	18.3ghi	66.3a	1.21de	45.4ef
S_2V_8	18.3ghi	48.6d	0.89f-i	33.4ghi
S_3V_1	9.6 l	41.3fg	0.39k	14.9k
S_3V_2	16.6hij	30.0i	0.50jk	18.7jk
S_3V_3	22.6efg	34.0hi	0.77ghi	28.8hi
S_3V_4	14.3h-l	30.6i	0.44jk	16.1k
S_3V_5	12.6jkl	37.3gh	0.47jk	17.8jk
S_3V_6	17.6g-j	44.6ef	0.78ghi	29.6hi
S_3V_7	13.6i-l	52.0cd	0.70hij	26.4ij
S_3V_8	15.3h-k	43.6ef	0.66ijk	25.1ijk

Figures having common letter(s) in a column do not differ significantly at 5% level as per DMRT. S_1: Pre winter, S_2: Winter, S_3: Summer, V_1: J-5, V_2: Binatomato-5, V_3: BARItomato-7, V_4: CLN-2026, V_5: CLN-2366, V_6: CLN-2413, V_7: CLN-2418, V_8: CLN-2443

Fruit yield: Fruit yield per plant was significantly influenced by the growing season (Table 3). The highest fruit yield per plant (1.49 kg) was found in winter season. The lowest fruit per plant (0.59 kg) was found in summer season. Fruit yield per plant was significantly influenced by difference in genotypes (Table 3). The fruit yield per plant greatly depends on individual fruit weight and number of fruits per plant. CLN-2413 had the highest fruit yield per plant (1.59 kg) while J-5 had the lowest fruit yield per plant (0.56 kg) was found in J-5. Although, the highest individual fruit was found in CLN-2418 but the number of fruits per plant is less than CLN-2413. The present result confirmed the earlier reports of Rehman *et al.* (2000) and Wagh *et al.* (2004) where they reported genotypic variations in tomato yield.

The effects of the interaction between seasons and genotypes were significant on the fruit yield per plant (Table 4). The highest fruit yield per plant (2.31 kg) was obtained from CLN-2413 in winter, which was statistically similar to BARItomato-7 in winter. The lowest fruit yield per plant (0.39 kg) was obtained from J-5 in summer which was statistically similar to J-5 in pre-winter, Binatomato-5, CLN-2026, CLN-2366 and CLN-2443 in summer.

Different seasons caused significant variation in yield (Table 3). The highest yield (56.1 t ha^{-1}) was found in winter season while the lowest yield (22.2 t ha^{-1}) was found in summer season. Yield (t ha^{-1}) was significantly influenced by difference in genotypes (Table 3). CLN-2413 had the highest yield (59.8 t ha^{-1}) while J-5 had the least yield (21.1 t ha^{-1}).

The effects of the interaction between seasons and genotypes were significant on the yield (Table 4). The maximum yield (86.9 t ha^{-1}) was obtained from CLN-2413 in winter, which was statistically similar to BARItomato-7 in winter. The minimum yield (14.9 t ha^{-1}) was obtained from J-5 in summer, which was statistically similar to J-5 in pre-winter, Binatomato-5, CLN-2026, CLN-2366 and CLN-2443 in summer.

CONCLUSION

It can be concluded from the results that tomato genotype CLN-2366 produced the highest number of flower and fruit clusters $plant^{-1}$ while CLN-2413 produced the highest number of fruits and fruit yield. In contrast, BARI tomato-7 and BINA tomato-5 showed higher plant height and maximum number of primary branches $plant^{-1}$. The genotype CLN-2413 showed the best yield performance over seasons.

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