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Yield and Morphophysiological Performance of Different Tomato Varieties in Winter Season

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Abstract: The pot culture experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka to study the morphophysiologycal and yield performance of different varieties of tomato during winter season of 2013-2014. Five tomato varieties viz., BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-15 were used as planting material. The experiment was carried out using Randomized Complete Block Design (RCBD) with four replications. The results revealed that the tallest plant height at different days after transplanting including final harvest was observed in BARI Hybrid Tomato-5. BARI Hybrid Tomato-5 also accumulated maximum root dry mass (1.82 g plant^{-1}) while accumulation of shoot vegetative dry mass (17.52 g plant^{-1}) was maximum in BARI Tomato-2. BARI Tomato-14 required minimum time (23.42 days) for first appearance of inflorescence. Maximum number of flower clusters (9.58 plant^{-1}) was observed in BARI Hybrid Toamto-4 whereas maximum floral buds (7.00 cluster^{-1}) were observed in Tomato-5. BARI Tomato-2 produced maximum fruits (4.81 cluster^{-1}) which were statistically similar with BARI Hybrid Toamto-5. BARI Hybrid Tomato-4 produced highest number of fruit plant^{-1} (41.33) with lowest average fruit weight (32.69 g fruit^{-1}) whereas BARI Tomato-14 produced lowest number of fruit plant^{-1} (28.66) with highest average fruit weight (74.19 g fruit^{-1}). Fruit of BARI Hybrid Tomato-5 contained highest level of Total Soluble Solid (5.42% TSS). The Highest fruit yield plant (2.09 kg) was obtained from BARI Tomato-14 followed by BARI Hybrid tomato-5 (1.98 kg) and BARI Tomato-2(1.95 kg) all of which were statistically none significant.

Key words: Tomato · Winter · Season · Variety · Yield

INTRODUCTION

Tomato (*Lycopersicon esculentum* L. Miller) belongs to the family Solanaceae is one of the most important vegetable crops grown throughout the world under field and greenhouse conditions. This plant is adapted to a wide variety of soil and climate. Tomato production has been reported from 144 countries including Bangladesh. Tomato is a major component of daily diet in many countries and constitutes an important source of minerals, vitamins and antioxidants [1]. Its food value is very rich because it contains vitamin A, B and C including calcium and carotene [2, 3]. The edible fruit has a range of uses in fresh and processed food items namely soups, juice, ketchup, sauce, conserved puree, paste, powder and other products. The taste, color and flavor of tomato made it a popular culinary worldwide.

Hybrid tomato varieties have higher yield potential over inbred tomato varieties, but hybrid varieties have certain limitations. Bangladesh Agricultural Research Institute (BARI) has released a number of yield promising inbred as well as hybrid tomato varieties such as BARI Tomato-2, BARI Tomato-4, BARI Tomato-14, BARI Tomato-15, BARI Hybrid Tomato-5, BARI Hybrid Tomato-6 etc. The performances of these recent tomato varieties in different growing seasons have not been well studied. Tomato is a thermo-sensitive plant and its climatic adaptability varies among the hybrid and inbred varieties. So, the adaptation of the hybrid tomato varieties for their proper growth and development in the winter would vary in comparison to inbred varieties. Cultivar selection is one of the critical decisions for commercial grower in each season. Again, Variety selection is a dynamic process. Some varieties may retain favor for

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many years while others might be supplanted by newer cultivars after a few seasons [4]. The research work has been undertaken to determine morpho-physiological and yield attributes of both hybrid and inbred tomato varieties in the winter season in order to select better performing variety for winter cultivation.

MATERIALS AND METHODS

The pot culture experiment was carried out at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh. The experimental site was characterized by scanty rainfall associated with moderately low temperature during October to March (*Robi* season).

The Randomized Complete Block Design (RCBD) was the experimental design with four replications was used in this experiment. The five tomato varieties i.e. BARI Tomato-2, BARI Hybrid Tomato-4, BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-15 were used as planting materials. The seeds were sown in well prepared seedbed in October 20, 2013 and healthy seedlings were transplanted to pot in November 20, 2013. Earthen pots of 12 inches surface diameter were pre-prepared for pot culture medium with sandy loam soil having 15% organic manure by weight and pH 6.0-6.4. Fertilizers other than Nitrogenous fertilizer were applied as per recommendations of Bangladesh Agricultural Research Council (BARC)-Triple Super Phosphate (TSP) @250 kg ha^{-1} and Muriate of Potash (MOP) @260 kg ha^{-1} during pot preparation [5]. Furadan 10 G, an insecticide @ 0.5 g pot^{-1} was applied during pot preparation to control cut worm and other soil insects.

Intercultural Operation: Irrigation and weeding was accomplished whenever necessary. After the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright. The crop was infested by aphid; a leaf sucking insect at vegetative and early reproductive stages, which was controlled by Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks for each time.

Harvesting: Harvesting of tomato was started from February 18, 2014 and it was continued up to March 30, 2014. During this time, fruits were harvested at 5-days intervals at ripening stage when they attained slightly red color.

Data Collection: In this experiment, three pots were allotted for each treatment in each plot for each replication that's why there were 12 sample plants for each treatment. Data was collected from each sample plant and mean value was calculated. The data on plant height at different days after transplanting; root dry weight $plant^{-1}$; shoot dry weight $plant^{-1}$; soil plant analysis development (SPAD) value of leaf; days to appearance of first inflorescence; flower clusters $plant^{-1}$; floral buds $cluster^{-1}$; flowers $cluster^{-1}$; fruits $cluster^{-1}$; fruit diameter; total soluble solid (% TSS) of fruit; total number of fruits $plant^{-1}$; average fruit weight (g); fruit yield $plant^{-1}$ were recorded.

Statistical Analysis: The statistical analysis of collected data was carried out by MSTAT-C statistical package programme and means were calculated. The mean differences among the treatments were determined by Least Significance Difference (LSD) test at 5% level of significance [6].

RESULTS AND DISCUSSION

Plant Height at Different Days after Transplanting: The growth pattern of a crop varies depending upon cultivars or varieties. Significant variation was observed in plant height of different tomato varieties throughout their lifespan. The height of BARI Hybrid Tomato-5 was higher compared to other tomato varieties at different DAT including final harvest (110 DAT). The height of BARI Hybrid Tomato-5 was 32, 26, 25 and 18% higher, compared to the height of BARI Tomato-14 at 25, 40, 55 and 110 DAT, respectively. Heights of BARI Hybrid Tomato-5 and BARI Tomato-2 were statistically similar in most cases. The shortest plant was observed in BARI Tomato-14 at all stages and it was statistically similar with BARI Hybrid Tomato-4 in all cases. Statistical variations of plant height among different tomato varieties at various weeks after planting have been reported by [7, 8].

From the results of plant height at different DAT and final harvest (Fig. 1), it can be stated that plants of all varieties possessed a variable but normal growth trend. It is clear that variety has significant effect on plant growth rate and they differ from each other. Growth of BARI Hybrid Tomato-5 was significantly higher in early vegetative to successive days after planting indicating its hybrid vigor over the other varieties. Although growth trend (indicated by plant height) of BARI Tomato-2 is

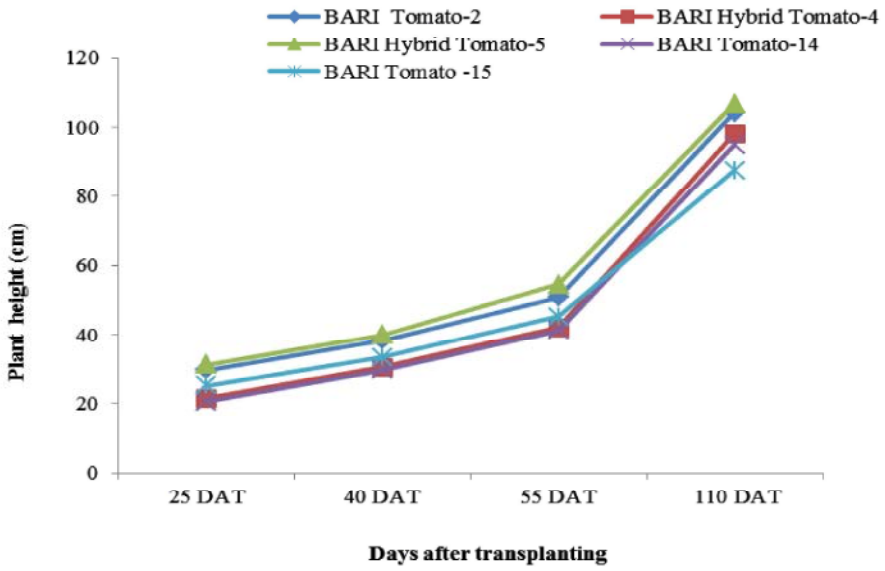

Fig. 1: Plant height of tomato varieties at different days after transplanting during winter season. ($LSD_{0.05}$ = 2.46, 3.07, 3.46 and 4.81 at 25 DAT, 40 DAT, 55 DAT and 110 DAT, respectively).

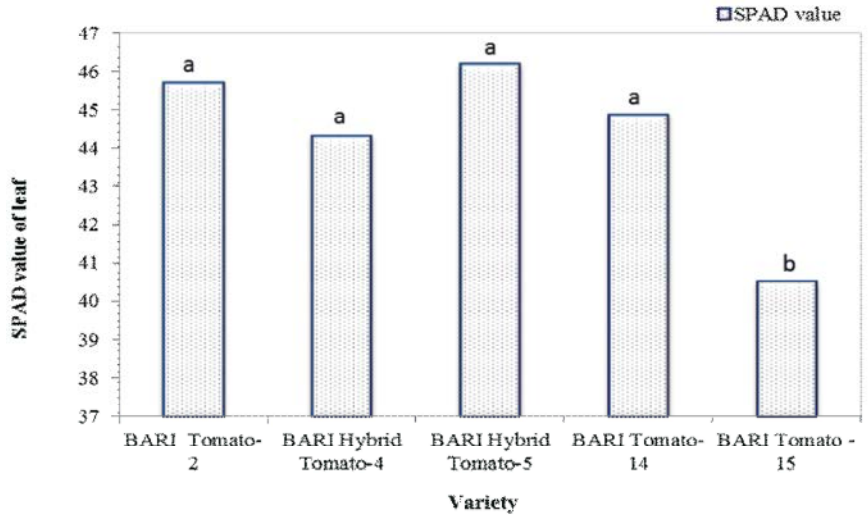

Fig. 2: Relative chlorophyll content of leaf of different tomato varieties during winter season. ($LSD_{0.05}$ = 3.73).

initially a little bit slower than BARI Hybrid Tomato-5 but final plant height indicated its potential to grow over the growth stages up to final harvest.

SPAD Value of Leaf: SPAD meter reading of leaf was analyzed and presented in order to get an idea about relative leaf chlorophyll content per unit leaf area of the tomato varieties. The highest SPAD value (46.20) was obtained from BARI Hybrid Tomato-5 followed by BARI Tomato-2 (45.7), BARI Tomato-14 (44.88) and BARI Hybrid Tomato-4 (44.32) all of which were not statistically significant (Fig. 2). The lowest SPAD value (40.53) was obtained from BARI Tomato-15. Significant variation of leaf chlorophyll content among twenty tomato cultivars have been reported [8].

Root Dry Weight: The result of root dry matter accumulation plant^{-1} at final harvest indicated non-significant variation among BARI Hybrid Tomato-5, BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15 but varied significantly with BARI Hybrid Tomato-4. The maximum accumulation of root dry matter (1.82 g plant^{-1}) accumulation was found in BARI Hybrid Tomato-5 (Fig. 3). Root is one of the most important plant

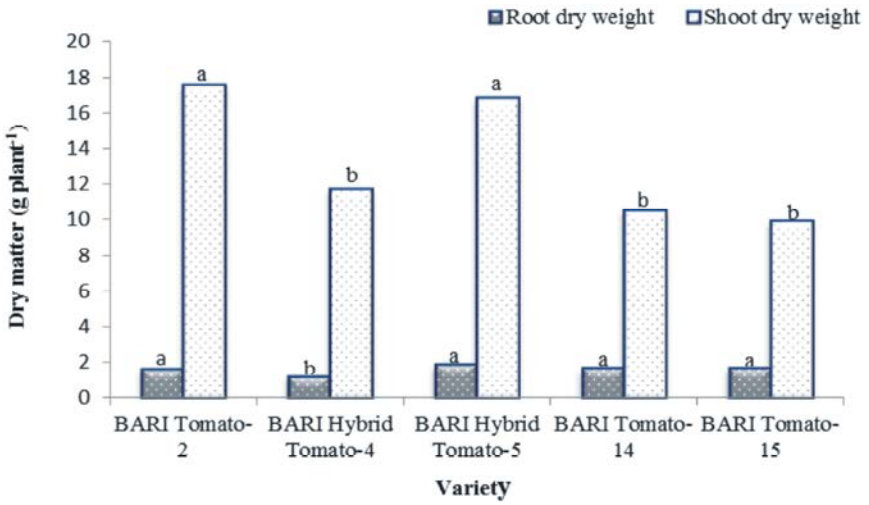

Fig. 3: Dry matter accumulation in root and shoot of different tomato varieties during winter season. ($LSD_{0.05}$ = 0.32).

organs that facilitate plant to anchor soil and absorb water, mineral nutrients etc. Plants develop extensive root system in order to get water and other mineral salts for ensuring proper growth and development. From the result of statistical analysis, it has been observed that varietal influence on root dry matter accumulation of all the five tomato varieties were very close, it could be due to comparatively smaller growth environment of root system in the earthen pots or easy availability of soil water as provided by frequent irrigation.

Shoot Dry Weight: The varieties varied significantly in shoot dry matter accumulation (Fig. 3). The maximum accumulation of shoot dry matter (17.52 g plant^{-1}) obtained from BARI Tomato-2. The accumulation of shoot dry matter of BARI Tomato-2 and BARI Hybrid Tomato-5 was statistically similar. The lowest shoot dry matter (9.90 g plant^{-1}) by the plants of BARI Tomato-15 did not significantly varied from BARI Hybrid Tomato-4 as well as BARI Tomato-14. An identical tendency of variation of shoot dry matter accumulation plant^{-1} among tomato varieties have been reported [9].

Days to First Appearance of Inflorescence: Early flowering indicates relative earliness of starting the reproductive phase of a tomato variety which directly influences early production of harvestable fruits. Number of days taken by tomato varieties to first appearance of inflorescence was significantly different. BARI Tomato-2 required maximum time (29.50 days) for the first appearance of inflorescence which was statistically similar to that of BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5 (Fig. 4). The minimum time (23.42 days) for first appearance of inflorescence was required by BARI Tomato-14, which was statistically similar with BARI Tomato-15. Das *et al*. (2013) reported that the BARI Toamato-2 (Ratan) transplanted in November 25 required 28.67 days for first flowering [9].

Clusters Plant^{-1}: Varietal differences of tomato cultivars induce significant variance in production of flower cluster (Table 1). Results revealed that maximum flower clusters (9.58 plant^{-1}) was produced by BARI Hybrid Tomato-4 which was significantly higher than the other varieties. The minimum flower clusters (6.24 plant^{-1}) was produced by BARI Tomato-2. In case of cluster production, BARI Toamato-2 and BARI Hybrid Tomato-5 were statistically identical. BARI Tomato-14 and BARI Toamto-15 also produced statistically similar number of flower clusters. It have been reported that the number of flower clusters differences between genotypes varied due to the differential GA promoted flower primordial production [10]. Onofeghara [11] and Leonard *et al*. [12] also observed similar trend of cluster production.

Floral Buds Cluster^{-1}: Plant population of the tomato cultivars varied significantly in floral bud production per unit cluster (Table 1). The maximum number floral buds (7.0 cluster^{-1}) were produced by BARI Hybrid Tomato-5 which was statistically similar with that of BARI Hybrid Tomato-4. The minimum number of floral buds (5.42 cluster^{-1}) was produced by BARI Tomato-14. BARI Tomato-2, BARI Tomato-15 and BARI Hybrid Tomato-4 were statistically similar in floral bud production cluster^{-1}.

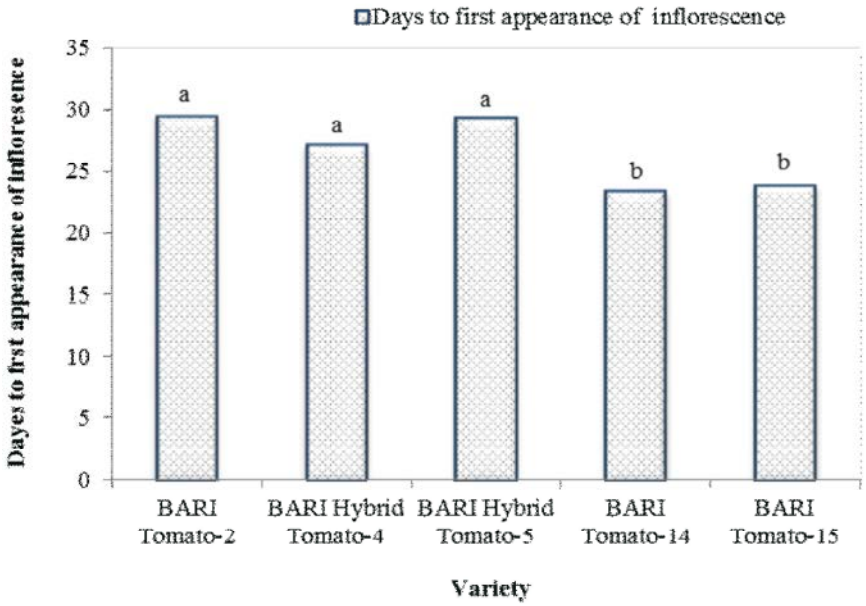

Fig. 4: Days to first appearance of inflorescence of different tomato varieties during winter season. ($LSD_{0.05}$ = 2.43).

Table 1: Reproductive growth attributes of different tomato varieties during winter season.

Variety	Clusters plant^{-1}	Floral buds cluster^{-1}	Flowers cluster^{-1}	Fruits cluster^{-1}
BARI Tomato-2	6.24 d	6.01 bc	5.31 a	4.81 a
BARI Hybrid Tomato-4	9.58 a	6.35 ab	5.02 a	4.32 abc
BARI Hybrid Tomato-5	6.58 cd	7.00 a	5.12 a	4.55 ab
BARI Tomato-14	8.00 b	5.42 c	3.95 b	3.62 c
BARI Tomato-15	7.83 bc	5.89 bc	4.42 ab	3.95 bc
$LSD_{0.05}$	1.32	0.83	0.93	0.82
CV (%)	11.21	8.80	12.69	12.62

Means within the same column followed by different letter are significantly different at p=0.05, LSD: Least significant difference, CV: Coefficient of variation.

Flowers Cluster^{-1}: Statistically significant variations exist among the varieties in production of flowers per unit cluster. The maximum number of flower (5.31 cluster^{-1}) was produced by BARI Tomato-2 which was statistically similar with that of BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. The minimum number flower (3.95 cluster^{-1}) was produced by BARI Tomato-14. BARI Tomato-14 and BARI Tomato-15 produced statistically similar number of flower cluster^{-1}. Significant variations among tomato varieties as well as lines in the production of number of flowers cluster^{-1} have been reported [13]. Zahedi and Ansari [14] also found similar results.

From the result of bud per cluster and flower cluster^{-1} it is clear that certain percentage of floral bud of all tomato varieties dropped before blooming. Minimum bud dropping (11.60%) of BARI Tomato-2 indicated its potential ability to reduce floral bud dropping over the other tomato varieties. About 25% floral bud dropping was observed in BARI Hybrid Tomato-5, BARI Tomato-14 and Tomato-15. About 20% of floral buds were dropped before blooming was observed in BARI Hybrid Tomato-4.

Fruit Cluster^{-1}: Varieties differ statistically in production of fruit cluster^{-1} (Table 1). BARI Tomato-2 produced maximum number of fruits (4.81 cluster^{-1}). Statistical results referred indifference variation in BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5. BARI Tomato-14 produced the minimum number of fruits (3.62 cluster^{-1}), which was statistically similar with BARI Hybrid Tomato-4 and BARI Tomato-15. BARI Hybrid Tomato-5 and BARI Tomato-15 were also statistically similar in production of fruit cluster^{-1}.

The result of flower cluster^{-1} and fruit cluster^{-1} revealed that about 10% flower of all tomato varieties withered before fruit set. Minimum withering of flower (8.40%) was observed in BARI Tomato-14 indicated its potential ability in pollination, fertilization and fruit

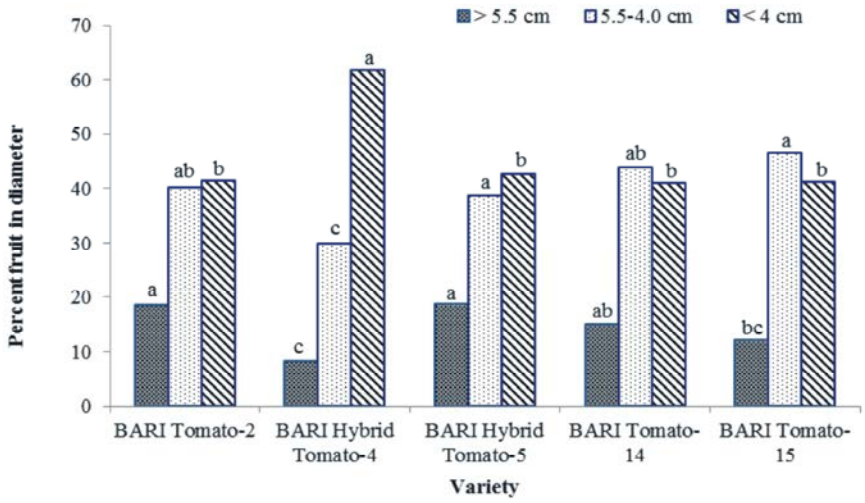

Fig. 5: Percent fruit in diameter ranges of different tomato varieties during winter season. ($LSD_{0.05}$ = 4.43, 7.53 and 10.22 for percent fruit diameter at >5.5 cm, 5.5-4.0 cm and < 4.0 cm).

formation over the other tomato varieties. Highest rate of flower withering (about 14%) observed in BARI Hybrid Tomato-4. The flower may wither due to problem in pollen viability, pollen receptive capacity of stigma, temperature, hormonal imbalance and many more [15, 16].

Fruit Diameter: Varieties have significant influences on percent fruit production at different diameter ranges (Fig. 5). Results revealed that BARI Hybrid Tomato-5 produced the maximum number of fruits (18.66%) having >5.5 cm in diameter which was statistically similar to BARI Tomato-2 and BARI Tomato-14. BARI Hybrid Tomato-4 produced minimum number of fruits (8.25%) having the same diameter. The results of BARI Hybrid Tomato-4 and BARI Tomato-15 were statistically similar. In terms of larger fruit production (>5.5 cm in diameter), BARI Tomato-14 and BARI Tomato-15 were also statistically identical.

BARI Tomato-15 produced 46.59% fruits having 5.5-4.0 cm diameter which was statistically similar to BARI Tomato-2 (40.15%) and BARI Tomato-14 (43.90%). BARI Hybrid Tomato-4 produced minimum number of fruits (29.89%) having the 5.5-4.0 cm diameter. The results also found that BARI Hybrid Tomato-4 produced 61.85% fruit having <4.0 cm diameter and that varied significantly with other varieties. BARI Tomato-2, BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-14 showed non-statistical variation on production of fruits having <4.0 cm diameter. Significant cultivar variations in fruit diameter have been reported by Mehraj *et al*. [8]. The finding is identical with that reported by Chernet and Zibelo (2014) who indicated the existence of variability in terms of fruit diameter among nine tomato varieties evaluated under lowland condition Tigray, Northern Ethiopia [17]. Balcha *et al*. also reported similar trend of results [18].

Total Soluble Solids (% TSS) Content of Fruit: Determination of total soluble solids (% TSS) or 'Degrees Brix' is important for a wide range of crops. It is measures of the total soluble solids in juice of ripen fruit. These soluble solids are primarily sugars; sucrose, fructose and glucose. As the flesh of fruit forms it deposits nutrients as starch that, as the fruit ripens, transform to sugars. The percentage sugar, measured in 'degrees Brix' (°Brix), indicates the sweetness of the fruit.

The fruits of different tomato varieties varied in total soluble solids content (% TSS). The highest total soluble solids (5.42%) was observed in fruit of BARI Hybrid Tomato-5 which varied statistically with other varieties. The lowest total soluble solids (3.86%) were observed in fruit of BARI Hybrid Tomato-4 which was also significantly lower from that of other varieties. The varieties *viz*., BARI Tomato-14 and BARI Tomato-15 were statistically similar for total soluble solid (% TSS) content of fruit. Patwary *et al*. [13] also reported significant variations of total soluble solid content of fruits of different tomato lines and varieties.

Fruit Plant^{-1}: When we consider leaves as major sources of photo-assimilation, it is obvious that the fruits are major sink of plant. So the total number of fruit plant^{-1} will indicate cumulative number of sink as well as total reproductive sink capacity when considered in combination with individual fruit weight.

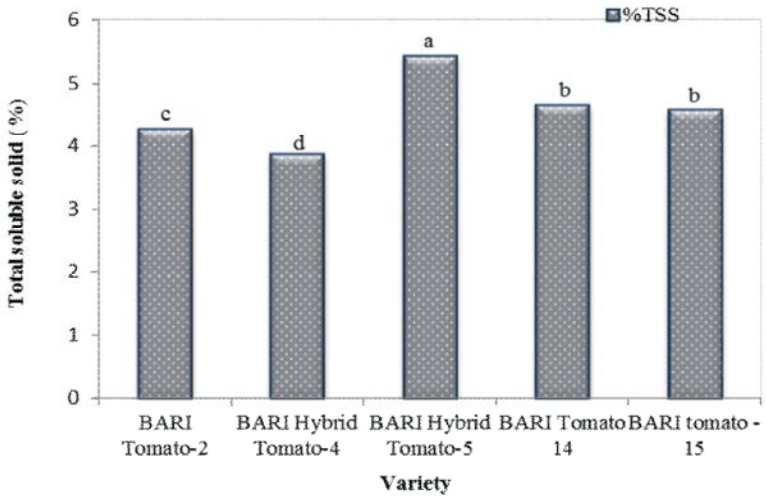

Fig. 6: Total soluble solid content in fruit of different tomato varieties during winter season. ($LSD_{0.05}$ = 0.29).

Table 2: Effect of variety on yield contributing characters and yield of tomato during winter season.

Variety	No. of Fruits plant^{-1}	Average fruit weight (g)	Fruit yield (kg plant^{-1})
BARI Tomato-2	29.69 bc	66.73 b	1.95 ab
BARI Hybrid tomato-4	41.33 a	32.69 d	1.32 c
BARI Hybrid tomato-5	30.08 bc	67.50 b	1.98 ab
BARI Tomato-14	28.66 c	74.19 a	2.09 a
BARI Tomato-15	30.91 bc	50.61 c	1.56 c
$LSD_{0.05}$	4.49	4.88	0.29
CV (%)	8.91	5.43	10.39

Means within the same column followed by different letter are significantly different at p=0.05, LSD: Least significant difference, CV: Coefficient of variation.

The total number of fruit plant^{-1} varied significantly among the tomato varieties studied (Table 2). The highest number of fruit (41.33plant^{-1}) was observed from the variety BARI Hybrid Tomato-4 which was statistically significant with other varieties. The lowest number of fruit (28.66plant^{-1}) was observed from the variety BARI Tomato-14 which was statistically similar with other tomato varieties except BARI Hybrid Tomato-4. Result also revealed that there was non-significant variation existed among BARI Tomato-2, BARI Hybrid Tomato-5 and BARI Tomato-15 on number of fruits plant^{-1}. The value of fruit plant^{-1} from the variety BARI Tomato-14 was the lowest. This was attributed to the fact that the variety produced largest fruits (Table 2). Significant variation among varieties and lines of tomato on number of fruit plant^{-1} was also reported by Patwary *et al*. [13].

Average Fruit Weight: Average fruit weight showed significant difference among tomato varieties (Table 2). The highest value of fruit weight (74.19g fruit^{-1}) was observed in BARI Tomato-14 which was statistically higher over the other tomato varieties. The lowest value (32.69g fruit^{-1}) was observed from BARI Hybrid Tomato-4 and this varied statistically with other varieties. The average fruit weight obtained from BARI Hybrid Tomato-5 (67.50g) followed by BARI Tomato-2 (66.73g) both of which were statistically identical.

Fruit Yield Plant^{-1}: Analysis of variance (ANOVA) revealed that fruit yield plant^{-1} and fruit yield ha^{-1} varied significantly among the studied tomato varieties (Table 2). The highest fruit yield (2.09 kg plant^{-1}) was obtained from BARI Tomato-14 followed by BARI Hybrid tomato-5 (1.98 kg plant^{-1}) and BARI Tomato-2 (1.95 kg plant^{-1}) all of which were statistically non-significant from each other. The lowest fruit yield (1.32 kg plant^{-1}) was obtained from BARI Hybrid Tomato-4 which varied statistically with other varieties. The cause behind the result was variation in the number of fruits plant^{-1} and average fruits weight. Although, BARI Hybrid Tomato-4 produced the highest number of fruits plant^{-1} (41.33), but individual fruit weight was lowest (32.69 g fruit^{-1}). BARI Tomato-14 produced the minimum number of fruits (28.66 plant^{-1}), but average fruit weight was maximum (74.19 g fruit^{-1}).

The fruit yield plant^{-1} obtained from the current study agreed with previous reports of Patwary *et al*. [13] who reported that the highest fruit yield per plant^{-1} ranging from 1.22 kg to 2.67 kg in winter in Bangladesh. Similarly, Chernet *et al*. [19] reported that the highest fruit yield plant^{-1} was (2.10 kg) when comparing 36 tomato genotypes. The fruit weight plant^{-1} ranging between 1.1 kg and 1.7 kg has been reported by Regassa *et al*. [20]. The result is also in line with the findings of Saleem *et al*. [21] who found the highest fruit yield plant^{-1} (2.48 kg) when evaluating 30 tomato genotypes in Pakistan.

CONCLUSIONS

The quantitative performance of BARI Tomato-14 was superior over the other varieties when parameters like, plant height, shoot dry weight plant^{-1}, days to first appearance of inflorescence and fruit yield plant^{-1} were considered. This was because the variety had high load bearing capacity facilitated by its height, maximum stem reserve translocation ability reflected by lowest shoot dry weight plant^{-1}, minimum days required to flowering as well as highest sink capacity observed on highest individual fruit size and weight (Fig. 6, Table 2). But when all the parameters were considered, all the vegetative and reproductive parameters as well as fruit size and the quality fruit produced, obviously the performance of BARI Hybrid Tomato-5 was superior over the rest of the other tomato varieties studied including BARI Tomato-14. It is important to mention that the overall performance of BARI Tomato-2 was also satisfactory. So, any one variety from these three best performed tomato varieties, *viz.,* BARI Hybrid Tomato-5, BARI Tomato-2, BARI Tomato-14 can be adapted by the commercial tomato grower based on their relative preference and market demand.

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