

Original Research Paper

Morphological and biochemical characterization of *Passiflora quadrangularis* L. - A source of vegetable from East Siang district, Arunachal Pradesh, India

Shankar K.^{1*} and Singh S.R.

¹Department of Fruit Science, College of Horticulture & Forestry
Central Agricultural University, Pasighat - 791 102, Arunachal Pradesh, India, ¹Present address: Division of Fruits and
Horticultural Technology, ICAR - Indian Agricultural Research Institute, Pusa, New Delhi -110 012, India.

*Corresponding author email: rawkripa.s99@gmail.com

ABSTRACT

Present research investigation was aimed at morphological and biochemical assessment of *Passiflora quadrangularis* L. commonly known as giant granadilla and locally called as vegetable squash grown as vegetable crop by the *Adi* tribe of Arunachal Pradesh. Seven genotypes collected during survey were characterized for different morphological and biochemical traits. Results showed that average fruit weight was 432.57g/fruit, with juice content 100.11 mL/fruit, vitamin C content 25.79 mg, vitamin A content 1.65 mg, Mean total flavonoids content was 16.75 mg/100 g of fruit juice, total soluble solids 12.04^o Brix, antioxidant activity (DPPH) 6.07 %, titratable acidity 1.69 %, total carbohydrates 9.95 %, phenol content 338.38 mg/100 g of leaf was noted among the genotypes tested. The mean anthocyanin content in leaf was 1.20 mg/100 g, tendril 0.90 mg/100 g and petiole 1.69 mg/100 g among the genotypes. Seed protein profiling of *Passiflora quadrangularis* L. with SDS-PAGE showed diverse molecular weights ranging from 11 KD to 163.53 KD. However, monomorphic banding pattern among the protein profiling of giant granadilla was recorded among the selected genotypes. The results of the study show that the collected genotypes are belonged to *Passiflora quadrangularis* L. and are good source of nutritive value which can be used as source of vegetable.

Keywords : Giant granadilla, *Passiflora quadrangularis*, SDS-PAGE and vegetable source

INTRODUCTION

Passiflora quadrangularis L. commonly known as Giant granadilla, belongs to Passifloraceae family consists of about 700 species and 16 genera and among them only two genera, *Passiflora* and *Tetraphaea* are cultivated (Feuillet, 2004) and about 520 species of the genus *Passiflora* are distributed to Neotropics and Africa (Ulmer and MacDougal, 2004). The most important genus is *Passiflora*, with the most common commercial species being the purple passion fruit (*Passiflora edulis*) for the fresh market and the more acid yellow passion fruit (*Passiflora edulis* f. *flavicarpa*) for the juice industry (Tripathi *et al.*, 2014). Leaves of purple and yellow passion fruit are used as leafy vegetable in Manipur and also used as folk traditional medicine as anti-diabetic (Singh *et al.*, 2014). The total area under passion fruit cultivation is about 0.014 million hectares with a production of

0.082 million tonnes in India during 2020 (Anon, 2020). *P. quadrangularis* L. is a lesser-known member of the genus also grown for its fruit as well as vegetable. It is locally known as vegetable squash by the *Adi* tribe of Arunachal Pradesh.

This novel *P. quadrangularis* helps the rural sectors in mitigating the malnutrition and hence enabling them a quality life. During investigation it was observed that *P. quadrangularis* L. is grown by the *Adi* tribe of Arunachal Pradesh and sold as squash in the market. However, very few systematic, inventory and documentation about the *Passiflora* species found in Northeast India and sporadic attempts have been made on characterization of passion fruit found in Arunachal Pradesh. Therefore, the present research was initiated to explore and document for the morphological and biochemical characteristics features of *P. quadrangularis* L. found in East Siang district of Arunachal Pradesh.



MATERIALS AND METHODS

Survey was carried out in East Siang district of Arunachal Pradesh during the year 2019-2020 which is located at 28° 03'N, 95° 20'N covering an area of 1865 sq. km. and having the altitude of 176.57m above MSL and represent a mild subtropical zone with cool, dry winter, a warm summer and a moderate season. The identification and description of the plant were adopted from De Jesus *et al.* (2017). During the survey, *Passiflora* species *viz.* purple passion fruit, yellow passion fruit and giant granadilla were found growing in East Siang district. Data on passion fruit uses were obtained through interview of knowledgeable elderly people of *Adi* tribe (both genders of 30-75 ages) inhabiting in the East Siang district to which the *P. quadrangularis* L. identified on the basis of vernacular name, regional floras and published literatures (Singh *et al.*, 2003). Totally seven genotypes were collected during the survey and the passport information of the collected genotypes are presented in Table 1. The collection of fruits and leaves have been done from different direction of single plant. Fifty fruits were collected from each genotype and every replication had 10 fruits with five replications. Recorded morphological traits *viz.*, leaf length (cm), leaf breadth (cm), flower length (cm), number of flowers/node, peduncle length (cm), fruit length (cm), fruit breadth (cm), fruit weight (g), number of fruits/vine, fruit yield (kg/vine), peel weight (g), seed length (cm), seed breadth (cm), number of seeds/fruit and seed weight/fruit. Biochemical traits *viz.*, juice content (mL/fruit), total soluble solid content (°Brix), titratable acidity (%) (AOAC, 2006), Vitamin C content (mg/100 g) (Ranganna, 1986), total carbohydrate (%) (Hedge, 1962), reducing sugar (%) (Somogyi, 1952), Vitamin A (mg/100 g) (Bayfield and Cole, 1980), total flavonoid (mg/100 g) (Vijay and Rajendra, 2014), and antioxidant activity (%) (AOAC, 2006). Anthocyanin content (mg/100 g) of leaf, tendril and petiole (Malick and Singh, 1980), vitamin C content of leaf (mg/100 g) (Ranganna, 1986) and phenol content of leaf (mg/100 g) using Folin-Ciocalteu reagent (Malick and Singh, 1980) and chlorophyll content of leaf (mg/g) (Arnon, 1949) and shelf life (days) at room temperature were estimated for the collected genotypes.

Seed protein extraction

Seed protein extraction was as described Lowry *et al.* (1951) in seven genotypes and was carried out protein

banding pattern was determined using SDS-PAGE as described by Laemmli (1970). 0.2 g of seeds were soaked overnight in phosphate buffer (pH 7.0) solution. Seeds were crushed with a solution of Tris-HCl 0.06 M (PH 7.4), 10 mM urea, 1 mM EDTA, 0.1% TCA, 2.5% glycerol, 0.5% SDS and 1.25% β -mercaptoethanol. Electrophoresis was performed in vertical electrophoresis unit and gel run at 25 mA. Silver staining was performed as described by Mortz *et al.* (2001) and sensitizing with 0.02% sodium thiosulphate solution. The reaction was stopped with 12% acetic solution. Gel was washed thoroughly but gently with double distilled water until protein bands became clearly visible for bands scoring. The electrophorograms developed on protein mobility and density expressed in Rm values. The gels were scored as presence (+) or absence (-) of protein bands. Depending upon the presence (+) or absence (-) of bands, similarity index between the genotypes were calculated (Nei and Li, 1979).

Data analysis

The statistical analysis *viz.*, standard error of mean, coefficient of variance and test of significance were performed by following Singh and Chowdhury (1985).

RESULTS AND DISCUSSION

Morphological characters are important for identification and documentation of horticultural traits for crop improvement. A large variability having unique characters was recorded for morphological traits of fruits and other plant parts of the collected giant granadilla (Fig 1a and Fig 1b). There are no significant variations in different qualitative traits recorded. All the accessions had quadrangular stem, large green cordate leaves having entire margin and leaf lamella. Leaf had deep sinus, stipule and heterophylly was absent. All the lines showed axillary tendrils bearing 2.33 to 3.00 flowers/node. Flowers had light red color petals and sepals are green from outside and whitish pink from inside with yellowish-green ovary. The flowers possess yellowish green stamens with violet dots, blue, brown speckled corona. All the lines produced light yellowish brown oblong fruits possessing dark brown seeds. The same qualitative characters were also reported by Lim, 2012. Among the genotypes leaf length varied from- 9.95 to 12.08 cm, leaf width from- 8.89 to 11.14 cm.

Table 1 : List of collected *Passiflora quadrangularis* L. genotypes from East Siang district, Arunachal Pradesh, India and their sources

S.No.	Genotypes	Code	Source	Latitude	Longitude	Altitude
1	<i>Passiflora quadrangularis</i> L.	P1	Pasighat, Arunachal Pradesh	28° 03' N	95° 20' N	156 m
2	<i>Passiflora quadrangularis</i> L.	P2	CHF, Pasighat, Arunachal Pradesh	28° 04' N	95° 19' N	183 m
3	<i>Passiflora quadrangularis</i> L.	P3	Baptist Church, Pasighat, Arunachal Pradesh	28° 05' N	95° 18' N	192 m
4	<i>Passiflora quadrangularis</i> L.	P4	Agami House, Pasighat, Arunachal Pradesh	28° 06' N	95° 31' N	168 m
5	<i>Passiflora quadrangularis</i> L.	P5	Police line, Pasighat, Arunachal Pradesh	28° 05' N	95° 32' N	166 m
6	<i>Passiflora quadrangularis</i> L.	P6	Teachers Residence, Pasighat, Arunachal Pradesh	28° 03' N	95° 19' N	159 m
7	<i>Passiflora quadrangularis</i> L.	P7	Tekang, Pasighat, Arunachal Pradesh	28° 04' N	95° 22' N	212 m

Flowers are 8.40 to 9.41 cm in length which was maximum among other cultivated passion fruit. Significant variation for quantitative traits like peduncle length, fruit length, fruit breadth, fruit weight and peel weight, seed length, seed breadth, number of seeds/fruit and weight of seeds/fruit were recorded (Table 2a and 2b).

This *Passiflora* species is commonly used as vegetable in unripe stage having an average yield of 15.88 to 23.89kg/vine. Fruit juice content of giant granadilla

was about 53.39 to 131.04 mL/fruit which was maximum in comparison to other *Passiflora* species because of bigger size of fruits. This finding was similar with the result of Arjona and Matta, 1991. Based on the yield and yield attributing traits genotypes for leaf length (P7; 12.08 cm), number of flowers per node (P6; 3.67), fruit weight (P1; 488.33), number of fruits/vine (P2; 51.33), peel weight (P1; 352.33), number of seeds/fruit (P1; 172) and flower length (P7; 9.41 cm) were identified. Selecting the genotypes with large leaf and flower aid in imparting

Table 2a : Morphological characters of *Passiflora quadrangularis* L. genotypes from East Siang district, Arunachal Pradesh

Genotypes	Leaf Length (cm)	Leaf Breadth (cm)	Flower length (cm)	Number of flowers/nodes	Peduncle length (cm)	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)
P1	9.95	8.89	9.15	2.33	2.37	14.60	9.59	488.33
P2	11.64	11.14	8.40	2.67	1.96	13.42	9.11	463.67
P3	10.99	9.48	9.11	2.67	2.50	13.89	11.04	476.67
P4	10.51	9.70	8.77	3.00	2.62	12.19	10.08	408.00
P5	11.25	9.65	9.40	2.33	2.42	11.82	9.84	407.00
P6	11.46	10.19	8.57	3.67	2.52	12.83	10.80	402.67
P7	12.08	10.59	9.41	2.67	2.65	12.43	10.44	381.67
Mean	11.12	9.95	8.97	2.76	2.43	13.03	10.13	432.57
CV (%)	3.18	6.54	5.92	1.14	3.81	4.19	5.96	9.93
SE (m)±	0.78	0.55	0.46	0.38	0.08	0.69	0.52	12.32
C.D (5%)	1.31	1.62	1.36	0.54	0.24	1.59	1.55	3.34

Table 2b : Morphological characters of *Passiflora quadrangularis* L. genotypes from East Siang district, Arunachal Pradesh

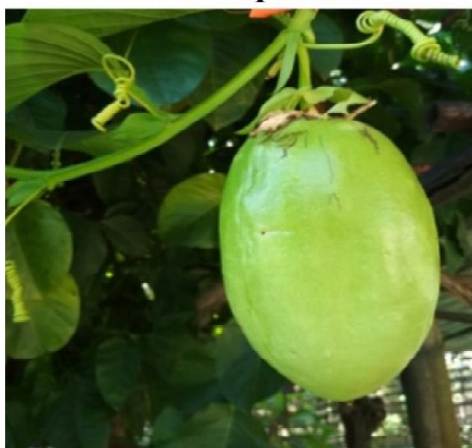
Genotypes	No. of Fruits/vine	Peel weight (g)	Fruit yield (Kg/vine)	Seed length (cm)	Seed breadth (cm)	No. of seeds/Fruit	Seed weight/Fruit (g)
P1	48.00	352.33	23.44	0.77	0.61	172.00	9.33
P2	51.33	320.67	23.86	0.69	0.59	168.00	9.13
P3	42.00	343.33	20.05	0.65	0.61	156.67	8.78
P4	45.33	306.33	18.45	0.68	0.59	157.67	9.03
P5	42.67	304.33	17.36	0.71	0.64	149.67	8.34
P6	45.00	349.67	18.19	0.72	0.64	153.00	9.07
P7	40.67	296.67	15.55	0.71	0.65	168.00	8.83
Mean	45.00	324.76	19.56	0.70	0.62	160.71	8.93
CV (%)	8.04	2.38	4.76	1.10	1.24	2.96	1.60
SE (m)_±	4.69	4.90	2.23	0.01	0.02	2.75	0.19
C.D (5%)	2.83	27.11	1.58	0.04	0.04	8.10	0.55



Fruits with peduncle



Ripe fruits



Fruit on vine



Fruits in local market

Fig. 1a : Fruits of *Passiflora quadrangularis* L.



Fig. 1b : Leaf, flower and ovary colour of *Passiflora quadrangularis* L.

maximum photosynthate accumulation to the sink leading to high crop yield.

Biochemical characteristics

Biochemical characterization also revealed that the TSS content of fruit juice was ranging from 10.26 to 13.44 °Brix which is in agreement with data of Ramaiya *et al.* (2021) in *P. quadrangularis*. The higher TSS may be due to the fact the fruit tree is grown under natural water scarce condition without care and management and eventually increasing the TSS content Meghwal *et al.* (2004). In giant granadilla, citric acid is the predominated organic acid followed by malic acid that is about 1.49 to 1.80 % which is in conformity to the data of Velente *et al.* (2011). The high acidity may be due to the prevalence of primary organic acids, such as malic and citric acid, in mature fruits, which accumulate in the mesocarp cells during the fruit development process and are controlled by both genetic and environmental factors. Ascorbic acid varied from 22.45 to 29.53 mg/100 g in fruit juice and 44.78 to 50.15 mg/100 g in fresh leaf and finding similar with Ramaiya *et al.* (2021).

Total carbohydrate content data showed variation from 9.49 to 10.75 % and is in agreement with Shanmugam *et al.* (2018). Reducing sugar content was about 5.00 to 5.68 % and similar results were reported by Patel *et al.* (2014). The increasing sugar is due to the hydrolysis of starch to sucrose as fruit approach to ripening (Pandy and Deen, 2018). Vitamin A (mg/100

g) content was recorded between 1.62 to 1.69 mg/100 g of fruit juice and data was in agreement with Oliveira *et al.* (2014); Homnava *et al.* (1990) and it may be due to biosynthesis genes controls its accumulation and composition in fruit during maturity. The DPPH free radical scavenging antioxidant (%) activity was recorded as 5.91 to 6.28 % which is in conformity with Loizzo *et al.* (2019) and Marroquin *et al.* (2011). As these fruits are known to contain a variety of antioxidant compounds, and ascorbic acid (vitamin C) which implying that fruits high in vitamin C are powerful antioxidants as reported by Esti *et al.* (2002).

Chlorophyll content of leaves were ranging from 1.56 to 1.69 mg/g which was an agreement with Do Valle *et al.* (2018). Phenol content was as 319.67 to 351.32 mg/100 g of fresh leaf and similar data was reported by Rudnicki *et al.* (2005) and Marroquin *et al.* (2011). Anthocyanin (mg/100 g) content in leaf, petiole and tendril varied from 1.17 to 1.24 mg/100 g, 1.59 to 1.76 mg/100 g and 0.85 to 0.94 mg/100 g respectively which was in agreement with Aizza *et al.*, 2019 and Reis *et al.*, 2018. The anthocyanin, phenol and chlorophyll concentration of petioles, tendrils and leaves might differ according to a variety of external and internal factors such as genetic, agronomic and climatic factors (Kayesh *et al.*, 2013). Shelf life (days) of *Passiflora quadrangularis* genotypes at room temperature was recorded maximum for genotype P1 which is 27.22 days at room temperature. It is due to

Table 3 : Biochemical parameters in fruits of *Passiflora quadrangularis* L. genotypes from East Siang district, Arunachal Pradesh

Genotype	Juice content (mL/fruit)	Vit. C (mg/100 g)	TSS (° Brix)	Vit. A (mg/100 g)	Total flavonoids (mg/100 g)	Antioxidant Activity (%)	Titratable Acidity (%)	Total carbohydrates (%)	Reducing sugar (%)	Shelf-life (days)
P1	123.78	29.53	13.21	1.67	17.42	6.28	1.80	10.75	5.54	27.22
P2	131.04	29.04	12.74	1.61	16.62	6.22	1.49	9.49	5.54	25.57
P3	124.38	22.45	11.90	1.69	16.37	5.98	1.72	9.83	5.29	22.25
P4	92.67	25.66	13.44	1.62	17.20	6.01	1.69	10.29	5.00	18.67
P5	95.03	25.68	11.73	1.64	15.78	6.09	1.69	9.29	5.14	18.67
P6	53.39	23.26	10.97	1.64	16.40	5.91	1.68	9.51	5.21	19.00
P7	80.49	24.93	10.26	1.67	17.45	6.00	1.77	10.48	5.68	25.67
Mean	100.11	25.79	12.04	1.65	16.75	6.07	1.69	9.95	5.34	22.43
CV (%)	4.65	5.35	3.13	1.75	0.69	2.50	2.42	1.59	0.68	3.11
SE (m)±	2.69	0.80	0.22	0.02	0.07	0.09	0.02	0.09	0.02	1.70
C.D (5%)	7.93	2.35	0.64	0.05	0.20	0.26	0.07	0.27	0.06	1.01

Table 4 : Biochemical parameters in leaves, petioles and tendrils of *Passiflora quadrangularis* L. genotypes from East Siang district, Arunachal Pradesh

Genotypes	Leaf				Petiole	Tendrill
	Anthocyanin (mg/100 g)	Vit. C (mg/100 g)	Phenol (mg/100 g)	Chlorophyll (mg/g)	Anthocyanin (mg/100 g)	Anthocyanin (mg/100 g)
P1	1.24	47.69	351.32	1.67	1.76	0.94
P2	1.19	50.15	336.33	1.56	1.73	0.92
P3	1.24	47.67	343.00	1.64	1.69	0.91
P4	1.19	44.78	319.67	1.61	1.74	0.89
P5	1.18	46.06	324.33	1.66	1.69	0.92
P6	1.17	48.72	345.00	1.69	1.59	0.88
P7	1.22	46.72	349.00	1.57	1.64	0.85
Mean	1.20	47.40	338.38	1.63	1.69	0.90
CV (%)	1.81	3.75	3.34	1.11	0.80	1.81
SE (m)±	0.01	1.03	12.39	0.01	0.01	0.01
C.D (5%)	0.04	3.03	9.55	0.03	0.02	0.03

the thick exocarp which prevents easy decay under biotic and abiotic stress.

Present investigation recorded a total 70 numbers of bands having molecular weights ranging from 11 KD to 163.53 KD. All the seven selected genotypes found in East Siang District, Arunachal Pradesh exhibited

monomorphic banding pattern in the protein profiling of giant granadilla. Beena and Beevy, (2015) also reported the highest molecular weight i.e., 69.94 KD was generated by *Passiflora foetida* var. *hispidia*, while the lowest (12.95KD) was produced in *Passiflora foetida* var. *gossippifolia* in *Passiflora* species.

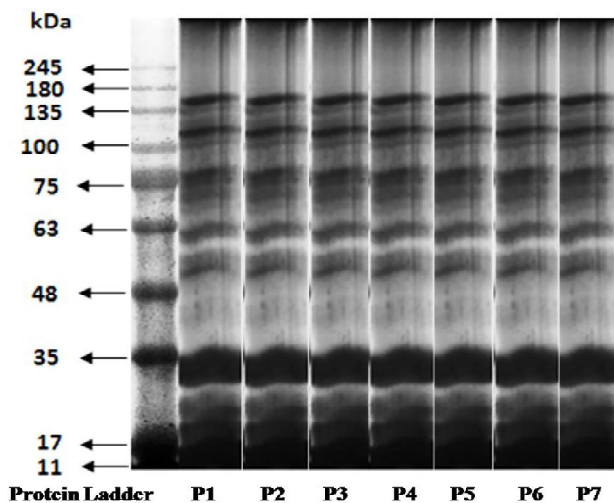


Fig. 2 : SDS-PAGE protein profiling of seven genotypes of *Passiflora quadrangularis* L. from East Siang district, Arunachal Pradesh

From the study of morphological, biochemical and seed protein profiling it could be concluded that all seven genotypes belong to same species *i.e.*, *Passiflora quadrangularis* L. locally known as vegetable squash (by Adi tribe of Arunachal Pradesh). As its green fruits and leaves are nutritious this novel underexploited *Passiflora* species can be explored for commercial cultivation as a source of vegetable in the future. Because of its higher fruit yielding capability, the fruits also have a lot of potential in the food processing industry.

ACKNOWLEDGEMENT

We are obliged to the Department of Fruit Science, College of Horticulture & Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, India for the cooperation during the research work on this underutilized fruit crop.

REFERENCES

- Aizza, L.C.B., Sawaya, A.C.H.F. and Dornelas, M.C. 2019. Identification of anthocyanins in the corona of two species of *Passiflora* and their hybrid by ultra-high-performance chromatography with electrospray ionization tandem mass spectrometry (UHPLC-ESI-MS/MS). *Biochem. Systematics Ecol.*, **85**: 60-67.
- Alquezar, B., Rodrigo, M.J. and Zacarias, L. 2008. Carotenoid biosynthesis and their regulation in citrus fruits. *Tree For. Sci. Biotech.*, **2**(1): 23-35.
- Anonymous. 2020. Passion fruit area and production. In: Ministry of Agriculture and Farmers Welfare, Horticultural statistics-Agricoop, Government of India. 2020, p. 9.
- AOAC. 2006. Official methods of analysis of AOAC International, 18thedn (Gaithersburg, USA: Association of Official Analytical Chemists), pp. 210.
- Aoshima, H., Tsunoue, H., Koda, H. and Kiso, Y. 2004. Aging of whiskey increases 1,1-diphenyl-2-picrylhydrazyl radical scavenging activity. *J. Agric. Food Chem.*, **52**(16): 5240-5244.
- Arjona, H.E. and Matta, F.B. 1991. Post-harvest quality of passion fruit as influenced by harvest time and ethylene treatment. *Hort. Sci.*, **25**: 1278-1281.
- Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts: Polyphenol oxidase in *Beta vulgaris*. *Plant Physiol.*, **24**: 1-15.
- Ballesteros, V.D., Alvarez-Rivera, G., Ibanez, E., Parada-Alfonso, F. and Cifuentes, A. 2019. Integrated strategy for the extraction and profiling of bioactive metabolites from *Passiflora mollissima* seeds combining pressurized-liquid extraction and gas/liquid chromatography-high resolution mass spectrometry. *J. Chromatography A.*, **1595**: 144-157.
- Bayfield, R.F. and Cole, E.R. 1980. Colorimetric estimation of vitamin A with trichloroacetic acid. *Methods Enzymol.*, **67**: 180-195.
- Beena, V.L. and Beevy, S.S. 2015. Genetic diversity in two species of *Passiflora* L. (Passifloraceae) by karyotype and protein profiling. *The Nucleus*, **58**(2): 101-106.
- De Jesus, O. N., de Oliveira, E. J., Faleiro, F. G., TL, S. and Girardi, E. A. 2017. Illustrated morpho-agronomic descriptors for *Passiflora* spp. Embrapa Mandioca e Fruticultura-Livrocientifico (ALICE), p. 122
- Do Valle, K. D., Chaves, V. B. S., Pereira, L. D., dos Reis, E. F., Salazar, A. H. and Da Silva, D. F. P. 2018. Chlorophyll content and degrees day accumulation in passion fruit species in the Southwest of Goias, Brazil. *Comunicata Scientiae*, **9**(3): 351-355

- Esti, M., Cinquanta, L., Sinesio, F., Moneta, E. and Di Matteo, M. 2002. Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage. *Food Chem.*, **76**: 399-405.
- Feuillet, C. 2004. *Passiflora ceae* (Passionflower family). In: N., Mori, S.A., Henderson, A., Stevenson, D.W. and Heald, S.D. (eds) Flowering plants of the neotropics, Oxford, USA, p. 286–287.
- Gunathilake, K.D.P.P., Ranaweera, K.K.D.S. and Rupasinghe, H.P.V. 2018. Analysis of rutin, β carotene, and lutein content and evaluation of antioxidant activities of six edible leaves on free radicals and reactive oxygen species. *J. Food Biochem.*, **42**(5): e12579.
- Hedge, J.E. and Hofreiter, B.T. 1962. Carbohydrate chemistry 17. Whistler, R.L. and Be Miller, J. N., Eds., Academic Press, New York, pp. 380-394.
- Homnava, A., Rojert, W. and Eitenmiller, R.R. 1990. Pro-vitamin A activity of specialty fruit marketed in the United States. *J. Food Composition analysis*, **3**(2): 119-133.
- Kayesh, E., Shangguan, L., Korir, N.K., Sun, X., Bilkish, N., Zhang, Y., Han, J., Song, C., Cheng, Z.M. and Fang, J. 2013. Fruit skin color and the role of anthocyanin. *Acta Physiol. Plant.*, **35**: 2879-2890.
- Laemmli, U.K. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nat.*, **227**: 680-685.
- Lim, T.K. 2012. *Passiflora quadrangularis*. In: Edible Medicinal And Non-Medicinal Plants. Springer, Dordrecht. pp. 181-186.
- Loizzo, M.R., Lucci, P., Nunez, O., Tundis, R., Balzano, M., Frega, N.G., Lanfranco, C., Sabrina, M., Daria, F., Encarnacion, M. and Pacetti, D. 2019. Native Colombian fruits and their by-products: Phenolic profile, antioxidant activity and hypoglycaemic potential. *Foods*, **8**(3): 89.
- Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent. *J. Biol. Chem.*, **193**: 265-275.
- Malick, C.P. and Singh, M.B. 1980. Plant enzymology and histo enzymology. Kalyani Publishers. New Delhi, p. 286.
- Marroquin, M.N., Cruz, S.M. and Caceres, A. 2011. Antioxidant activity and phenolic compounds in three species of Passifloraceae (*Passiflora edulis*, *P. incarnata*, *P. ligularis*) from Guatemala. Proceedings of international symposium on medicinal and aromatic plants. June 19, 2010. Shiraz, Iran. pp. 93-98.
- Meghwal, P.R. Azam, M.M. 2004. Performance of some aonla cultivars in arid region of Rajasthan. *Indian J. Hortic.* **61**: 87-88.
- Mortz, E., Krogh, T.N., Vorum, H. and Gorg, A. 2001. Improved silver staining protocols for high sensitivity protein identification using matrix-assisted laser desorption/ionization-time of flight analysis. *Proteomics*, **1**(11), 1359-1363.
- Nei, M. and Li, W. H. 1979. Mathematical model for studying genetic variation in terms of restriction endonuclease. *Proc. Nat. Acad. Sci.*, **76**, 5269-5273.
- Oliveira, G., Castillos, F., Renard, K. and Bureau, S. 2014. Comparison of NIR and MIR spectroscopic methods for determination of individual sugars, organic acids and carotenoids in passion fruit. *Food Res. Int.*, **60**: 154–162.
- Pandey, S. and Deen, B. 2018. Studies on the pattern of changes biochemical constitutes of ber (*Zizyphus mauritiana* Lamk.) fruits cv. Narendra Ber Selection-1. *Int. J. Curr. Microbiol. Appl. Sci.*, **7**(4): 636-640.
- Patel, R.K., Singh, A., Prakash, J., Nath, A. and Deka, B.C. 2014. Physico- biochemical changes during fruit growth, development and maturity in passion fruit genotypes. *Ind. J. Hort.* **71**(4): 486-493.
- Ramaiya, S.D., Lee, H.H., Xiao, Y.J., Shahbani, N.S., Zakaria, M.H. and Bujang, J.S. 2021. Organic cultivation practices enhanced antioxidant activities and secondary metabolites in giant granadilla (*Passiflora Quadrangularis* L.). *PLoS One*. **16**(7): e0255059
- Ranganna, S. 1986. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw Hill Publishing Co. Ltd., New Delhi. pp.190-210.

- Reis, L.C.R.D, Facco, E.M.P., Salvador, M., Flores, S.H. and de Oliveira Rios, A. 2018. Antioxidant potential and physicochemical characterization of yellow, purple and orange passion fruit. *J. Food Sci. Technol.*, **55**(7): 2679-2691.
- Rudnicki, M., de Oliveira, M.R., Pereira, T.V., Reginatto, F.H., Dal-Pizzol, F. and Moreira, J.C.F. 2005. Antioxidant and antiglycation properties of *Passiflora alata* and *Passiflora edulis* extracts. *Food Chem.*, **100**(2007): 719-724.
- Shanmugam, S., Gomes, I.A., Denadai, M., dos Santos Lima, B., de Souza Araujo, A.A., Narain, N., Maria T.S.L., Neta, M.R.S., Lucindo, J.Q.J. and Thangaraj, P. 2018. UHPLC-QqQ-MS/MS identification, quantification of polyphenols from *Passiflora subpeltata* fruit pulp and determination of nutritional, antioxidant, α -amylase and α -glucosidase key enzymes inhibition properties. *Food Res. Int.*, **108**: 611-620.
- Singh, H.B., Singh RS, Sandhu JS. 2003. Herbal medicine of Manipur: A colour Encyclopedia, Daya publishing House, New Delhi.
- Singh, R.K., Chowdhury, B.D. 1985. Biometrical method in quantitative genetic analysis. 2nd Ed. Kalyani publishers, Ludhiana, New Delhi. pp. 54-57.
- Singh, S.R., Phurailatpam, A.K., Wangchu, L., Ngangbam, P. and Chanu, T.M. 2014. Traditional medicinal knowledge of underutilized minor fruits as medicine in Manipur. *Int. J. Agric. Sci.*, **4**(8): 241-247.
- Somogyi, M. 1952. Notes on sugar determination. *J. Biol. Chem.*, **195**: 19-23.
- Tripathi P.C., Karunakaran, G., Sakthivel, T., Sankar V. and Senthilkumar, R. 2014. Cultivation of passion fruit. Technical bulletin, Central Horticultural Experiment Station Indian Institute of Horticultural Research Chettalli-571 248, Kodagu, Karnataka.
- Ulmer, T. and MacDougal, J.M. 2004. *Passiflora: Passion flowers of the World*. Timber Press Portland, p. 430.
- Valente, A., Albuquerque, T.G., Sanches-Silva, A. and Costa, H.S. 2011. Ascorbic acid content in exotic fruits: A contribution to produce quality data for food composition databases. *Food Res. Int.* **44**(7): 2237-2242.
- Vijay, D.T. and Rajendra, S.B. 2014. Estimation of total phenol, tannin, alkaloid and flavonoid in *Hibiscus tiliaceus* L. wood extracts. *Res. Rev.J. Pharmacog. Phytochem.*, **2**(4): 41-47.