**Original Research Article**

**Morpho-biochemical characterization of cherry tomato genotypes grown in open condition**

**ABSTRACT**

Cherry tomatoes are high value vegetables that can be the vegetable replacement of grapes. Variation in cherry tomatoes’ shape and colour are attractive to the consumers and therefore, earn high market value. Cherry tomatoes are mostly grown under protected conditions, but in India farmers mostly do not have access to protected structures. Thus, genotypes suited for open field condition are needed to be studied. Seven cherry tomato genotypes were grown on the trellis system in open field at the Indo-Gangetic plains of Bihar, India and morpho-biochemical characterization of the genotypes was carried out in the autumn-winter season of 2022-23. All the genotypes except one had indeterminate growth habit. The fruits were of red (, pink and yellow colour and round, oval, plum and pyriform shape. The average fruit weight was below 10 g which is ideal for cherry type tomatoes. The total soluble solids ranged between 5.13 to 11.47 ºBrix, titrable acidity from 0.13 to 0.28%, ascorbic acid content from 12.34 to 23.66 mg per 100g FW. Among the seven genotypes, BRCT-1, BRCT-37, BRCT-38 and Swarna Ratan performed well under open field conditions with respect to fruit morphological and quality aspect and may be recommended for open field condition or used as donor parents in breeding programmes.

KEYWORDS: Cherry tomatoes, plum and pyriform, grapes, donor parents

**INTRODUCTION**

Cherry tomatoes, believed to be progenitors of modern-day cultivated tomatoes (Ram, 2014) is botanically known as *Solanum lycopersicum* var. *cerasiforme*. Cherry tomatoes are usually small sized and round shaped tomatoes, and supposedly are genetic admixture of domesticated garden tomatoes and wild current type tomatoes (Nesbitt and Tanksley, 2002). The first domestication of tomatoes occurred in the Puebla-Veracruz area of Mexico from its centre of origin at South America in form of weedy cherry tomatoes (Kiple and Ornelas, 2000).

Cherry tomatoes may be of spherical or slightly oval in shape and the size may range from the tip of a thumb to the diameter of a golf ball (1.5-3.5 cm). Red is the most commonly available fruit colour, while orange, yellow, and pink coloured fruits are also available. Cherry tomatoes are an excellent source of phytochemicals and antioxidants, including lycopene and beta-carotene, flavonoids, vitamin C, carotenoids, and a variety of other crucial bioactive compounds (Lenucci et al., 2006). It can be consumed raw, like fresh fruit, or cooked. They are also perfect for preparing dishes like sauce, soup, ketchup, puree, curries, paste, powder, rasam, and sandwiches. According to the USDA (2018), one cup (149 g) of cherry tomatoes contains about 27 kcal energy, 1.31 g protein, and 5.80 g carbs. It has a broad range of applications in the treatment of chronic diseases and as a pain reliever due to its anti-inflammatory properties (Lekshmi and Celine, 2015). The increased dry matter and soluble solids content of cherry tomato varieties compared to regular-sized fresh market cultivars which is attributed to the enhanced amount of sugars (fructose and glucose) and organic acids (citric and malic acid), which in turn plays a significant role in determining the greater sweetness, sourness, and overall flavour intensity of most cherry varieties. The ripe fruits of cherry tomatoes contain different important pigments and phytonutrients (Schierle et al. 1997; Holloway et al. 2000; Livny et al. 2002; Canene-Adams et al. 2005; Toor and Savage 2005; Perveen et al. 2013; Campestrini et al. 2019). Carotenoids, which impart the ripe tomatoes their red, orange, or yellow colour, are the main pigments found in cherry tomatoes. Carotenoid synthesis occurs in chromoplast. Lycopene and β-carotene, offer a variety of health benefits (Khachik et al. 2002), i.e., reduces blood pressure, diminishes the risk of prostate and other cancers, cardiovascular diseases, has positive effect on skeletal system and neurogenerative diseases including Alzheimer’s and Parkinson’s (Przybylska 2020). Natural mutant alleles are available in tomato germplasm which modify the ripe tomato fruit colour and pigment composition and result in variation of colour (Chattopadhyay et al, 2021).

Cherry tomatoes are considered high value crops and often grown under protected structures. Farmers in eastern and north-eastern India are taking up cultivation of cherry tomatoes and their use in local food habit is on an increasing trend (Dutta et al., 2023). However, Indian small and marginal farmers often do not have facilities to grow these crops under protected structures. Therefore, genotypes that perform efficiently under open conditions are the need of time. The present study was undertaken where a set of cherry tomato genotypes was grown under open field condition and their morpho-biochemical performance was studied.

**MATERIAL AND METHOD**

In this study, a total of seven parental tomato genotypes, collected from different institutes across India or developed at Bihar Agricultural University, Sabour were used. The details of the parental genotypes are given in Table 1. These genotypes were grown in open field condition at Vegetable Research Farm, Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur (Bihar) which lies in the Indo-gangetic plains of Bihar, during *Rabi* season, i.e., autumn-winter season of 2022-23 and the plants were trained on iron trellis. The plants were planted at a spacing of 60 cm x 50 cm.

**Table 1: List of parental genotypes used in the current study**

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Parents**  | **Source** |
|  | BRCT-1 | Developed and maintained at BAU, Sabour |
|  | BRCT-1 R | Developed and maintained at BAU, Sabour |
|  | BRCT-32  | Developed and maintained at BAU, Sabour |
|  | Swarna Ratan | Collected from ICAR-RCER, Palandu, Ranchi and maintained at BAU, Sabour |
|  | BRCT-37  | Developed and maintained at BAU, Sabour |
|  | BRCT-23  | Developed and maintained at BAU, Sabour |
|  | BRCT-38  | Developed and maintained at BAU, Sabour |

Twelve qualitative morphological traits, six fruit morphological traits (polar and equatorial diameter, fruit shape index, average fruit weight, pericarp thickness and locule number) and three traits related to quality aspect (total soluble solids, titrable acidity and ascorbic acid content) were studied. Total soluble soilds was estimated using a hand refractometer (ERMA) and temperature correction was done to get the final value. Titrable acidity was measured as per Ranganna (1977) by titrating diluted fruit sample against 0.1(N) NaOH using phenolphthalein as indicator. The ascorbic acid was estimated by volumetric method as per AOAC (2001) using 2,6-indophenol dichlorophenol dye. The quantitative data were subjected to statistical analyses, i.e., Analysis of variance for CRD and Duncan’s multiple range test for estimation of variation between the genotypes. The analyses were carried out by using the OPSTAT software (Sheohar et al., 1998).

**RESULT AND DISCUSSION**

The morphological attributes and biochemical composition of the seven cherry tomato genotypes namely BRCT-1, BRCT-32, Swarna Ratan, BRCT-37, BRCT-23, and BRCT-38 was studied. Evidently, these genotypes hold promise for unravelling the intricacies of fruit colour variation in cherry tomatoes. All parental lines had a consistent predominant plant structure characterized by indeterminate nature, except BRCT-32 which was semi-determinate in nature. The usual practice of growing of the cherry tomatoes in protected condition has mostly led to cherry tomato varieties with indeterminate growth habit, and cherry tomatoes being wild relatives has the dominance of indeterminate type plant growth habit.

The presence of green pigmentation in both the leaf and stem, as well as the occurrence of medium leaf serration, was noted in the majority of the genotypes, as detailed in Table 2. In immature fruits, all lines had a green colouration, whereas mature fruits of the BRCT-1 were yellow while BRCT-32, BRCT-37 and BRCT-38 exhibited pink colour and BRCT-23 and Swarna Ratan showed red colour. Fruit from all genotypes had yellow peel, with the exception of BRCT-32, BRCT-37 and BRCT-38, which had colourless skin. It may be noted that tomato fruit colour is a resultant of colour and skin colour together and red colour with colourless skin gives the pink colouration to the fruit. Pink colour tomato fruits were first described by Lindstorm (1925) characterized by transparent epidermis lacking yellow pigment. During ripening of tomato, the flavonoid naringenin chalcone accumulates in the skin of the tomato, which is responsible for the natural yellow skin colour of the fruits (Hunt and Baker 1980). The presence of the single dominant *Y* allele results in this natural process, while mutations at the *y* locus leading to recessive *y* locus result in the absence of the naringenin chalcone and thereby leading to pink tomato fruits (Lindstrom 1925; Rick and Butler 1956). The candidate gene governing this colourless skin phenotype responsible for the *y* locus is the flavonoid biosynthetic pathway transcription factor *Solanum lycopersicum* *MYB12* (*SlMYB12*) (Wang et al. 2018; Ballester et al. 2010; Adato et al. 2009).

The majority of these genotypes exhibited a persistent presence of dark green shoulders at immature stage. Two genotypes, BRCT-1 and Swarna Ratan, were reported to have low ribbed fruits, while others did not exhibit ribbing on fruits. The presence of a pointed and indented blossom end pattern of fruits was seen in the BRCT-32 and Swarna Ratan genotypes respectively, while the remaining genotypes exhibited a flat pattern. Each parental line exhibited additional characteristics such as yellow flowers and ease of peeling of fruit. Plum fruit shape was detected in BRCT-1 and BRCT-1-R, pyriform in BRCT-32, oval in BRCT-37 and round in BRCT-23, BRCT-38 and Swarna Ratan.

**Table 2. Qualitative traits of the seven cherry tomato genotypes**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parent**  | **BRCT-1** | **BRCT-1-R** | **BRCT-32** | **Swarna Ratan**  | **BRCT-37** | **BRCT-23** | **BRCT-38** |
| **Plant Structure** | Indeterminate | Indeterminate | Semi-determinate | Indeterminate | Indeterminate | Indeterminate | Indeterminate |
| **Leaf Colour** | Green | Green | Green | Green | Green | Green | Green |
| **Leaf Serratior** | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| **Stem Colour** | Green | Green | Green | Green | Green | Green | Green |
| **Immature Fruit Colour** | Green | Green | Green | Green | Green | Green | Green |
| **Mature Fruit Colour** | Yellow | Red | Pink | Red  | Pink  | Red | Pink |
| **Green Shoulder** | Dark Green Shoulder | Dark Green Shoulder | Dark Green Shoulder | Dark Green Shoulder | Dark Green Shoulder | Dark Green Shoulder | Dark Green Shoulder |
| **Fruit Ribbing** | Low | No | No | Low | No | No | No |
| **Fruit Blossom End** | Flat | Flat | Pointed | Indented | Flat | Flat | Flat |
| **Flower Colour** | Yellow | Yellow | Yellow | Yellow | Yellow | Yellow | Yellow |
| **Fruit Shape** | Plum Shaped | Plum Shaped | Pyriform Shaped | Round | Oval | Round | Round |
| **Easiness of Pelling** | Easy | Easy | Easy | Easy | Easy | Easy | Easy |
| **Peel Colour** | Yellow | Yellow | Colourless | Yellow | Colourless | Yellow | Colourless |



**Fig. 1. Fruits of seven tomato genotypes under study**

Among the fruit morphological characters, average fruit weight ranged from 6.14 to 8.35 g, polar diameter from 23.22 to 43.80 mm, equatorial diameter from 16.89 to 23.49 mm, fruit shape index from 1.01 to 2.61 and pericarp thickness from 1.83 to 2.23 mm. These values are in line with the findings of Chandni et al. (2021) and Akter et al (2021). All the fruits were bilocular. Highest average fruit weight was observed in BRCT-1-R which was at par with Swarna Ratan, while the lowest values were noted in BRCT-23 and BRCT-38. The polar diameter was highest, while equatorial diameter was least in BRCT-32, which reflected in its highest fruit shape index also, and the shape of this genotype was pyriform in shape. Three genotypes, BRCT-23, BRCT-37 and Swarna Ratan were round with their fruit shape index being 1.00 or near to 1.00, while BRCT-1 and BRCT-1-1 were plum shaped and BRCT-38 was oval in shape. Vasquez et al. (2024) depicted the relation between fruit shape index and tomato shape and suggested that higher values of fruit shape index pointed towards long, obovoid, pyriform and cylindrical shape of tomato fruits, while lower values could mean flattened fruits.

**Table 3. Fruit morphological traits of the seven cherry tomato genotypes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Genotypes** | **Equatorial Diameter (mm)** | **Polar Diameter (mm)** | **Fruit shape index** | **Average fruit weight(g)** | **Pericarp thickness** | **Locule number** |
| BRCT-1 | 20.79 bcd | 24.22 a | 1.17 ab | 7.49 bc | 2.23 c | 2 a |
| BRCT-1-R | 20.53 bc | 32.24 b | 1.57 c | 8.35 d | 2.03 abc | 2 a |
| BRCT-23 | 23.49 d | 23.54 a | 1.00 a | 6.14 a | 1.93 ab | 2 a |
| BRCT-38 | 19.55 b | 24.16 a | 1.24 b | 6.14 a | 2.13 bc | 2 a |
| BRCT-37 | 22.58 cd | 24.53 a | 1.09 ab | 7.00 b | 1.83 a | 2 a |
| BRCT-32 | 16.89 a | 43.80 c | 2.61 d | 7.07 b | 1.93 ab | 2 a |
| SWARNA RATAN | 22.89 cd | 23.22 a | 1.01 a | 7.90 cd | 1.93 ab | 2 a |

Note: values with different alphabets are significantly different

Among the biochemical traits, total soluble solids (TSS) ranged between 5.13 to 11.67 °Brix, titrable acidity from 0.13 to 0.28%, ascorbic acid content from 12.34 to 23.66 mg per 100g FW. Previous studies by Yimchunger et al. (2018) have reported TSS content between 5.25 to 8.63 °Brix, which corroborates with our findings. Studies of Chandni et al. (2020) also revealed similar values of TSS, acidity and ascorbic acid for cherry tomatoes grown under open field conditions. The previous findings of Lakra et al. (2020) for ascorbic acid is also in accordance with our findings. TSS was highest in BRCT-1-R, while it was least in BRCT-37. The three genotypes, BRCT-1-R, BRCT-1, BRCT-38 and Swarna Ratan had high TSS (>7.5 ºBrix), which is considered ideal for cherry tomatoes. These genotypes may serve as donors for TSS. The titrable acidity was highest in Swarna Ratan and least in BRCT-1-R. The ascorbic acid content was highest in BRCT-38, at par with BRCT-23, Swarna Ratan BRCT-32, BRCT-1-R and BRCT-32. The least ascorbic acid was observed in BRCT-1 which was at par with BRCT-37.

**Table 4 Fruit quality traits of the seven cherry tomato genotypes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Genotypes** | **TSS (ºBrix)** | **Acidity (%)** | **Ascorbic acid (mg/100g FW)** |
| BRCT-1 | 10.20 d | 0.20 bc | 12.34 a |
| BRCT-1-R | 11.47 e | 0.14 a | 19.9 b |
| BRCT-23 | 5.93 b | 0.18 b | 20.6 b |
| BRCT-38 | 8.00 c | 0.23 c | 23.6 b |
| BRCT-37 | 5.13 a | 0.19 b | 15.4 a |
| BRCT-32 | 6.00 b | 0.21 bc | 19.73 b |
| SWARNA RATAN | 7.97 c | 0.28 d | 20.57 b |

Note: values with different alphabets are significantly different

Wide variability in cherry tomato genotypes across the world for morphological and quality traits as well as bioactive compounds has been reported by various researchers like Mukherjee (2019), Venkadeswaran et al. (2018), Ramya et al. (2016), Renuka et al. (2014), Rosales et al. (2011), Stommel et al. (2005) and Medina and Lobo (2001), indicating great potential for improving the crop.

The seven genotypes under study have exhibited high levels of variation for the different visual qualitative traits, fruit morphological and quality traits and their performance has been quite good under open field conditions. These genotypes, particularly, BRCT-1, BRCT-37, RCT-38 and Swarna Ratan may be recommended for cultivation in the open field or serve as good donors for improving the quality of cherry tomatoes and creation of diversity.

**CONCLUSION**

Sufficient variation for qualitative traits including plant morphology, fruit quality and morphological traits among the seven cherry tomato genotypes was observed. BRCT-1, BRCT-37, BRCT-38 and Swarna Ratan were found to be of attractive colour and shape and also performed well under open field conditions and may be used as donors for quality traits and other morphological traits.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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1.

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**REFERENCES**

Adato, A., Mandel, T., Mintz-Oron, S., Venger, I., Levy, D., Yativ, M., Domínguez, E., Wang, Z., De Vos, R.C.H., Jetter, R., Schreiber, L., Heredia, A., Rogachev, I. & Aharoni, A. (2009). Fruit-surface flavonoid accumulation in tomato is controlled by a *SlMYB12-*regulated transcriptional network. PLOS Genetics, 5(12), e1000777.

Akhter, A., Nabi, A., Afroza, B., Dar, Z. A., Malik, A. A., Ali, G., Akhter, S., Indrabi, S. A., Sultan, A., & Javeed, I. (2021). Study of Genetic Variability and Heritability in Cherry Tomato (Solanum lycopersicum L. Var. cerasiforme) Genotypes. Journal of Experimental Agriculture International, 43(7), 76–81. <https://doi.org/10.9734/jeai/2021/v43i730715>

AOAC (2001). Official methods of analysis of Association of Official Analytical Chemists, Arlington, Virginia, USA, 17(1-2): 22209.

Ballester, A.R., Molthoff, J., De Vos, R., BtL, H., Orzaez, D., Fernández-Moreno, J.P., Tripodi, P., Grandillo, S., Martin, C., Heldens, J., Ykema, M., Granell, A. & Bovy, A. (2010). Biochemical and molecular analysis of pink tomatoes: Deregulated expression of the gene encoding transcription factor SlMYB12 leads to pink tomato fruit color. Plant Physiology, 152(1), 71–84.

Campestrini, L.H., Melo, P.S., Peres, L.E.P., Calhelha, R.C., Ferreira, I.C.F.R. & Alencar, S.M. (2019). A new variety of purple tomato as a rich source of bioactive carotenoids and its potential health benefits. Heliyon, 5(11), e02831.

Canene-Adams, K., Campbell, J.K., Zaripheh, S., Jeffery, E.H. & Erdman, J.W. Jr. (2005). The tomato as a functional food. Journal of Nutrition Research, 135(5), 1226–1230.

Dutta, R., Bhutia, N. D., Raja, P., Singh, S., Hazarika, B. N., Deo, C., Rozerto, K., Yumkhaibam, T., & Yumkhaibam, P. (2023). In-vivo Screening of Cherry Tomato [Solanum lycopersicum L. var. cerasiforme (Dunnal) A. Gray] Genotypes and Hybrids against Fusarium Wilt in Arunachal Pradesh, India. International Journal of Environment and Climate Change, 13(11), 415–422. <https://doi.org/10.9734/ijecc/2023/v13i113185>

Holloway, D.E., Yang, M., Paganga, G., Rice-Evans, C.A. & Bramley, P.M. (2000). Isomerization of dietary lycopene during assimilation and transport in plasma. Free Radical Research, 32(1), 93–102.

Hunt, G.M. & Baker, E.A. (1980). Phenolic constituents of tomato fruit cuticles. Phytochemistry, 19, 1415–1419.

Khachik, F., Carvalho, L., Bernstein, P.S., Muir, G.J., Zhao, D.Y. & Katz, N.B. (2002). Chemistry, distribution, and metabolism of tomato carotenoids and their impact on human health. Experimental Biology and Medicine, 227(10), 845–851.

Kiple, K.F. & Ornelas, K.C. (Eds.). (2000). The Cambridge world history of food (Vol. 2). Cambridge University Press.

Lakra, A., Trivedi, J. & Mishra, S. (2020). Evaluation of tomato genotypes for fruit yield and quality traits under Chhattisgarh plain conditions. Journal of Pharmacognosy and Phytochemistry, 9(3), 185–189.

Lekshmi, S.L. & Celine, V.A. (2015). Evaluation of tomato hybrids for fruit, yield and quality traits under polyhouse conditions. International Journal of Applied and Pure Science and Agriculture, 1(7), 58–64.

Lenucci, M., Cadinu, D., Taurino, M., Piro, G. & Dalessandro, G. (2006). Antioxidant composition in cherry and high-pigment tomato cultivars. Journal of Agricultural and Food Chemistry, 54, 2606–2613.

Lindstrom, E.W. (1925). Inheritance in tomatoes. Genetics, 10, 305–317.

Livny, O., Kaplan, I., Reifen, R., Polak-Charcon, S., Madar, Z. & Schwartz, B. (2002). Lycopene inhibits proliferation and enhances gap-junction communication of KB-1 human oral tumor cells. The Journal of Nutrition, 132(12), 3754–3759.

Medina, C.I. & Lobo, M. (2001). Morphological variability in the tomato bird (Lycopersicon esculentum var. cerasiforme), precursor of the cultivated tomato. Revista Corpoica, 3, 39–50.

Mukherjee, D. (2019). Breeding cherry tomato for higher yield and nutritional qualities. M.Sc. Thesis, Department of Vegetable Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India.

Nesbitt, T.C. & Tanksley, S.D. (2002). Comparative sequencing in the genus Lycopersicon: Implication for the evolution of fruit size in the domestication of cultivated tomatoes. Genetics, 162, 365–379.

Perveen, R., Suleria, H.A.R., Anjum, F.M., Butt, M.S., Pasha, I. & Ahmad, S. (2013). Tomato (Solanum lycopersicum) carotenoids and lycopenes chemistry; metabolism, absorption, nutrition and allied health claims – A comprehensive review. Critical Reviews in Food Science and Nutrition, 55(7), 919–929.

Przybylska, S. (2020). Lycopene – A bioactive carotenoid offering multiple health benefits: A review. International Journal of Food Science & Technology, 55(1), 11–32.

Ram, H.H. (2014). Vegetable breeding: Principles and practices (3rd ed.). Kalyani Publication.

Ramya, R., Ananthan, M. & Krishnamoorth, V. (2016). Evaluation of cherry tomato (Solanum lycopersicum L. var. cerasiforme (Dunnal) A. Gray) genotypes for yield and quality traits. Asian Journal of Horticulture, 11, 329–334.

Ranganna, S. (1986). Handbook of Analysis and Quality Control of Fruit and Vegetable Products. 2nd Edition, Tata McGrow-Hill Education, New York.

Renuka, D.M., Sadashiva, A.T., Kavita, B.T., Vijendrakumar, R.C. & Hanumanthiah, M.R. (2014). Evaluation of cherry tomato lines (Solanum lycopersicum var. cerasiforme) for growth, yield and quality traits. Plant Archives, 14, 151–154.

Rick, C.M. & Butler, L. (1956). Cytogenetics of the tomato. Advances in Genetics, 8, 267–382.

Rosales, M.A., Cervilla, L., Sanchez-Rodriguez, E., Rubio-Wilhelmi, M. & Blasco, B. (2011). The effect of environmental conditions on nutritional quality of cherry tomato fruits: Evaluation of two experimental Mediterranean greenhouses. Journal of the Science of Food and Agriculture, 91(1), 152–162.

Schierle, J., Bretzel, W., Bühler, I., Faccin, N., Hess, D., Steiner, K. & Schüep, W. (1997). Content and isomeric ratio of lycopene in food and human blood plasma. Food Chemistry, 59(3), 459–465.

Stommel, J.R., Abbott, J.A. & Saftner, R.A. (2005). USDA 02L 1058 and 02L1059: Cherry tomato breeding lines with high fruit β-carotene content. HortScience, 40, 1569–1570.

Toor, R.K. & Savage, G.P. (2005). Antioxidant activity in different fractions of tomatoes. Food Research International, 38, 487–494.

Venkadeswaran, E., Irene Vethamoni, P., Arumugam, T., Manivannan, N. & Harish, S. (2018). Evaluating the yield and quality characters of cherry tomato (Solanum lycopersicum L. var. cerasiforme Mill.) genotypes. International Journal of Chemical Studies, 6, 858–863.

Wang, S., Chu, Z., Jia, R., Dan, F., Shen, X., Li, Y. & Ding, X. (2018). SlMYB12 regulates flavonol synthesis in three different cherry tomato varieties. Scientific Reports, 8, 1582.

Yimchunger, T.L., Sarkar, A. & Kanaujia, S.P. (2018). Evaluation of different genotypes of cherry tomato (Solanum lycopersicum var. cerasiforme) under foothill condition of Nagaland. Annals of Plant and Soil Research, 20(3), 228-232.

Sheoran, O.P; Tonk, D.S; Kaushik, L.S; Hasija, R.C & Pannu, R.S (1998). Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar (139-143)

Chandni, Singh, D., Akhtar, S., Kumar, R. & Bahera, S. (2021). Effect of Growing Conditions on Growth and Yield Attributes of Cherry Tomato (*Solanum lycopersicum* L. var. *cerasiforme*). International Journal of Environment and Climate Change, 11(8), 15-23

Chandni, Singh, D., Akhtar, S. & Mahesh, S.S. (2020). Evaluation of Cherry Tomato Genotypes for Qualitative Traits under Open Field and Protected Condition. International Research Journal of Pure & Applied Chemistry, 21(9), 9-16, 2020

Vazquez, D. V., Spetale, F. E., Nankar, A. N., Grozeva, S., & Rodríguez , G. R. (2024). Machine Learning-Based Tomato Fruit Shape Classification System. *Plants*, *13*(17), 2357.