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Performance of Tomato (*Solanum lycopersicum* Mill) Cultivars for Quality Production under Protected Cultivation in Subtropics

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A B S T R A C T

Under the climate change scenario, protected cultivation may possibly provide ample scope for 'off' season production of high value vegetable crops like tomato (*Solanum lycopersicum* Mill.). The performance of four tomato cultivars (Heemsohna, NS-1218, KSP-1113 and Heemshikhar) in terms of yield and quality parameters under polyhouse (greenhouse) condition was evaluated. The lycopene content and three pectin fractions (water soluble, ammonium oxalate soluble and alkali soluble) of fruits were analyzed by spectrophotometric methods. The total fruit weight/plant varied from 4.16 kg (KSP-1113) to 18.04 kg (Heemsohna). The fruit number per plant varied from 114.2-263.0 and individual fruit weight ranged from 18.47-121.12 g. Heemsohna registered higher yield along with maximum marketable shelf life (13 days) as compared to other cultivars. Lycopene content ranged from 2.63 to 5.81 mg/100 g FW with maximum lycopene in KSP-1113. Though alcohol insoluble solid was maximum (2.36%) in KSP-1113, water soluble and ammonium oxalate soluble pectin fractions were maximum in Heemsohna (9.02 and 15.76 g/100 g AIS, respectively) and alkali soluble pectin was maximum in NS-1218 (4.72 g/100 g AIS). Heemsohna can be grown in polyhouse for higher yield and overall quality characters and KSP-1113 (cherry tomato) can be grown particularly for higher lycopene content under protected condition in subtropics.

Introduction

Tomato (*Solanum lycopersicum* Mill.) is currently the second largest vegetables in India in terms of production. It is consumed in various ways including raw as an ingredient in many dishes and in processed form. Tomato is an outstanding source of many bioactive compounds like lycopene, β-carotene, phenols, flavonoids and vitamins (Kaur *et al.*, 2013; Shivashankara *et al.*, 2015). It is one of the richest sources of lycopene, which is a powerful antioxidant helping in decreasing the lipid peroxidation and hydroxyl radical formation by quenching the singlet oxygen (Di Mascio *et al.*, 1989; Shi *et al.*, 2002; Dumas *et al.*, 2003). Epidemiological studies had also indicated positive health benefits by consumption of diets high in lycopene (Matos *et al.*, 2000; Jian *et al.*, 2007). Besides providing disease resistance power to human bodies, vegetables can also generate high income and year round employment per unit area. Because of the changing climate scenario due to increase in global mean annual temperature from last century by 0.4–0.7ºC, open cultivation of vegetables is becoming harsher and less economical (IPCC, 2007). This would lead to negative impact on the production of vegetable crops.

Protected structures like polyhouses, tunnels, mulching, etc. can play important role to mitigate the impact of temperature fluctuation, over/under precipitation, fluctuating sun shine hour and infestation of diseases and pests (Singh and Satpathy, 2005; Spaldon *et al.,* 2015). Therefore, cultivation under protected condition has been proved to be more remunerative than open condition. This technology has considerably contributed for improving productivity for areas having adverse weather conditions through slight modification of the natural environment to prolong the harvest period, increase yield, improve quality, enhance the stability of production and make possible round the year production of good quality produce particularly in peri-urban areas. Cultivars with indeterminate growth habit and capacity to produce fruits in 'off' season are found suitable for polyhouse cultivation (Singh *et al.,* 2016).

Though sufficient literature is available on performance of determinate type of tomato cultivars under open field condition, studies on performance of indeterminate type of tomato cultivars under protected condition suited to sub-tropical climate are scanty. The present experiment was, therefore, conducted during the period of 2017-2018 to evaluate the performance of four indeterminate cultivars of tomato having different growth behavior in terms of yield and quality parameters under greenhouse condition.

Materials and Methods

The experiment was carried out in greenhouse at ICAR-Central Institute for Subtropical Horticulture, Lucknow, India located at latitude 26.55 °N and longitude 85.59 °E in the sub-tropical zone of India. Conducive temperature and relative humidity inside greenhouse were maintained in the range of 26-28 ^{o}C and 65-90%, respectively (Singh *et al.*, 2015). The experiment was laid out in a randomized block design with three replications. Four indeterminate cultivars of tomato viz. Heemsohna, NS-1218, KSP-1113 (Cherry tomato), and Heemshikhar were considered for evaluation. Seedlings were raised in 98 cups pro-tray with soil less media containing FYM, cocopeat and vermiculite in uniform ratio. Transplanting was done after seedling attained 25 days of age and 20-25 cm in height during September 2017. Seedlings were transplanted in 15 meter long paired rows spacing 65 x 45 cm accommodating 48 plants in each raised bed with three replications for each variety. The recommended cultural practices along with drip irrigation with 2 LPH discharge on alternate days was adapted to provide irrigation at 1-2 liter/plant/day. The indeterminate type plants were regularly trellised and trained to two stem by removing all side shoots/suckers developing. Application of NPK at 250:150:350 in the form of water soluble fertilizers through fertigation at weekly intervals was done.

The total fruit yield per plant, individual fruit weight (average of 100 fruits), fruit number per cluster and fruit number per plant were recorded periodically and pooled. The uniform unblemished tomato fruits having similar size were sampled at red ripe stage for quality analysis. After equilibrating freshly harvested fruit samples to room temperature, ten fruits from three replications of each variety were randomly selected. Fruits were washed thoroughly with distilled water to remove dirt and other undesirable particles from the surface and cut into pieces, crushed in a blender and known quantity of homogeneous mass was set apart for quality analysis. Marketable shelf life was assumed on the basis of visual appearance, physiological loss of weight (PLW) and deterioration after storage of 20 fruits of each cultivar at ambient temperature. The PLW of the fruits was calculated as cumulative per cent loss in weight based on the initial fruit weight and loss in weight recorded by sampling daily. Peel thickness was calculated with micrometer (0-25 x 0.01 mm).

The total soluble solid (TSS) was determined by digital hand held refractometer (Model PAL-1, Atago Co. Ltd., Japan) with a range of 0 to 53 °Brix by placing 1 to 2 drops of clear juice on the prism. Acidity was estimated by titration of the tomato extract against 0.1 N NaOH using phenolphthalein indicator and expressed in per cent using citric acid as equivalent (AOAC, 2000). TSS/acidity ratio was calculated by dividing total soluble solid to titratable acidity of the given sample under analysis. Total lycopene content of the homogenized fruits was analyzed by spectrophotometric method (Lichtenthaler, 1987) and results were expressed as mg/100 g fresh weight (FW). After estimation by soxhlet extraction, alcohol insoluble solids (AIS) was characterized into three pectin fractions using distilled water, 0.05 M ammonium oxalate and 0.05 M sodium hydroxide by subsequent extraction as per the method described by Roe and Bruemmer (1981). Pectin fractions were estimated colorimetrically by adding 1.0 ml of carbazole reagent (0.1% in absolute alcohol) and 12.0 ml of concentrated sulfuric acid to 2.0 ml of pectin solution with constant agitation. The tubes were closed with rubber stoppers, allowed to stand for 10 min and colour was read at 525 nm in a double beam UV-VIS spectrophotometer (Labomed Inc., USA). Blank sample was prepared by adding 1 ml of purified alcohol instead of 1 ml carbazole in the reaction mixture. Standard was made by using galacturonic acid (100 µg/ml).

The statistical data was analyzed using scientific data analysis and graphing software Sigma Plot 12 Systat Software Inc., San Jose, California, USA and Web Agri Stat Package (WASP) version 2.0 developed at ICAR Research Complex for Goa, Goa, India following completely randomized design.

Results and Discussion

Fruit physical parameters

Average fruit yield per plant and its attributes *viz.*, number of fruits per plant, fruit number per bunch, individual fruit weight and marketable shelf life of four tomato cultivars are presented in Table 1. The average fruit yield per plant ranged from 4.16 to 18.04 kg with maximum in Heemsohna (18.04 kg) followed by Heemshikhar (17.48 kg) and minimum in KSP-1113 (4.16 kg). Weekly performance of four cultivars in terms of yield from 2nd week of March to 1st week of June, 2017 has been shown in Table 2. Fruit number per plant in KSP-1113 was maximum (263 fruits) as compared to other cultivars which ranged from 114.2 – 153.2 fruit per plant, wherein minimum number of fruit (114.2 fruit per plant) was recorded in NS-1218. Amongst the cultivars, KSP-1113 (Cherry tomato) registered highest number of fruits (21.4) per cluster and lowest (5) was in NS-1218. On the other hand, KSP-1113 had lowest (18.50 g) individual fruit weight as compared to the rest of the cultivars which ranged from 86.76 – 121.12 g with highest individual fruit weight was in Heemsohna (Table 1). Variation in yield and contributing parameters may be due to their different genetic characteristics. Among the cultivars, Heemsohna exhibited maximum marketable shelf life (13.2 days) and KSP-1113 the minimum (5 days) based on visual appearance. The perusal of data on physiological weight loss (PLW) clearly indicated that Heemsohna had low PLW (7.1, 8.7 and 10.9%) for the fruits harvested during different months (Fig. 1) with highest marketable shelf life (13.2 days) followed by Heemshikhar (12.0 days). On the other hand, KSP-1113 registered maximum PLW (16.8, 15.2 and 14.4%) with lowest marketable shelf life (5 days).

Table.1 Yield parameters and shelf life of different indeterminate cultivars of tomato

Cultivar	Total no. of fruits per plant*	No. of fruits per cluster*	Individual fruit weight (g) **	Total fruit weight (kg/ plant)	Peel thickness of ripe fruit (mm)	Marketable Shelf Life (Days)***
Heemsohna	153.24[b]	7.80[b]	121.12[a]	18.04[a]	0.75[a]	13.2[a]
NS-1218	114.27[c]	5.00[c]	86.76[b]	9.53[b]	0.65[ab]	7.4[b]
KSP-1113	263.01[a]	21.43[a]	18.50[c]	4.16[c]	0.37[c]	5.0[c]
Heemshikhar	149.80[b]	7.20[bc]	118.29[a]	17.48[a]	0.50[bc]	12.0[a]
LSD at 5%	8.706	1.80	7.666	0.98	0.154	1.551

*Average of 20 plants/bunch, **Average of 20 fruits, ***Average of 20 fruits based on visual appearance, Data with same number in column as superscript are statistically non-significant

Table.2 Yield of different cultivars of tomato during different periods

Cultivar	Yield (kg/plant)									
	March 2nd Week	March 3rd Week	March 5th Week	April 1st Week	April 3rd Week	April 4th Week	May 2nd Week	May 3rd Week	May 4th Week	June 1st Week
Heemsohna	1.924	2.32	2.251	2.178	2.173	2.112	1.804	1.702	0.898	0.673
NS-1218	1.32	0.886	1.400	1.31	0.76	1.064	0.923	0.384	0.842	0.662
KSP-1113	0.76	0.38	0.412	0.362	0.304	0.374	0.435	0.59	0.314	0.224
Heemshikhar	2.542	1.782	2.354	1.906	2.17	1.88	1.332	1.836	0.998	0.684

Table.3 Chemical parameters of four tomato cultivars

Cultivar	TSS (^{o}Brix)	Acidity (%)	TSS/Acidity ratio	AIS* (%)
Heemsohna	4.10[b]	0.50	8.18[b]	1.77[b]
NS-1218	4.08[b]	0.61	6.69[c]	1.35[c]
KSP-1113	8.28[a]	0.62	13.29[a]	2.36[a]
Heemshikhar	4.03[b]	0.53	7.66[bc]	2.11[a]
LSD at 5%	0.248	NS	1.06	0.308

*AIS = Alcohol insoluble solids, Data with same number in column as superscript are statistically non-significant

Fig.1 Physiological loss in weight (%) for four tomato cultivars at different harvesting period (average of 20 fruits based on weight loss)

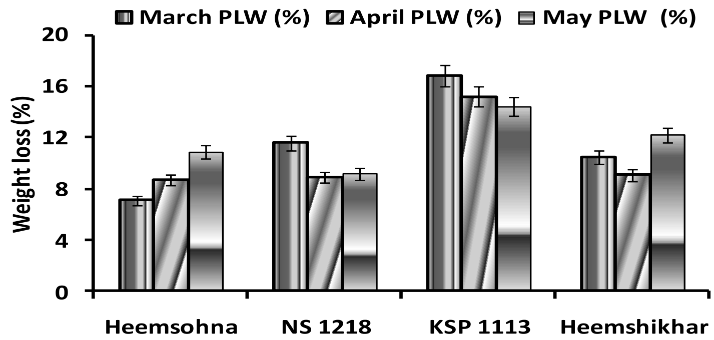
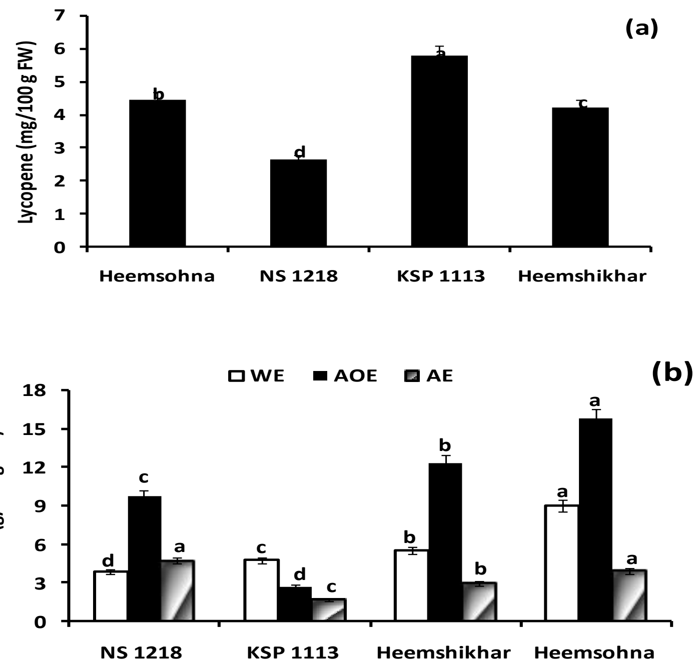


Fig.2 Variations in (a) lycopene content (LSD at 5% = 0.212) and (b) pectin content [WE = water soluble (LSD at 5% = 0.701), AOE = Ammonium oxalate soluble (LSD at 5% = 1.053) and AE = Alkali soluble (LSD at 5% = 0.829)] of four tomato cultivars



Fruit chemical parameters

TSS, acidity and their ratio are key determinant of shelf life and quality of the crops, whether it is for the fresh produce or for processing. At red ripe stage, TSS ranged from 4.03 °B in Heemshikhar to 8.27 °B in KSP-1113 and the acidity in cultivars ranged between 0.50 and 0.62 per cent which is desirable traits for shelf life and processing of tomato (Table 3). TSS/acidity ratio was in the range of 6.69 to 13.29 being maximum in KSP-1113 and minimum in NS-1218. Peel thickness in four cultivars ranged from 0.75-0.37 mm. Higher thickness (0.75 mm) of peel and lower TSS in Heemsohna may be one of the reasons for the higher shelf life as compared to lower shelf life with higher TSS and lower peel thickness (0.37 mm) in KSP-1113. The lycopene content varied among the cultivars in the range of 2.63 to 5.81 mg/100 g FW. Cherry tomato cv. KSP-1113 exhibited maximum lycopene content (5.81 mg/100g FW) and minimum in NS-1218 (2.63 mg/100 g FW) (Fig. 2a). The pectin content in red ripe tomato fruit was estimated. AIS content was recorded maximum in KSP-1113 (2.36%) and minimum in NS-1218 (1.35%). The recovery of water soluble and ammonium oxalate soluble pectin was maximum in Heemsohna (9.02 and 15.76 g/100 g AIS), however, NS-1218 contained maximum amount of alkali soluble pectin (4.72 g/100 g AIS) (Fig. 2b). Interestingly, the pulp of KSP-1113 contains maximum level of alcohol insoluble solids (2.36%) and minimum in NS-1218 (1.35%).

The parameters of economic importance like fruit weight and yield are better under protected conditions compared to open field conditions (Rana *et al.,* 2014). Tomato fruit yield under greenhouse condition may reach 5.7 to 6.0 kg/plant while under open field condition 1.4 to 2.0 kg/plant can be achieved under favourable climatic condition (Singh *et al.,* 2015). TSS and acidity ratio can contribute strongly to the tomato shelf life and consistency (Carrari and Fernie, 2006). TSS/acidity ratio has also been reported as one of the important components in tomato fruit flavour and storage stability (George *et al.,* 2004). Visible fruit colour of tomato is one the most important visual quality parameters for consumers as it imparts attractive red colour due to predominant constituent pigment, lycopene. There are several important factors that affect the fruit quality and lycopene content in tomato *viz.,* light and temperature, besides other cultural practices. Wide variations in lycopene content (3.0 to 11.0 mg/100 g) have been reported in Hungarian, Spanish and Indian tomatoes (Adalid *et al.,* 2010). Cherry tomatoes have also contained higher content of lycopene than local cultivars which were grown under open conditions (Raffo *et al.,* 2006). Differences between small, high pigmented cherry tomato and other normal size cultivars have been attributed to genotypic factors triggering enhanced enzymatic activity of phytoene synthase-I that causes a massive production of lycopene precursors. Fraser *et al.,* (2009) reported that reduced cycling rate of this molecule to synthesize carotenes resulted in higher accumulation of lycopene during ripening. Another plausible explanation accounting for significant differences between the cherry tomato and other cultivars is related to their smaller fruit size and high peel percentage. All the cultivars were normal sized (86.76 – 121.12 g) with low peel percentage; on the other hand the cherry tomato, which was smaller sized fruits (18.50 g), had higher peel percentage (data not shown). As peel is the main reservoir of lycopene and accumulates 3-4 times higher content, small sized cherry tomato tends to have higher lycopene content than the bigger sized fruits of other cultivars. This adequately explains highest lycopene content observed in KSP-1113 in comparison to other three cultivars. Similar observations were recorded in small sized Corbarini and Campari cultivars (Toor and Savage, 2005). Genotype influenced the lycopene content of fruit which varied from 6.95 mg/100 g fresh fruit (Carmem) to 8.88 mg/100 g fresh fruit (BGH-320) (Caliman *et al.,* 2010). Apart from genotypic factors, environmental factors such as temperature and sunlight can also considerably affect the biosynthesis of lycopene in tomato. Under high-tech greenhouse condition, the optimum temperature (26-28 °C), relative humidity (65-85%) for lycopene synthesis as well as partial shading to reduce the surface temperature help in minimizing lycopene degradation (Zoltán *et al.,* 2013). The work on lycopene biosynthesis under tropical conditions was also reported by Kaur *et al.,* (2013). The authors reported that optimum temperature range for biosynthesis of lycopene is between 12 to 32 °C. In subtropics during May-June, temperature shoots up above 32 °C and can reach beyond 40 °C. This coupled with excessive sunlight hinders lycopene synthesis in tomato. The AIS content was found significantly low in all cultivars at red ripe stage. Lower AIS upon ripening was also reported in other fruit crops like mango (Tandon and Kalra, 1984) where the authors mentioned that sharp decline in starch content could be the reason for fall of AIS. The solubilization of pectic substances during ripening by various enzymes might be the reason for decrease in AIS. This result was well supported by Jagtiani *et al.,* (1988) in papaya fruit where the activity of pectin methyl esterase increased and more pectin was solubilized during ripening of papaya fruit. Earlier literatures supported that water soluble (high methoxyl) and ammonium oxalate soluble (low methoxyl) pectin increased while alkali soluble pectin (protopectin) decreased at the time of ripening in many horticultural crops *viz.,* mango (Tandon and Kalra, 1984), guava (Killadi *et al.,* 2018), sweet cherry (Fils-Lycaon and Buret, 1990) and bael (Anup *et al.,* 2017), which is evident in the present study. All the authors opined that the initiation of solubilization of pectin by some enzymes caused the increase in WE and AOE contents and decrease in AE content during ripening of fruits. Thus, Heemsohna was found better in terms of high amount of water soluble pectin.

Based on different attributes recorded, it can be concluded that tomato cultivars grown under greenhouse condition offers an opportunity to improve the quality and extended availability period in subtropical regions. On the basis of higher yield, better marketable shelf life and higher pectin content, cultivar Heemsohna and on the basis of higher lycopene content, cultivar KSP-1113 can be recommended for cultivation under protected condition even at higher temperature in subtropics.

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