Biological Forum – An International Journal **14(3): 395-403(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Performance of Cherry Tomato (*Solanum lycopersicum* var. *cerasiforme* (Dunal) A. Gray) Genotypes for Physico-chemical Attributes under Naturally Ventilated Protected Structure

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(Received 25 May 2022, Accepted 06 July, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The cherry tomato is considered as an important protective food due to its well-balanced nutritional and high antioxidant property. Wide adaption to a particular environment and consistent performance of recommended genotypes is the key question for its commercialization. Although few varieties for cultivation of cherry tomato have been evaluated and recommended so far but the information on the stability is still far behind for the agro-climatic condition. Therefore, a pertinent need was felt initially to evaluate and screen the potential genotypes of cherry tomato for their growth, yield and nutritional quality, fruit colour under protected growing conditions. The diverse climatic conditions as well as heavy rainfall during monsoon and severe cold and snowfall during winters in Kumaon hills of Uttarkhand favours cultivation of cherry tomatoes under protected structures. So far very meager systematic work on evaluation, identification and development of cherry tomato genotype has been reported and very few varieties of cherry tomato have been evaluated and recommended for cultivation in agro-climatic condition of Uttarakhand. The current study was aimed to assess the performance of various cherry tomato genotypes under polycarbonate sheet covered natural ventilated protected structure conditions for their growth, yield, quality and fruit colour attributes. In this field-laboratory experiment, conducted during 2017-18, eleven diverse genotypes were evaluated at an altitude around 2170m above sea level of Kumaun hills of Uttarakhand (India) for growth, yield and quality parameters under Naturally Ventilated Polycarbonate Sheet Green House condition in a Randomized Complete Block Design (RCBD) with three replications. The growth and yield parameters were determined in the field observations, while as the ripen fruits were analyzed for biochemical parameter in the laboratory following standard procedures. The study revealed that the genotype CITH-M-CT-6 manifested the maximum plant height (330.23 cm) and number of fruits/plant (275.00) whereas highest average fruit yield per plant (1.54 kg) and TSS content (6.80^0B) were determined in CITH-CT-7. Highest carotene (1693.47mg/100g) and antioxidant activity (35.32 mMTE/L) were observed in CITH-M-CT-1 and CITH-M-CT-5, respectively. The fruits of CITH-M-CT-2 (Red) and CITH-M-CT-4 possessed highest value of ascorbic acid (54.65 mg $100g^{-1}$). The genotypes CITH-M-CT-2 (Yellow) exhibited highest values for luminous (L) (50.03) yellow-blue (b) (+60.35), chroma (C) (62.57) and h^o (h^o = 77.19). Higher values of GCV and heritability and genetic advance were estimated for average fruit weight, number of fruits/plant, carotene content and ascorbic acid content which indicated that these traits had additive gene effect and, therefore, are more reliable for effective selection. Further, the traits *viz*., average fruit weight, number of fruits/plant, carotene content and ascorbic acid content are under additive gene effects and more reliable for effective selection in present context of this experimentation.

Keywords: Cherry tomato, genotype, genetic variability, Heritability quality, yield.

INTRODUCTION

Tomato (S*olanum lycopresicum* L.) is one of the most important solanaceous vegetable crops grown widely all over the world and is native to South America (Rick, 1969). Cherry tomato (*Solanum lycopersicum* var. *cerasiforme* (Dunal) A. Gray) is a botanical variety of the cultivated tomato having chromosome number 2n=24. It is thought to be the ancestor of all cultivated tomatoes. It is less popular in India due to lack of awareness for its nutritive values and unavailability of high yielding varieties of cherry tomato. It is widely cultivated in Central America and is distributed in California, Korea, Germany, Mexico and Florida. It is a warm season crop reasonably tolerant to heat and drought. It is also known as salad tomato possessing good taste and is one of the emerging delicious high value fruit vegetable crops and is considered as an exotic vegetable bringing new taste and appearance to dishes. Thapa *et al.* (2014) considered it's an important protective food due to its well-balanced nutrition consisting of minerals (K, Mn, P, Cu, Ca, Fe, Zn), Vitamins (A, B1, B2, C, E, K, etc), dietary fibre, citric acid and high antioxidant property. Carotenoids are also responsible for the colour of tomatoes, in that lycopene is mainly responsible for red color (Holden *et al.,* 1999). The information on the nature and extent of genetic variability for various characteristics would help in choosing the right parent for the development of variety with improved desirable genotype of cherry tomato. Though cherry tomato became popular as a cash crop in some Asian countries, but is still new in India. It is, therefore, essential to assess the quantum of genetic variability, heritability and expected genetic advance with respect to different characters, which would help plant breeders in planning a successful breeding programme to breed new ecotype. Genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance are useful biometrical tools for determination of genetic variability present in the germplasm material. As the yield is a complex character, quantitative in nature and an integrated function of a number of component traits, therefore, information on the nature and degree of genetic divergence for fruit characters would help in choosing the right parent for the development of variety with improved desirable genotype of cherry tomato.

Wide adaption to a particular environment and consistent performance of recommended genotypes is the key question for its commercialization. Although few varieties for cultivation of cherry tomato have been evaluated and recommended so far but the information on the stability is still far behind for the agro-climatic condition. Some researchers *viz*., Malavika and Sheela (2017); Yimchunger *et al.* (2018); Anwarzai *et al.* (2020); Pandurangaiah *et al.* (2020); Mathew and Caitlin (2022) have assessed the performance of genotypes of cherry tomato under various conditions. Malavika and Sheela (2017) assessed the performance of ten genotypes of cherry tomato inside rain shelter and reported SLc-10 and SLc-9 genotypes for cultivation inside rain shelter in Vellanikkara. Yimchunger *et al.* (2018) evaluated six genotypes of cherry tomato under foothill condition of Nagaland and Swarna Ratan was found potential yielding variety. Anwarzai *et al.* (2020) evaluated twenty one cherry tomato genotypes evaluated for growth, and yield parameters and recorded maximum fruit length in COHBT-198 (5.00 cm), maximum fruit girth (4.00 cm) in COHBT-209, COHBT-198 and COHBT-208, whereas genotype COHBT-198 recorded maximum average fruit weight (43.90 g) and fruit yield per plant (2.30 kg). Similarly, Mathew and Caitlin (2022) six varieties of cherry tomatoes in six cropping system at four locations and observed that productivity often varied among cultivars within a cropping system. 'Terenzo' and 'Tumbler' were always some of the most productive cultivars, whereas 'Micro Tom' was normally among the least productive cultivars. The production from 'Red Robin', 'Tiny Tim', and 'Sweat 'n' Neat' was more variable, sometimes producing high, moderate, or low mass. The diverse climatic conditions as well as heavy rainfall during monsoon and severe cold and heavy snowfall during winters in Kumaon hills of Uttarkhand favours cultivation of cherry tomatoes under protected structures. Therefore, a pertinent need was felt initially to evaluate and screen the potential genotypes of cherry tomato for their growth, yield and nutritional quality, fruit colour under protected growing conditions. Keeping this in view, 11 cherry tomato inbred lines were evaluated for growth, yield, and quality attributes as well as genetic components *viz*., genetic variability, heritability and genetic advance with a view to identify suitable genotype for greenhouse cultivation as well as to breed new varieties/hybrids for growing under protected structures in high altitude.

MATERIALS AND METHODS

The present experiment was conducted at ICAR-CITH Regional Station, Mukteshwar, Nainital (UK) during summer-kharif season of 2017-18. The campus is located in the Nainital district of Uttarakhand (29° 0′ to 29°5′ N; 78°80′ to 80°14′E), elevated at around 2170 m above sea level. Eleven genotypes were evaluated for growth, yield and quality parameters under Naturally Ventilated Polycarbonate Sheet Green House condition in a Randomized Complete Block Design (RCBD) with three replications at plant spacing of 45×60cm following uniform cultivation practices of plants. Total soluble solids (TSS) was measured by hand refractometer and other quality parameters were determined as per AOAC (1975). The fruit juice was used to determine total soluble solids (TSS) by using a refractometer (ERMA refractometer 0-32 brix). Titratable acidity (TA) was measured by titration of 2 ml of homogenated juice with added 2 drops of 1 % phenolphthalein and titrated by N/10 NaOH solution till it becomes light pink in colour. Ascorbic acid content was measured by using 2, 6 Di chlorophenol indophenols method and reducing sugar was estimated as per the procedure described by Ranganna (2010).For estimation of total carotenoids, the samples were extracted in 3% acetone in petroleum ether. Total carotenoids were read colorimetrically using 3% acetone in petroleum ether for baseline correction and the absorbance at 452 nm was recorded against a reagent blank. The antioxidants activity was expressed as m mol Trolox per litre (mMTE/L) and analyzed as per the method of Apak *et al.* (2004).

The colour value of different tomato genotypes were obtained in terms of *viz.* luminous (L*), red colour (a*), yellow colour (b*), chroma (C*) and hue angle (h°) values using a Lovibond RT series reflectance tintometer. The 'L*' describes luminosity or lightness and varies from Zero (Black) to 100 (perfect white). The chromaticity dimension 'a*' magnitude redness when positive, greyness when zero and greenness when negative. The 'b*' value describes yellowness when positive, grey when zero and blueness when negative. The 'C*' measures the chroma (saturation) of the colour, a measure of how far from the great tone the colour is. Hue angle (h°), measures the hue of the colour, *i.e.,* colour tonalities (red, green, yellow etc.) (Kishor *et al*., 2017). The data were statistically analyzed by using the standard statistical procedure (Gomez and Gomez, 1984). Genotypic and phenotypic coefficients of variation were calculated as per the formulae given by Burton and De Vane (1953). The heritability in broad sense and expected genetic advance were calculated as per the method of Jonson *et al.* (1955) while as estimates of genetic advance as percentage of mean were calculated following method of Comstock and Robinson (1952).

RESULTS AND DISCUSSION

A. Growth components

Statistically analyzed mean data of the experiment revealed that most of the growth contributing characters under observation had shown significant differences among the genotypes. The per se performance of cherry tomato genotypes for growth characters is given in Table 1. Perusal of data of Table 1 depicted that genotype differed significantly among themselves for plant growth characteristics and the wide variation among the genotypes for plant growth traits *viz*., plant height, number of branches/plant, average length of branch and plant spread (E-W & N-S) may be due to genetic constitution of different genotypes. A wide variation among the different genotypes in growth parameters *viz*., plant height, number of primary branches, average length of primary branches and plant spread (east-west and north-south) were observed which may be due to genetic constitution of different genotypes. The variation in plant growth in terms of plant height, number of primary branches/plant, average length of primary branches and plant spread (east-west and north-south) were observed among the genotypes and varied from 81.43 cm to 330.23 cm, 3.33 to 6.66, 65.33 cm to 229.00cm, 43.36 cm to 91.60 cm and 46.56 cm to 83.96 cm, respectively. The maximum plant height of 330.23 cm was recorded in genotype CITH-M-CT-6 followed by 313.33 cm in CITH-M-CT-6 while it was minimum in 2016/TOCVR-1 (81.43 cm). The genotype CITH-M-CT-5 produced maximum number of primary branches/plant (6.66) and the second tallest genotype *i.e*., CITH-M-CT-7 exhibited maximum average length of primary branches (229.00 cm). These results were supported by the findings of Swaroop and Suryanarayan (2005) who found the significant variation on plant growth and yield in all different 24 lines of tomato (*Lycopersicon esculentum* Mill) lines. The significant variation among the tomato genotypes under polyhouse was also reported by Narayan *et al.* (2020). The optimum temperature, high carbon dioxide concentration and better light distribution are necessary for optimum plant growth and development under polyhouse conditions. Performance of any crop with respect to growth, yield and quality are highly influenced by various factors especially the genetic constitution of a variety, the microclimate of an area and crop management. The wide range of variation obtained may be due to divergent genotypes included in the study. Similar findings have been reported for plant height, yield/plant and fruit diameter (Patil *et al.,* 2013). It is also influenced by the microclimatic condition surrounding the tomato plant and cultural practices under the polyhouse conditions. Malavika *et al.* (2017) also observed significant variation for plant height among the 10 genotypes of cherry tomato evaluated under rain shelter. Wide variations among the genotypes of cherry tomato in regard to plant height and number of branches/plant were also reported by Yimchunger *et al.* (2018).

B. Fruit yield components

The genotypes differed significantly for yield attributes and ranged from 20.98 to 33.71 mm, 15.45 to 30.36 mm, 78.33 to 275.00 and 0.298 to 1.540 g in fruit length, fruit breadth, and number of fruits/plant and fruit yield/plant, respectively. Perusal of data of Table 1 depicted that among the genotypes, CITH-M-CT-6 exhibited maximum number of fruits/plant (275.00) while as highest average fruit breadth (30.36mm), fruit weight (19.17g) and fruit yield/plant (1.54 kg) were recorded in CITH-CT-7 under polycarbonate sheet covered natural ventilated protected structure. The top yielding genotype also possessed higher values for average length of primary branches, fruit breadth and average fruit weight. The highest number of fruits producing genotype *i.e.* CITH-M-CT-6 was stood third in production of fruits/plant with 1.160 g fruits/plant and second was CITH-M-CT-2 (R) with 1.356 g fruit yield/plant. Whereas, minimum number of fruits/plant (78.33), average fruit weight (5.34 g) and fruit yield/plant (0.298 g) were recorded in CITH-M-CT-3, 2016/TOCVR-6 and CITH-M-CT-2 (Y), respectively (Table 1). More number of fruits/plant may be due to more plant height. Likewise, the variation in average fruit weight might be due to inverse relationship existing between average fruit weight, and number of fruits/cluster. This was conformity with the findings of Renuka *et al.* (2017) and Anwarzai *et al.* (2020). The highest fruit yield may be attributed to the favorable growth conditions that prevailed under polyhouse and also due to its protective ability against major abiotic stresses, which reduces the effect of excessive rainfall, water logging as well as provide controlled environment. Shorter fruit length, fruit girth and fruit width of cherry tomato genotype may due to character of *cerasiforme* species. The present result correlates with the findings of (Kumar *et al.,* 2014) in cherry tomato. Malavika *et al.* (2017); Yimchunger *et al.* (2018) are also observed the significant variations on yield and yield attributing characters in different accessions of cherry tomato. The vigorous growth of tomato inside shed net house might be due to prevalence of micro climate and optimum light intensity inside the shade net house, and the result was in accordance with the findings of (Rana *et al*., 2014) in tomato. Higher yield of cherry tomato was mainly due to more number of fruits/ plant resulting from more number of flowers and fruits/cluster in addition to comparatively more number of primary, secondary branches and plant height.

Table 1: Per se performance of cherry tomato genotypes for growth and yield attributes.

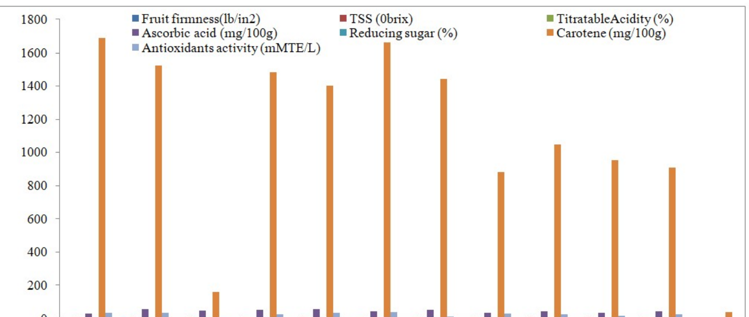
Genotypes	Av. plant height (cm)	Av. length of primary branches (cm)	No. of primary branches / plant	Av.plant spread (E-W) (cm)	Av.plant spread (N-S) (cm)	Av. fruit length (mm)	Av. fruit breadth (mm)	No. of fruits/ plant	Av. fruit weight (g)	Av. fruit yield/ plant (kg)	Fruit yield (q/ha)
CITH-M-CT-1	150.56	83.36	3.33	43.96	47.93	28.24	25.76	138.33	13.73	1.100	407.40
CITH-M-CT-2 (R)	141.86	121.83	4.66	58.63	59.20	25.35	18.22	207.66	7.073	1.356	502.22
CITH-M-CT-2 (Y)	107.06	93.86	4.00	52.16	46.56	26.21	16.30	82.00	6.21	0.298	110.37
CITH-M-CT-3	227.63	174.90	4.33	91.60	90.33	23.18	21.18	78.33	7.89	0.673	249.25
CITH-M-CT-4	240.46	177.20	5.66	85.80	83.96	21.66	23.44	250.67	8.38	1.233	456.66
CITH-M-CT-5	296.20	220.63	6.66	77.90	66.90	29.79	17.75	101.33	6.44	0.743	275.18
CITH-M-CT-6	330.23	198.25	5.00	80.30	63.50	20.98	20.54	275.00	6.97	1.160	429.62
CITH-M-CT-7	313.33	229.00	6.00	77.03	73.53	29.89	30.36	145.33	19.17	1.540	570.36
2016/TOCVR-1	283.40	195.63	6.33	70.56	73.56	33.71	22.04	136.33	11.84	1.093	404.81
2016/TOCVR-4	81.43	65.33	6.00	49.60	47.50	21.85	22.27	153.33	8.70	0.923	341.85
2016/TOCVR-6	176.70	125.60	5.33	43.36	48.93	25.49	15.45	104.33	5.34	0.480	177.77
Mean	213.53	153.23	5.21	66.44	63.81	26.03	21.21	152.06	9.25	0.963	356.86
CD (P≤0.05)	45.31*	37.75*	1.47*	20.83*	16.02*	6.11*	5.62*	43.30*	5.83*	0.337*	
CV	12.37	14.36	16.49	18.27	14.63	13.69	15.45	16.60	36.78	20.54	

Av.-Average; No.-Number; CD - critical Difference; CV-Coefficient of variation
*Significant at P 0.05; NS- Non Significant at P > 0.05

C. Nutritional quality attributes of fruit

The genotypes studied for different nutritional quality characteristics of fruit are represented in Table Fig. 1. The cherry tomatoes developed for fresh market and processing should have distinct quality characteristics. For processing and fresh market consumption, fruits should be firm, well coloured with acceptable flavour. Genotypes exhibited significant differences for the biochemical attributes and showed wide variation among themselves for qualitative fruit traits namely fruit firmness, TSS, titrable acidity, ascorbic acid, reducing sugar, carotene, antioxidant contents and colour of fruits which might be due to genetic constitution of different genotypes. Among the present materials of cherry tomato, most firmer fruits (5.41 lb/in^2) were produced by the CITH-M-CT-2 (R) and it was at par with CITH-M-CT-1 (3.75 lb/in^2) and CITH-M-CT-5 (3.66 lb/in^2) while as least firmer fruits were found in CITH-M-CT-2 (Y) CITH-M-CT-3, 2016/TOCVR-4 and 2016/TOCVR-6 (2.25 lb/in^2). A high total soluble solid (TSS) is the major attribute considered for preparation of processed products. According to Berry *et al.* (1988); Shivanand (2008), one per cent increase in TSS content of fruits results in 20 per cent increase in recovery of processed product. The data pertaining to the total soluble solid (°B) showed significant differences among the different cherry tomato genotypes. The variation in TSS content in different genotypes of cherry tomato was noticed from 4.53°B to 6.80°B. The maximum TSS content (6.80°B) was recorded in genotype CITH-M-CT-7 which was significantly superior to other genotypes namely CITH-M-CT-3, CITH-M-CT-2, 2016/TOCVR-4 whereas it was found minimum (4.53°B) in CITH-M-CT-3. The genotype CITH-M-CT-7 with 6.80°B TSS was statistically *at par* with remaining genotypes and also possessed maximum values for reducing sugars *i.e.* 4.31%. Titrable acidity showed significant differences among the different cherry tomato genotypes and maximum acidity (0.78%) was observed in CITH-M-CT-5 followed by CITH-M-CT-3 (0.84%) and 2016/TOCVR-6 (0.78%) while as it was minimum acidity in CITH-M-CT-2 (R) (0.23%) and CITH-M-CT-2 (Y) (0.44%). Rana *et al.* (2014) stated that the low values of titrable acidity were because of red fruits used for analysis. Similar results for TSS and acidity were reported by Yimchunger *et al.* (2018); Anwarzai *et al.* (2020) in cherry tomato and Narayan *et al.* (2020) in tomato. The ascorbic acid content in different genotypes of cherry tomato varied from 24.45 mg to 54.65 mg/100g of pulp with highest of 54.65 mg/100g in genotype CITH-M-CT-2 (R) and CITH-M-CT-4while the lowest was recorded in genotype CITH-M-CT-1 with 24.45 mg/100 g of fruit pulp. These results are in conformity with findings of Caliman *et al.* (2010) and Manna and Paul (2012).

Lycopene pigment in cherry tomato fruit is considered as a nutritional factor because of its antioxidant nature. The carotene content in fruits (mg/100g) showed significant differences among the different cherry tomato genotypes (Fig. 1). The genotype CITH-M-CT-1 recorded maximum carotene content of 1693.47mg/100g which was followed by CITH-M-CT-5 (1663.29mg/100g) and CITH-M-CT (R) (1524.54mg/100g) while it was found minimum CITH-M-CT (Y) (160.19mg/100g). Similar results are reported by Najeema *et al.* (2018). It was envisaged that the attractive yellow fruit colour might be due to presence of β-carotene and the red colour of the fruit due to lycopene which act as an antioxidant. Bhandari *et al.* (2016) recorded high antioxidant and lycopene contents (>1930 mg/kg) in cherry tomato. Highest antioxidant activity (35.32 mMTE/L) was found in CITH-M-CT-5 followed by CITH-M-CT-5 (32.22 mMTE L^{-1}), CITH-M-CT-1 (30.89 mMTE L^{-1}) CITH-M-CT-2 (Red) (30.45 mMTE/L) whereas minimum values were noted in CITH-M-CT-2 (R) (6.40 mMTE/L). Present findings supported by the results obtained by Narayan *et al.* (2020) in tomato. Prema *et al.* (2011) also observed variation in cherry tomato genotype in respect of quality attributes *viz*., firmness of fruits and TSS, ascorbic acid, lycopene content of fruits.

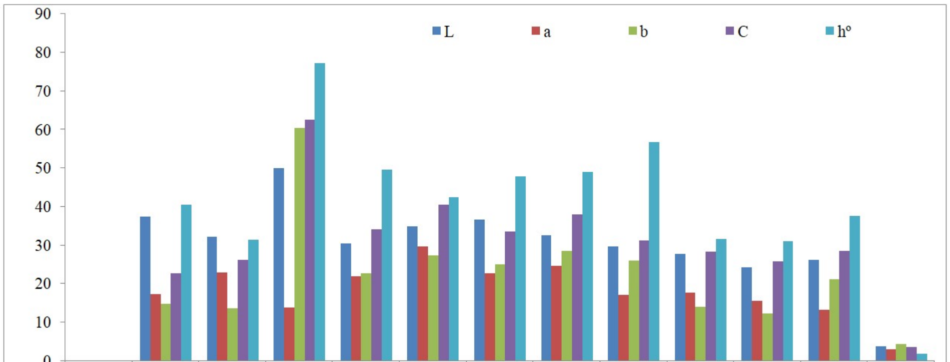


	CITH-M-CT-1	CITH-M-CT-2 (R)	CITH-M-CT-2 (Y)	CITH-M-CT-3	CITH-M-CT-4	CITH-M-CT-5	CITH-M-CT-6	CITH-M-CT-7	2016/TOCVR-1	2016/TOCVR-4	2016/TOCVR-6	CD (P≤0.05)
Fruit firmness(lb/in2)	3.75	5.41	2.25	2.25	2.75	3.66	3.08	2.41	2.5	2.25	2.25	2.02
TSS (0brix)	6.2	6.53	6	4.53	6.7	6.4	6.3	6.8	5.11	5.4	5.9	0.71
TitratableAcidity (%)	0.5	0.23	0.44	0.84	0.67	1.01	0.67	0.66	0.54	0.65	0.78	0.04
Ascorbic acid (mg/100g)	25.45	54.65	43.72	50.27	54.65	41.53	51.37	32.79	42.56	33.55	38.82	0.47
Reducing sugar (%)	3.57	3.2	3.64	2.5	3.2	2.85	3.44	4.31	2.02	2.64	2.01	0.44
Carotene (mg/100g)	1693.47	1524.54	160.19	1487	1402.92	1663.39	1446.63	886.08	1052.25	958.34	912.62	39.04
Antioxidants activity (mMTE/L)	30.89	30.45	6.4	25.19	32.22	35.32	10.21	29.03	21.62	11.78	20.85	0.46

Fig. 1. Graphical representation of variation in nutritional components of ripen fruits of cherry tomato genotypes.

D. Fruit colour parameters

The fruit colour parameters of different cherry tomato genotypes are presented in Fig. 2. The ground colour and blush depend on sunlight during ripening. Low value of 'L*' indicates dark fruit skin. The genotypes CITH-M-CT-2 (Y) (L*= 50.03) was found the most luminous, followed by CITH-M-CT-1 (L*= 37.29) and CITH-M-CT-1 (L*= 36.56); while the lowest values were observed in 2016/TOCVR-4 (L*= 24.25). The 'a*' or red-green values showed significant difference in the present material of study. The highest red colour was found in CITH-M-CT-4 (a*= +29.63) followed by CITH-M-CT-6 (a*= +24.49) and CITH-M-CT-2 (R) (a*= +22.84) while lowest red colour values were noted in 2016/TOCVR-6 (a*= +13.19). The 'b*' or yellow-blue component values were highest (b*= +60.35) in CITH-M-CT-2 (Y) and the lowest values were in 2016/TOCVR-4 (b*= +12.28). The croma (C*) values measure colour saturation intensity, a measure of how far from the great tone the colour is. The CITH-M-CT-2 (Yellow) depicted maximum chroma (C*= 62.57) followed by CITH-M-CT-4 (C*= 40.39) whereas minimum values of chroma was noticed in CITH-M-CT-1 (C*= 22.64). The hue angle (hº) correlates with 'a*' and 'b*' values. It is a good factor to assess the changes of characteristics colour in these genotypes. Lowest hº values indicates a redder colour as exemplified by 2016/TOCVR-4 (hº= 30.90) which was at par with CITH-M-CT-2(R) (hº= 31.38) and 2016/TOCVR-1 (hº= 43.61); whereas CITH-M-CT-2 (Y) (hº= 7.19) showed the highest hº value (Fig. 2). Pandurangaiah *et al.* (2020) found a strong correlations between color surface value a* and total carotenoids (0.82) and lycopene content (0.87). They also observed positive correlation for the b* color value with carotene (0.86). The L* value was negatively correlated (-0.78) with an increase in carotenoids. These close associations between color space values L*, a*, b* and carotenoids will help the breeders to quickly screen large germplasm/breeding lines in their breeding program for improvement in carotenoid content through this time saving, inexpensive and nondestructive method at fully ripe stage.



	CITH-M-CT-1	CITH-M-CT-2 (R)	CITH-M-CT-2 (Y)	CITH-M-CT-3	CITH-M-CT-4	CITH-M-CT-5	CITH-M-CT-6	CITH-M-CT-7	2016/TOCVR-1	2016/TOCVR-4	2016/TOCVR-6	CD (P≤0.05)
L	37.29	32.09	50.03	30.31	34.84	36.56	32.48	29.53	27.59	24.25	26.22	3.76
a	17.27	22.84	13.82	21.85	29.63	22.56	24.49	17.01	17.63	15.54	13.19	2.82
b	14.69	13.63	60.35	22.65	27.25	24.88	28.49	26.03	13.94	12.28	21.15	4.29
C	22.64	26.09	62.57	34.01	40.39	33.4	37.86	31.14	28.21	25.8	28.5	3.48
hº	40.45	31.38	77.19	49.6	42.44	47.76	48.89	56.66	31.5	30.9	37.52	1.81

Fig. 2. Graphical representation of variation in fruit colour attributes of ripen fruits in cherry tomato genotypes.

E. Estimation of coefficient of variations, heritability and genetic advance

The extent of variability among the genotypes was estimated in term of lowest and highest mean values for all characters, phenotypic coefficient of variations (PCV), genotypic coefficient of variations (GCV), heritability, genetic advance and genetic advance as percentage of mean studied for growth yield and quality parameters except fruit colour attributes and data are presented in Table 2. Perusal of data of Table 3 exhibited high estimates of GCV and PCV for average fruit weight (897.81 & 934.71), ascorbic acid content (256.47 & 256.52), carotene content (144.34 & 144.39), number of fruits/plant (238.10 & 244.38), fruit yield/plant (61.97& 63.17) and average length of primary branches (42.76 & 44.07); indicating the presence of wide range of genetic variability for these traits and chances for improvement of these traits though selection to be fairly high. Most of the traits under study depicted very good scope for improvement through selection as indicative of the presence of sufficient coefficients of genotypic and phenotypic variations. Similar findings were also reported by Narayan *et al.* (2020) in tomato.

Table 2: Estimates of mean, range, genotypic and phenotypic coefficient of variations, heritability and genetic advance in cherry tomato.

Traits	Range		Mean	Coefficient of variation		H^2 (%)	GA	GA (% of mean)
	Min	Max		(GCV)	(PCV)			
Average Plant height (cm)	81.43	330.23	213.53	37.15	37.66	80.00	0.094	4.22
Average length of primary branches (cm)	65.33	229.00	153.23	42.76	44.07	94.00	76.21	46.93
Number of primary branches/plant	3.33	5.21	5.21	4.59	4.96	85.00	1.42	28.68
Number of fruits/ plant	52.66	379.66	152.06	61.97	63.17	96.00	104.46	71.87
Average Fruit length (mm)	23.69	39.20	26.03	5.28	6.92	58.00	3.73	14.53
Average Fruit breadth (mm)	20.66	37.61	21.21	8.94	10.01	79.00	5.81	26.78
Average Fruit weight (g)	8.43	19.17	9.25	897.81	934.71	91.00	546.55	2851.06
Total Soluble Solids (^{0}brix)	4.53	6.80	6.00	2.71	8.23	89.00	0.942	15.24
Titratable Acidity (%)	0.23	1.01	0.63	3.03	3.03	100.00	0.33	53.22
Ascorbic acid (mg/100g)	24.45	54.65	42.67	256.47	256.52	99.00	14.84	33.49
Reducing sugar (%)	2.50	4.31	3.03	2.87	2.98	92.00	0.730	21.85
Carotene mg/100g	160.19	1693.47	1198.86	144.34	144.39	99.00	720.46	56.15
Antioxidants activity (mMTE/L)	6.40	35.32	23.09	2.66	3.60	54.00	2.06	6.66
Av. fruit yield/plant (kg)	533.33	2363.3	0.963	3.15	5.78	81.00	0.547	35.51

Genotypic coefficients of variation do not estimate the variations that are heritable (Falconer, 1960), hence estimation of heritability becomes necessary. Heritability in broad sense is a parameter of tremendous significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression. Data revealed that the estimates of heritability were high for most of traits under study and ranged from 58 to 100%, except for antioxidants activity (54.00) and average fruit length (58.00) which showed moderate heritability. The heritability estimates worked out in present study are in consonance with earlier reports by (Mohamed *et al.,* 2012) for plant height, fruit weight and number of branches/plant in different genotypes of tomato; Kumar and Arumugam (2010) for polar diameter, TSS, plant height, fruits/plant, average fruit weight and yield/plant. The highest heritability for vegetative and yield traits were found for traits like plant height (80%), primary branch length (94%), number of branches/plant (85%) number of fruits/plant (96%), fruit weight (91%) and fruit yield/plant (81%). Likewise, the qualitative attributes *viz*., titrable acidity (100%), ascorbic acid (99%), carotene content (99%) and reducing sugar (92%)also exhibited highest values for heritability. Johnson *et al.*(1955) stated that the estimates of heritability along with genetic advance are more reliable than heritability alone for predicting the effect of selection. Maximum genetic advance was exhibited in carotene content (720.46) followed by average fruit weight (546.55) and number of fruits/plant (104.46) whereas genetic advance as parentage of mean was highest for average fruit weight (2851.06) followed by number of fruits/plant (71.87), carotene content (56.15) and titrable acidity content (53.22). Heritability, genetic advance as percent of mean and genotypic coefficient of variation together could provide best image of the amount of advance to be expected from selection (Johnson *et al.,* 1955). Therefore, this observation indicated that these traits are under additive gene effects and more reliable for effective selection. In present study, high GCV and heritability estimates associated with greater genetic advance was observed for average fruit weight, number of fruits/plant, carotene content and ascorbic acid content which indicated that these traits had additive gene effect and, therefore, are more relative for effective selection. However, high heritability but low GA and low GCV for number of primary branches/plant, average fruit breadth, TSS, titrable acidity, reducing sugar and average fruit yield/plant showed the involvement of non-additive gene action and the selection upon these traits might not be promising. Similar results were reported by Singh and Narayan (2004), and Narayan *et al.* (2020) in tomato varieties. According to Burton and De Vane (1953), genetic coefficients of variability along with heritability estimates would provide a reliable indication of expected degree of improvement through selection in plant breeding.

Characters with low heritability and low genetic advance can be improved through hybridization (Liang and Walter, 1968; Anjum *et al.,* 2009). Therefore, the traits like average fruit length and antioxidants activity of cherry tomato can only be improved through hybridization since both traits produced low heritability along with low genetic advance.

Variation in fruit colour & shape in Cherry tomato genotypes.

Islam *et al.* (2012) also obtained high geno- and phenotypic coefficients of variation for individual fruit weight, number of fruits/plant as well as high estimates of heritability, genetic advance and genotypic coefficient of variation for the traits like individual fruit weight, number of fruits/plant in cherry tomato, indicated that these characteristics were controlled by additive gene action and the selection based on phenotype for these traits might be effective. Similarly high heritability coupled with moderate GA and GCV for fruit breadth suggested that selection might be effective for this trait.

CONCLUSION

From the present study, it was found that among eleven cherry tomato genotypes namely CITH-M-CT-7, CITH-M-CT-2 (R), CITH-M-CT-7 and CITH-M-CT-4 were superior for yield and some quality attributes and for better and attractive colour CITH-M-CT-2 (Y) was the best genotype. Hence, these genotypes have the potential for cultivation inside protected structure at high altitude of Kumaon hills. Sufficient variability existed in the present genetic materials of cherry tomato which could be used as breeding materials for further improvement and to breed new ecotype through selection and/or hybridization procedures. It is also inferred that the superior genotypes namely CITH-M-CT-7, CITH-M-CT-2 (R), CITH-M-CT-7 and CITH-M-CT-4 could be recommended for cultivation in the region. Apart from it, the present genetic materials of cherry tomato could be used as breeding materials for further improvement and to breed new ecotype through selection and procedures as there is sufficient variability existed in the materials. Moreover, cherry tomato has a great scope of cultivation as off season crop under natural ventilated protected structures during summer-kharif in high hills of Kumaon region which will fetch higher remuneration to the growers.

Acknowledgement. The authors are grateful to Dr D.B Singh, Director, ICAR-Central Institute of Temperate Horticulture, Srinagar (J&K) for providing facilities and other resources to conduct this research work. Thank is also due to Dr S.K. Singh, Director, ICAR-ATARI Zone II, Jodhpur for his kind logistic support in preparation of this manuscript.

Conflict of Interest. None.

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How to cite this article: Raj Narayan, Arun Kishor, Sumati Narayan and Anil Kumar (2022). Performance of Cherry Tomato (*Solanum lycopersicum* var. *cerasiforme* (Dunal) A. Gray) Genotypes for Physico-chemical Attributes under Naturally Ventilated Protected Structure. *Biological Forum – An International Journal*, *14*(3): 395-403.