Journal of Applied Horticulture, 26(1): 127-131, 2024
https://doi.org/10.37855/jah.2024.v26i01.24
Journal of Applied Horticulture
ISSN: 0972-1045

Evaluation of diversity in dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala, India

K. Sethunath* and J. Bhaskar

[1]*Department of Fruit Science, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur 680656, India. *E-mail: keerthanasethu1996@gmail.com*

Abstract

The present study was conducted to evaluate the variability among the dragon fruit (*Hylocereus* spp.) genotypes in Kerala. The study was conducted in ten dragon fruit orchards of four different districts namely, Trivandrum, Pathanamthitta, Ernakulam and Thrissur during the period 2019-2021. The plants were evaluated based on the UPOV guidelines to identify the different genotypes that were being cultivated in Kerala with respect to their morphology and flowering along with yield and quality attributes. The results revealed that the commercial cultivation of dragon fruit in Kerala was found to be dominated by the dark pink/purple fleshed dragon fruit (*Hylocereus costaricensis*). The variability within this species was analysed using statistical techniques like factor analysis and cluster analysis. Maximum variability (59.38%) in the stem and flower characters were contributed by the intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape, bud apex shape, number of stigma lobes, length of style and distance between areoles. Similarly, maximum variability (62.74%) in the quality attributes were contributed by the fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour, fruit shape, width of base of bract, length of apical bract, outer TSS, TSS-acid ratio and core TSS. Based on the qualitative traits alone, six clusters were formed indicating the variations in plants which in turn, revealed the presence of different genotypes within the dark pink/purple fleshed dragon fruit.

Key words: Dragon fruit, Pitaya, genotype evaluation, *Hylocereus*, plant variations

Introduction

Dragon fruit (*Hylocereus* spp.), also referred to as Pitaya or Pitahaya in various countries is a perennial climbing vine belonging to the Cactaceae family. The fruit is now under cultivation throughout the state of Kerala. With the increase in health consciousness, the popularity and demand for dragon fruit is showing an increasing trend as the fruit is known to have numerous health promoting properties like anti-cancerous, anti-diabetic, anti-microbial, anti-oxidant and anti-ageing. Though it is found to be a potential future crop of Kerala, the extent of available information on its cultivation and related aspects is very scarce. The increasing demand for the fruit makes it highly remunerative and has immense potential for commercialization.

Recently, there has been a sudden upsurge in the production of dragon fruit in India which can even lead to a glut in the markets. Due to the high intra and inter-specific hybridization, high morphological and genetic heterogeneity is created in dragon fruit resulting in great difficulty to distinguish the species and the varieties and this is causing problems in analysing the performance for deciding the quality standards in dragon fruit (Tel-zur *et al.*, 2004, Abirami *et al.*, 2021). Most of the species belonging to the genus *Hylocereus* were similar in stem and flower characters but differed mainly in the fruit characters, creating an ambiguity regarding the limitations within the genus (De Dios 2005). Species under the *Hylocereus* genus exhibited greater polymorphisms with respect to stem, flower and fruit characters, which made the taxonomic identification and classification cumbersome (Hernandez and Salazar 2012).

Information on adopted genotypes, production technology followed and the crop management practices along with the crop production economics is essential for initiating any crop improvement programme and for popularising the crop region wise. There is a large scope for the commercial cultivation of the species belonging to *Hylocereus*, *Selenecereus* and *Epiphyllum* as there exist high genetic variability within the species of these climbing cacti.

Under this scenario, the present work holds the objective of studying the morphology, flowering, yield and quality attributes of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala, so as to provide more information which will eventually contribute to the popularisation and commercialization of dragon fruit cultivation in Kerala.

Materials and methods

The study was conducted in ten dragon fruit orchards in four different districts of Kerala namely, Trivandrum, Pathanamthitta, Ernakulam and Thrissur during the period 2019-2021. A preliminary survey was conducted in the locations and ten plants from each of the ten locations were selected and studied with respect to their morphology, flowering, yield and quality attributes. The plants were evaluated based on the UPOV guidelines to identify the different genotypes that are being cultivated in Kerala. The plants were denoted as P1 to P10, prefixed with the first two letters of the location from where they were collected, in the following format.

Ka: Karette, Thiruvananthapuram; Th: Thatta, Pathanamthitta; Ke: Keerukuzhy, Pathanamthitta; Ko: Kozhenchery, Pathanamthitta; Ai: Aikkad, Pathanamthitta; At: Athikkayam, Pathanamthitta; Ad: Adoor, Pathanamthitta; Mu: Muvattupuzha, Ernakulam; Pe: Perumbavoor, Ernakulam; Va: Vaniyampara, Thrissur

Stem characters: The stem morphology included observations on stem segment length, stem segment width, distance between areoles, arch height, stem waxiness, stem sturdiness, margin of rib, number of spines per areole, spine colour, height of pole, number of branches and number of stem segments per branch.

Flower characters: The traits like bud shape, shape of bud apex, petal colour, sepal colour, secondary colour pattern in sepal, intensity of red colour of bract, length of style and number of stigma lobes were observed for all the plants under study.

Yield characters: Fruits from each of the ten plants were observed to record the characters like fruit weight, fruit length and width, length to width ratio of the fruits, number of bracts, length of apical bract, width of base of the bract, position of bracts towards the peel, fruit weight without peel, fruit shape, colour of peel excluding bract, flesh colour and yield per post per year.

Quality attributes: The total soluble solids (TSS), titrable acidity and TSS/acidity ratio were measured for the entire group of plants from the concerned locations. Sensory evaluation of the fruits from different locations were done based on a 9-point hedonic scale.

Statistical analysis: Descriptive statistical parameters (mean, range, standard error mean, standard deviation, and coefficient of variation) were computed for quantitative variables, along with recording frequency distributions for qualitative characters (Fig. 11). Factor analysis and cluster analysis were conducted to assess variability among 100 plants, considering both qualitative and quantitative traits. Qualitative data was clustered using the single linkage method with Jaccard's similarity coefficient, resulting in a similarity matrix and dendrogram. Cluster analysis for mixed data (qualitative and quantitative) utilized Gower distance, with separate clustering for stem-flower characteristics and yield-quality attributes. All analyses were performed using R 4.1.0 software.

Results and discussion

Stem characters: The stem characters included stem segment length (33-210 cm), stem segment width ((1.80-6.60cm), distance between areoles (2.00-5.50 cm), arch height (1.00-4.20 cm), number of spines per areole (3-5), height of the pole (6.5-8 ft with 1-2 ft buried underground), number of branches (numerous) and number of stem segments per branch (1-6) (Table 1). Morphological traits like stem waxiness (strong and weak), stem sturdiness (high and low), margin of rib (convex and flat) and spine colour (medium brown and dark brown) showed wide variations among the genotypes (Fig. 1-3). However, the spine colour showed a trend of turning into grey colour with ageing. These results were in confirmation with the findings of Abirami *et al.* (2021) that the stem characters such as number of spines (3-5), margin of ribs of cladode (convex in *H. costaricensis*) and stem waxiness (weak or strong) could be effectively utilised for the identification of different *Hylocereus* spp. According to Warusawitharana *et al.* (2017), the training practice which was being followed in Kerala and Sri Lanka were the same, where

Fig. 1. Stem waxiness and stem sturdiness: (a) strong waxiness and low sturdiness (b) weak waxiness and high sturdiness

Fig. 2. Margin of rib: (a) convex (b) flat

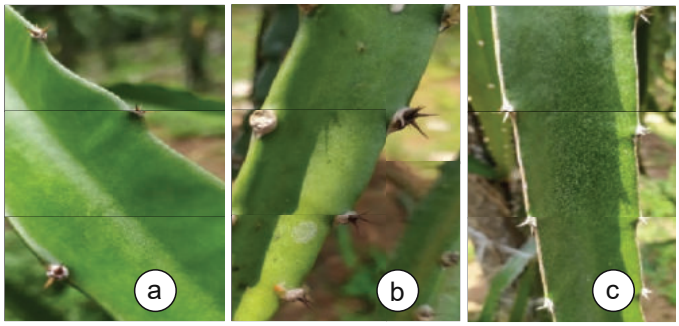

Fig. 3. Spine colour: (a) medium brown (b) dark brown (c) grey

Table 1. Descriptive statistics of stem and flower characters in dragon fruit

Descriptives	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch	Style length (cm)	Number of stigma lobes
Range	177.00	4.80	3.50	3.20	2.00	5.00	7.50	10
Minimum	33.00	1.80	2.00	1.00	3.00	1.00	23.50	26.00
Maximum	210.00	6.60	5.50	4.20	5.00	6.00	31.00	36.00
Average	116.00	4.06	3.50	1.86	3.94	2.61	28.06	29.62
Standard error of mean	8.97	0.18	0.14	0.11	0.09	0.24	0.36	0.40
Standard deviation	45.19	0.93	0.70	0.57	0.45	1.23	1.81	1.99
Co-efficient of variation	0.39	0.23	0.20	0.31	0.11	0.47	0.06	0.07

concrete poles and fixed frames were used for supporting the plants.

Flower characters: Variations were observed in flower characteristics, including bud shape (ovate and elliptic), bud apex shape (acute and rounded), sepal secondary color pattern (slightly red edged and red edged), and intensity of red color on bracts (weak, medium, and strong) (see Fig. 4-6). Style length ranged from 23.50 to 31.00 cm, and the number of stigma lobes varied from 26 to 36 among different genotypes (refer to Table 1). Petal color was consistently white, and sepal color was consistently green across all plants studied. Similar findings on bud shape, bud apex shape, petal and sepal color, and secondary color pattern were reported by Abirami *et al.* (2021) for *H. costaricensis*.

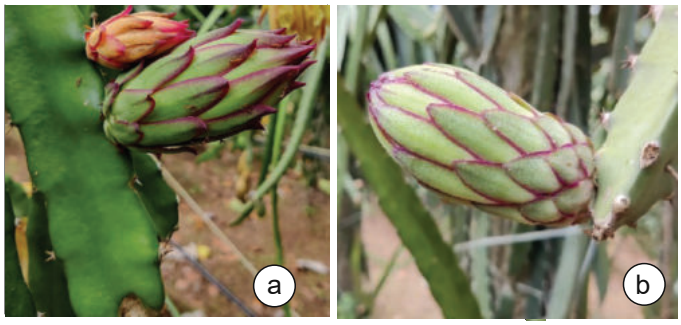

Fig. 4. Shape of bud and bud apex: (a) ovate with acute apex (b) elliptic with rounded apex

Fig. 5. Secondary colour of sepal: (a) slightly red edged (b) red edged

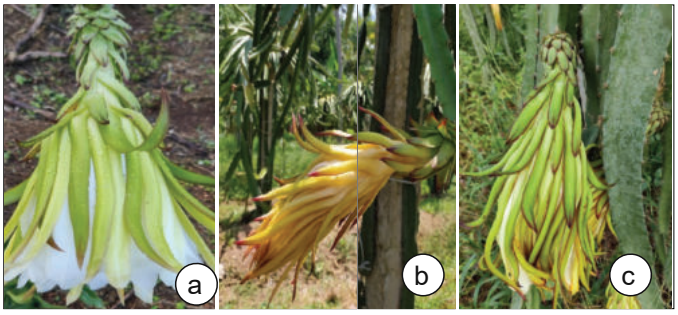

Fig. 6. Intensity of red colour of the bract: (a) weak (b) medium (c) strong

Dragon fruit flower pollination was facilitated by honey bees in all study locations, contrary to Valiente-Banueta *et al.* (2007), who reported insects and birds as pollinating agents for dragon fruit. Almeida *et al.* (2013) described the floral organ structure of dragon fruit, noting an inferior ovary secreting nectar to attract pollinators. They also observed a single-branched stigma and stamens arranged in groups, consistent with the findings of this study.

The frequency distribution for qualitative characters were analysed as a whole (Table 2) whereas the stem and flower characters were first analysed together for their descriptive statistics (Table 2) followed by the yield and quality attributes (Table 3).

Table 2. Frequency distribution of qualitative characters of dragon fruit

Character	Expression	Frequency percentage
Stem waxiness	Strong	88.00
	Weak	12.00
Stem sturdiness	High	12.00
	Low	88.00
Margin of rib	Convex	88.00
	Flat	12.00
Spine colour	Dark brown	12.00
	Medium brown	88.00
Bud shape	Ovate	88.00
	Elliptic	12.00
Bud apex shape	Acute	88.00
	Rounded	12.00
Sepal pattern of secondary colour	Red edged	58.00
	Slightly red edged	42.00
Intensity of red colour of bract	Strong	12.00
	Medium	46.00
	Weak	42.00
Position of bracts towards the peel	Adpressed	12.00
	Slightly held out	58.00
	Strongly held out	30.00
Fruit shape	Oval	37.00
	Spherical	63.00
Peel colour	Dark pink	63.00
	Medium pink	37.00
Flesh colour	Dark pink	88.00
	Purple	12.00

Yield characters: The yield characters studied were fruit weight (84-896 g), length of fruit (4.60-10.40 cm), width of fruit (4.40-10.40 cm), length/width ratio of fruit (1.00-1.21), number of bracts (18-50), length of apical bract (3.00-6.30cm), width of base of the bract (1.40-5.70 cm) and fruit weight without peel (52-592 g) as indicated in Table 3. Position of bracts towards

Table 3. Descriptive statistics of fruit characters and quality attributes in dragon fruit

Descriptives	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/ width ratio of fruit	Number of bracts	Length of apical bract (cm)	Width of base of the bract (cm)	Fruit weight without peel (g)	TSS (°Brix)	Titrable acidity (%)	TSS/acid ratio
Range	812.00	5.80	6.00	0.21	32.00	3.30	4.30	546.00	7.00	0.00	58.33
Minimum	84.00	4.60	4.40	1.00	18.00	3.00	1.40	52.00	11.00	0.12	91.67
Maximum	896.00	10.40	10.40	1.21	50.00	6.30	5.70	598.00	18.00	0.12	150.00
Average	381.10	7.94	7.83	1.02	29.24	4.68	3.35	269.60	15.17	0.12	126.42
Standard error of mean	35.01	0.31	0.31	0.01	1.42	0.15	0.17	26.08	0.38	0.00	3.12
Standard deviation	176.46	1.54	1.58	0.03	7.14	0.79	0.84	131.42	1.94	0.00	16.12
Co-efficient of variation	0.46	0.19	0.20	0.03	0.24	0.17	0.25	0.49	0.13	0.00	0.13

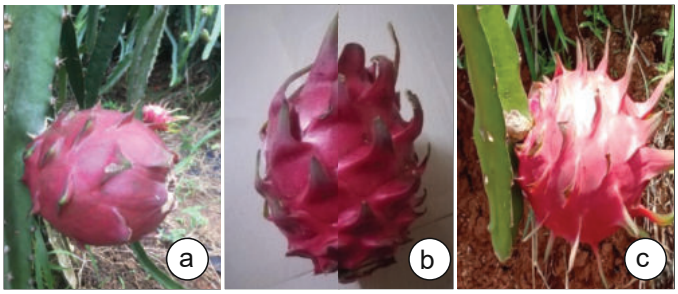

Fig. 7. Position of bract towards the peel: (a) adpressed (b) slightly held out (c) strongly held out

Fig. 8. Peel colour of fruit: (a) medium pink (b) dark pink

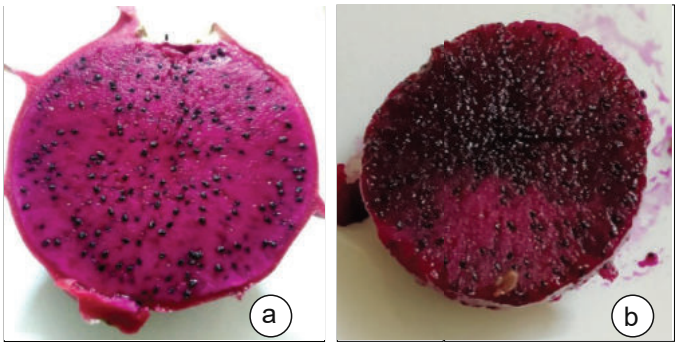

Fig. 9. Flesh colour: (a) dark pink (b) purple

the peel (adpressed, slightly held out and strongly held out), fruit shape (oval or spherical), colour of peel (medium pink and dark pink) and flesh colour (dark pink and purple) were recorded as distinguishing characters in different genotypes (Fig. 7-9). The fruit weight recorded was found to be in accordance with the fruit weight (140g to 945 g) obtained in Sri Lanka by Warusawitharana *et al.* (2017). Similar results were also obtained by Ramirez (1999) in Mexican *Hylocereus* accessions as they recorded fruit weight varying from 100g to 1200g. Maximum value for both fruit length and width obtained in the study was 10.40 cm, similar to the findings of Warusawitharana *et al.* (2017) where they recorded fruit length and width in the range of 11.30 cm-14.20 cm and 8.20 cm-9.50 cm respectively. Based on the length to width ratio of fruits, the fruits were classified into moderately elongated or medium in appearance and the number of scales/bracts on the peel was recorded to be in the range of 18-50 which were both in confirmation with the observations for *H. costaricensis* (moderately rounded or medium elongated with 27-33 bracts on peel) by Abirami *et al.* (2021). The position of bract towards the peel showed three different arrangements namely, adpressed, slightly held out and strongly held out from the peel. The colour of the peel was observed to be dark pink or medium pink and flesh colour was either dark pink or purple. These results were also in agreement with the findings of Abirami *et al.* (2021) for *H. costaricensis*.

The yield obtained from a single post per year varied from 5 kg to 20 kg in various locations under study depending upon the age of the plants. Tel-zur *et al.* (2011) stated that a yield of 15.4 kg and 14.8 kg were obtained from a post per year in *H. undatus* and *H. monocanthus* respectively.

Quality attributes: The values ranged from 11 to 18 °Brix with respect to TSS of the fruits whereas the titrable acidity was found to be 0.12% in all the fruits. Chavez (2011) obtained similar results from six Mexican genotypes in which the TSS varied from 14.5-17.6°Brix. Meija *et al.* (2013) also reported a TSS of 18°Brix in a group of wild species of *Hylocereus* and Abirami *et al.* (2021) also observed a TSS of 15.9°Brix for *H. costaricensis*.

The TSS/acidity ratio was found to be very high in pitaya attributing to the low values of titrable acidity. The ratio obtained was between 91.67 and 150.00 with an average value of 126.42. Similar observation of high Brix-acid ratio in dragon fruit was reported by Yah *et al.* (2008). The plants KoP1 to KoP10 from Kozhenchery received the maximum score for appearance, taste, flavour, after taste and overall acceptance.

Variability: The variability within the species was analysed using statistical techniques like factor analysis and cluster analysis. Maximum variability (59.38%) in the stem and flower characters was explained by two dimensions. The characters that contributed to the variability were intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape, bud apex shape, number of stigma lobes, length of style

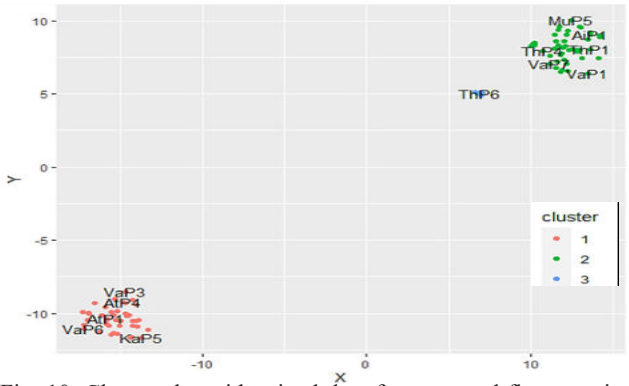

Fig. 10. Cluster plot with mixed data for stem and flower traits (At- Athikkayam; Th- Thatta; Ka- Karette; Ko- Kozhenchery; Ai- Aikkad; Mu- Muvattupuzha; Va- Vaniyampara; Ke- Keerukuzhy, Pe-Perumbavoor; Ad-Adoor)

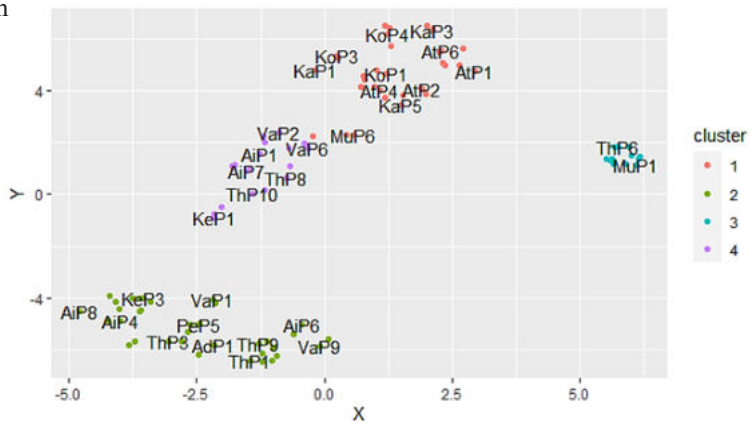

Fig. 11. Cluster plot with mixed data for yield and quality attributes (At- Athikkayam; Th- Thatta; Ka- Karette; Ko- Kozhenchery; Ai- Aikkad; Mu- Muvattupuzha; Va- Vaniyampara; Ke- Keerukuzhy, Pe- Perumbavoor; Ad- Adoor)

Table 4. Cluster wise summary of qualitative characters

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Stem waxiness	Weak	Strong	Strong	Strong	Strong	Strong
Stem sturdiness	High	Low	Low	Low	Low	Low
Margin of rib	Flat	Convex	Convex	Convex	Convex	Convex
Spine colour	Dark brown	Medium brown	Medium brown	Medium brown	Medium brown	Medium brown
Bud shape	Elliptic	Ovate	Ovate	Ovate	Ovate	Ovate
Bud apex shape	Rounded	Acute	Acute	Acute	Acute	Acute
Sepal secondary colour	Red edged	Red edged	Red edged	Slightly red edged	Slightly red edged	Slightly red edged
Intensity of red colour of bract	Strong	Medium	Medium	Weak	Weak	Weak
Position of bract towards peel	Adpressed	Slightly held out	Slightly held out	Slightly held out	Strongly held out	Strongly held out
Fruit shape	Spherical	Oval	Spherical	Spherical	Spherical	Spherical
Peel colour	Dark pink	Dark pink	Medium pink	Medium pink	Dark pink	Medium pink
Flesh colour	Purple	Dark pink	Dark pink	Dark pink	Dark pink	Dark pink

and distance between areoles. Similarly, maximum variability (62.74%) in the quality attributes were contributed by the first two dimensions out of four significant dimensions. The characters responsible for creating the variability were fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour, fruit shape, width of base of bract, length of apical bract, outer TSS, TSS-acid ratio and core TSS.

The factor analysis and cluster analysis of qualitative and mixed data revealed that plants AtP1-P10, KaP1-P10, and KoP1-P10 were closely related, likely due to a common source of planting material, forming a genotype. Other plants showed variations despite sharing the same source, suggesting multiple genotypes from that source. Plants AiP10, MuP1, MuP2, MuP3, VaP8, PeP3, PeP4, AdP5, and AdP7 were visually distinct in terms of qualitative traits. Six clusters were identified based on qualitative traits (Table 4), while clustering of mixed data revealed three clusters for stem and flower characters (Fig. 10) and four clusters for yield and qualitative characters (Fig. 11). These findings highlight variations among the studied plants, indicating the presence of different genotypes within the dark pink/purple fleshed dragon fruit.

Commercial dragon fruit cultivation in Kerala is primarily dominated by the dark pink/purple fleshed dragon fruit (*Hylocereus costaricensis*), with multiple genotypes identified within this species. Variability in stem, flower, yield, and quality attributes was observed, likely due to cross pollination leading to inter and intra-specific hybridization (Tel-zur *et al.*, 2004). The presence of various genotypes within the *Hylocereus* genus results in wide variability among its species (Tel-zur *et al.*, 2011), as reported by Betancur *et al.* (2020) regarding *H. undatus*.

Exploring the diversity of dragon fruit is beneficial in numerous ways. Its diversity contributes to nutritional variety, flavor profiles, visual aesthetics, culinary versatility, adaptability in cultivation, health benefits, and market appeal, making it a valuable addition to tropical fruits. Analyzing diversity can aid in identifying genotypes suitable for different functions and regions, assisting farmers in efficiently selecting genotypes for commercial cultivation.

Acknowledgement

We extend our gratitude to the Kerala Agricultural University, Thrissur, for their support and financial assistance throughout this research. Additionally, we thank the dragon fruit farmers of Kerala for their generous cooperation.

References

Abirami, K., S. Swain, V. Baskaran, K. Venkatesan, K. Sakthivel and N. Bommayasamy, 2021. Distinguishing three Dragon fruit (*Hylocereus* spp.) species grown in Andaman and Nicobar Islands of India using morphological, biochemical and molecular traits. *Sci. Rep.*, 11(1): 1-14.

Almeida, O.J.G., J.H. Cota-Sánchez and A.A.S. Paolia, 2013. The systematic significance of floral morphology, nectaries, and nectar concentration in epiphytic cacti of tribes Hylocereeae and Rhipsalideae (Cactaceae). *Perspectives in Plant Ecol. Evol. Syst.,* 15: 255-268.

Betancur, G.J.A, R.S.B. Muriel and J.E.P. Gonzales, 2020. Morphological characterization of the red dragon fruit - *Selenicereus undatus* (Haw.) D.R. Hunt – under growing conditions in the municipality of San Jeronimo (Antioquia, Colombia). *Revista Facultad Nacional de Agronomia Medellin*, 73(1): 9019-9027.

Chávez M.R. 2011. *Relaciones entre genotipo, productividad y calidad de fruto en pitahaya (Hylocereus spp.)* [Relationships between genotype, productivity and quality of pitahaya fruits (*Hylocereus* spp.)]. M.Sc. thesis, Colegio de Postgraduados, Montecillo.

De Dios, H.C, 2005. A new subspecies of *Hylocereus undatus* (Cactaceae) from south-eastern Mexico. *Haseltonia* 11: 11-17.

Hernandez, Y.D.O. and J.A.S. Salazar, 2012. Pitahaya (*Hylocereus* spp.): A short review. *Comunicata Sci*., 3(4): 220-237.

Meija, H.A., S.B.M. Ruiz, C.A. Montoya and C.R. Sequeda, 2013. *Revista Facultad Nacional de Agronomia Medellin,* 66(1): 6845-6854.

Ramírez, M.F.J., 1999. *Characterization and compatibility in pitahaya (Hylocereus spp.)*. M.Sc. thesis, Chapingo Autonomous University, Chapingo, Mexico, 108p.

Tel-zur, N., S. Abbo, D. Bar-zvi and Y. Mizrahi, 2004. Genetic relationships among *Hylocereus* and *Selenicereus* vine cacti (Cactaceae): Evidence from hybridization and cytological studies. *Ann. Bot.,* 94: 527-534.

Tel-zur, N, Y. Mizrahi, A. Cisneros, J. Moyal, B. Schneider and J.J. Doyle, 2011. Phenotypic and genomic characterization of vine cactus collection (Cactaceae). *Genet. Resources Crop Evol*., 57: 1075-1085.

Valiente-Banueta, A., R.S. Gallya, M.C. Arizmendib and A. Casas, 2007. Pollination biology of the hemiepiphytic cactus *Hylocereus undatus* in the Tehuaca´ınValley, Mexico. *J. Arid Environ*., 68: 1-8.

Warusavitharana, A. J., K.H.S. Peiris, K.M.D.G. Wickramatilake, A.T. Ekanayake, H.A.D.S. Hettiarachchi and J. Bamunuarachchi, 2017. Performance of dragon fruit (*Hylocereus undatus*) in the Low Country Wet Zone (LCWZ) of Sri Lanka. *Acta Hortic.*, 1178: 31-34.

Yah, A. R. C., S. S. Pereira, C. S. Veloz, R. B. Sañudo and E. S. Duch, 2008. Physical, chemical and sensory changes in pitahaya (*Hylocereus undatus*) fruits during their development. *Revista Fitotecnia Mexicana,* 31(1): 1-5.

Received: November, 2023; Revised: December, 2023; Accepted: January, 2024