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ASSESSMENT OF MORPHOLOGICAL DIVERSITY FOR THE QUALITATIVE TRAITS OF JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS* LAM.) GENOTYPES FOR VEGETABLE PURPOSE

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ABSTRACT

Jackfruit (*Artocarpus heterophyllus* Lam.), a member of the Moraceae family, is an important tropical fruit crop widely cultivated in Southeast Asia and India. Known for producing the world's largest tree-borne fruit, jackfruit possesses significant nutritional, economic and industrial value. Its tender fruit, increasingly popular as a meat substitute has garnered commercial importance, creating a need for identifying and characterizing genotypes suitable for vegetable use. The present study was conducted during 2020–21 and 2021–22 across different regions of Bengaluru, including Doddaballapura, Tumakuru, Ramanagara and the GKVK campus. Twenty genotypes were selected based on fruit bearing consistency were characterized using qualitative morphological descriptors. Extensive variability was observed among genotypes for traits such as crown shape, leaf morphology, inflorescence density, fruit shape, fruit rind colour, spine characteristics and latex exudation. The predominant crown shape was broadly pyramidal with spreading growth habit and medium branching density in most genotypes. Leaf shape was mostly elliptic with acuminate apex and oblique base. Fruits were primarily ellipsoid, green to greenish-yellow in colour, spiny and regularly borne in clusters. Latex exudation and browning intensity showed genotypic variation, while seedless fruits were observed in several accessions suited for tender fruit use. The results indicated a high level of morphological diversity among jackfruit genotypes, emphasizing the crop's genetic richness and its potential for varietal improvement, germplasm conservation and selection of superior lines for vegetable purposes.

Keywords **:** Vegetable jackfruit, Tender jackfruit, Fruit Shape, Fruit rind colour, Spine density, Latex exudation

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.) is a tropical fruit crop belonging to the Moraceae family, widely cultivated across Southeast Asia, India, and other tropical regions. It produces the largest tree-borne fruit in the world, reaching up to 20 kg in weight and about 80 cm in length (Baliga *et al.,* 2011). Owing to its impressive size, diverse applications and rich nutritional profile, jackfruit holds significant socio-economic importance. It is consumed fresh, cooked or processed and its seeds are valued for their high protein and starch content. The unripe green jackfruit is remarkably similar in texture to the animal meat and its ability to mimic the texture of chicken and pork meat when cooked, thus proves an excellent vegetarian substitute for meat. Hence it is referred as 'vegetable meat' (Stukin, 2016).

Morphologically, jackfruit exhibits extensive qualitative variation which is essential for its identification, breeding and conservation of germplasm. These traits include canopy shape, branching pattern, leaf morphology, fruit size and

shape, rind texture and colour, flake (edible bulb) characteristics, seed attributes, spine density and aroma. The fruits vary in shape from oval and oblong to spheroid or clavate, influenced by genetic and environmental factors such as pollination. Fruit rind colour ranges from green to yellowish or brownish, while flake colour spans from creamy white to deep orange or red, often correlating with carotenoid content and nutritional value. The distinctive aroma, reminiscent of pineapple and banana, is a key determinant of consumer preference. Such qualitative morphological diversity reflects both genetic variation and environmental adaptation, playing a crucial role in germplasm conservation and varietal improvement (Kumar *et al.,* 2016). The present study aims to identify the potential of jackfruit accessions for their suitability as vegetable. Evaluating the accessions for above said qualitative traits helps to identify the potential genotypes for the culinary benefits.

Material and Methods

The present study was carried out during the period of 2020-21 to 2021-22; precisely, during the off season (October to December, 2020) and main fruiting season (March to June, 2021) of 2020-21 and subsequently, off season (October to December, 2021) and the main season (March to June, 2022) of 2021-22. A Preliminary survey was conducted at different places around Bengaluru *viz.,* Doddaballapura, Tumakuru, Ramanagara, Kolar, Chikkaballapura and in the GKVK Campus. Among the surveyed trees, the genotypes established at different locations in GKVK campus and Kachahalli village of Doddaballapura were finalized based on bearing conditions, fruit availability and recovery of edible portion.

Table 1 : List of Jackfruit genotypes finalized for the study

Sl. No	Genotype/ Variety	Abbreviation Used
1.	Lalbagh Madhura	LM
2.	Byrachandra	BC
3.	Swarna	SW
4.	Muttamvarikka	MV
5.	Gumless	GL
6.	Horticulture Vegetable type -1	HV-1
7.	Horticulture Vegetable type -2	HV-2
8.	Kachahalli Vegetable type -1	KV-1
9.	Kachahalli Vegetable type -2	KV-2
10.	Kachahalli Vegetable type -3	KV-3
11.	GKVK Tissue Culture lab-1	GTC-1
12.	GKVK Tissue Culture lab-3	GTC-3
13.	GKVK Avenue-18	GA-18
14.	GKVK Avenue-20	GA-20
15.	National Seed Project-1	NSP-1
16.	National Seed Project-2	NSP-2
17.	National Seed Project-3	NSP-3
18.	GKVK Horticulture orchard-9	GH-9
19.	GKVK Horticulture orchard-11	GH-11
20.	GKVK Horticulture orchard-15	GH-15

Qualitative characters: The characters whose data is non-quantifiable were grouped as qualitative characters. These parameters were documented based on the score given for each possessing characters in three replicates. The morphological characters were recorded as per the guidelines of jackfruit descriptors by Bioversity International (IPGRI, 2000). The average of two 'on years' (production years) data recorded from trees and the morphological characters were presented.

1. **Crown Shape:** The tree canopy shape was recorded using 7-point scale based on the descriptor and given the score as 1 for *Pyramidal*, 2 for *Broadly pyramidal*, 3 for *Spherical*, 4 for *Oblong*, 5 for *Semicircular*, 6 for *Elliptical*, 7 for *Irregular.*
2. **Tree growth habit:** The tree growth habit was recorded using 3-point scale according to the descriptor and given the score as 1 for *Erect*, 2 for *Semi-erect*, 3 for *Spreading*
3. **Branching density:** The branching density was recorded using 3-point scale following the descriptor and given the score as 1 for *Sparse*, 2 for *Medium* and 3 for *Dense*.
4. **Branching pattern:** The branching pattern of the tree was recorded using 5-point scale according to the descriptor and the scores was given as 1 for Erect, 2 for *Opoosite*, 3 for *Vertiilliate*, 4 for *Horizontal* and 5 for *Irregular.*
5. **Leaf shape:** The leaves were collected from each genotype; The fourth leaf from tip was collected to maintain uniformity in leaf maturity and it was recorded using a 6-point scale. The score was given as 1 for *Obovate*, 2 for *Elliptic*, 3 for *Broadly elliptic*, 4 for *Narrowly elliptic*, 5 for *Oblong* and 6 for *Lyrate (wavy).*
6. **Leaf apex shape:** The shape of leaf apex was documented based on 4-pointed scale and the following score was given as 1 for *Acute*, 2 for *Acuminate*, 3 for *Retuse* and 4 for *Obtuse.*
7. **Leaf base shape:** The leaf base shape was recorded using 4-point scale and the score given as 1 for *Oblique,* 2 for *Rounded*, 3 for *Cuneate*, 4 for *Shortly attenuate*.
8. **Female Inflorescence density:** The density of female inflorescence on a tree is documented based on 3-point scale with the score given as 3 for *Sparse*, 5 for *Intermediate* and 7 for *Dense*.
9. **Fruit bearing habit:** Fruit bearing habit was recorded with 3-point scale and the score was

given as 1 for *Regular* and 2 for *Alternate bearing* and 3 for *off-season bearing*.

10. **Fruit rind colour:** The fruit rind colour was noted based on the scores assigned which include 1 for *Green*, 2 for *Greenish yellow*, 3 for *Yellow*, 5 for *Reddish-brown*.
11. **Fruit shape:** The shape of the fruit was documented based on scoring where the score 1 was given for *Obloid*, 2 for *Spheroid*, 3 for *Ellipsoid*, 4 for *Clavate*, 5 for *Oblong*, 6 for *Irregular*.
12. **Fruit attractiveness:** The attractiveness of fruit was judged based on combined assessment of shape, size and spine structure and the score was given as 1 for *Poor*, 2 for *Intermediate*, 3 for *Good* and 4 for *Excellent*.
13. **Spine density:** The number of spines present on 1 cm^3 of the rind surface at the base of fruit was observed and expressed as 3 for *Sparse* and 7 for *Dense.*
14. **Stalk attachment to fruit:** The type of stalk attachment to the fruit was recorded based on the score where 1 was given for *Depressed*, 2 for *Flattened* and 3 for *Inflated.*
15. **Shape of spine:** The shape of spine at the basal region of fruit was observed and documented as 1 for *Sharp pointed*, 2 for *Intermediate* and 3 for *Flat*.
16. **Latex exudation:** The latex exudation at the time of detaching a fruit and fully developed leaves was observed and recorded based on the score, given as 1 for *Low*, 2 for *Medium* and 3 for *High.*
17. **Browning:** The intensity of browning after cutting the fruit was observed and documented as *Low, Medium* and *High.*
18. **Seed development:** The seed development was observed and recorded as *present* or *absent* after the transverse cut.

Results and Discussion

The Salient findings of the study were presented below and discussed accordingly Tree crown shape, growth habit, branching density and branching pattern of twenty Jackfruit genotypes studied for tender fruit purpose As per the data recorded on the above qualitative parameters for 20 elite Jackfruit genotypes. The predominant tree crown shape was Broadly pyramidal (13 genotypes) followed by oblong (five genotypes). The predominant tree growth habit was spreading (16 genotypes) with medium branching density observed in 18 genotypes. The dominant branching pattern was opposite and the same was recorded in 19 genotypes (Table 2 and Fig.1).

These type of variations in tree morphological characters are due to the genetic factors, growing conditions and microclimate prevailed in that particular growing area. Tree's individual genetic makeup also contributes to the diversity of tree morphology (DeGraaf and Sendak, 2006). Similar kind of studies in qualitative characters of Jackfruit were done by Phaomei *et al.* (2017), where they observed seven erect and three spreading types in tree crown shape, sparse, medium and dense branching density; opposite, irregular and verticillate type of branching pattern among 10 jackfruit genotypes in West Garo Hills of Meghalaya. Chandrashekhar *et al.* (2018) also reported the dominant tree qualitative characters *viz.,* 'irregular' canopy shape (54.28%), erect tree growth habit (54.28%), 'erect' branching pattern (57.14%) among the thirty-five Jackfruit genotypes evaluated under coffee ecosystem surveyed in Pulney hills of Tamil Nadu. Other studies which reported diversity in tree morphological characters in Jackfruit are Palupi and Daryano (2021), Dey and Baruah (2019), Roy *et al.* (2018), Chandrasekhar *et al.* (2017) and Wangchu *et al.* (2005).

Leaf shape, leaf apex and leaf base shapes recorded in 20 Jackfruit genotypes

The morphology of leaf was recorded with respect to its shape, apex shape and leaf base shape. The major leaf shape observed was elliptic (16 genotypes) with acuminate leaf apex shape predominantly observed in 15 genotypes and oblique leaf base as dominant character and was exhibited in 14 genotypes (Table 2 and Fig.1).

The heterozygous nature of the seedling population and the cross pollination may have contributed to these types of variations. Dey and Baruah (2019) evaluated twenty-four local Jackfruit genotypes in Assam to study the morphological characters. Leaf shape was 'elliptic' in most of the genotypes (eleven accessions, 45.83%) followed by obovate and oblong in rest of the accessions. Azad *et al.* (2007) reported a dominance of 'ovate' leaf shape in the Jackfruit genotypes of Bangladesh. Chandrashekar *et al.* (2018) evaluated 35 Jackfruit genotypes under coffee ecosystem surveyed in Pulney hills. They reported that, the leaf apex shape was acuminate in all the genotypes and the dominant leaf base shape was oblique. Similar kind of results were reported in Jackfruit by Mitra and Maity (2002) and Sharma *et al.,* (2006).

Table 2 : Qualitative characters pertaining to tree crown shape, growth habit, branching density and branching pattern of twenty Jackfruit genotypes studied for tender fruit purpose

Sl. No.	Character	Category	Genotypes	Total
1.	Crown shape	Broadly pyramidal	LM, SW, MV, GL, HV-1, HV-2, GTC-1, GTC-3, GA-18, GA-20, GH-9 and GH-11	12
		Spherical	KV-1, NSP-1	2
		Oblong	BC, KV-2, NSP-2, NSP-3 and GH-15	6
2.	Tree growth habit	Erect	HV-1, HV-2, GTC-1 and GTC-3	4
		Spreading	LM, BC, SW, MV, GL, KV-1, KV-2, KV-3, GA-18, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	16
3.	Branching density	Medium	LM, BC, SW, MV, GL, HV-1, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	18
		Dense	HV-2 and GA-18	2
4.	Branching pattern	Opposite	LM, BC, SW, MV, GL, HV-1, HV-2, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, NSP-2, NSP-3, GH-9, GH-11 and GH-15	19
		Verticellate	NSP-1	1
5.	Leaf shape	Obovate	SW	1
		Elliptic	LM, MV, GL, HV-1, HV-2, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, GH-9, GH-11, GH-15	16
		Broadly elliptic	NSP-2 and NSP-3	2
		Narrowly elliptic	BC, NSP-1	2
6.	Leaf apex shape	Acute	MV, HV-2, GTC-1, GA-20 and NSP-1,	5
		Accuminate	LM, BC, SW, GL, HV-1, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, NSP-2, NSP-3, GH-9, GH-11 and GH-15	15
7.	Leaf base Shape	Oblique	LM, BC, SW, GL, HV-1, KV-1, GTC-3, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	14
		Cuneate	MV, HV-2, KV-2, KV-3, GTC-1 and GA-18	6

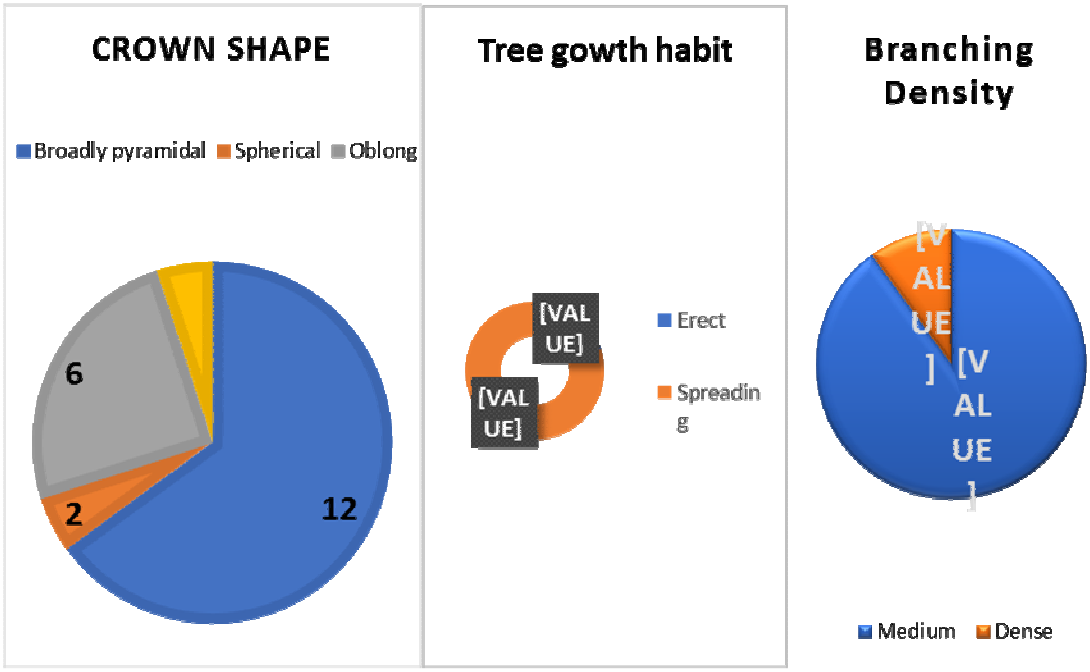

Fig. 1 : Diversity in tree crown shape, growth habit and branching density in twenty Jackfruit genotypes

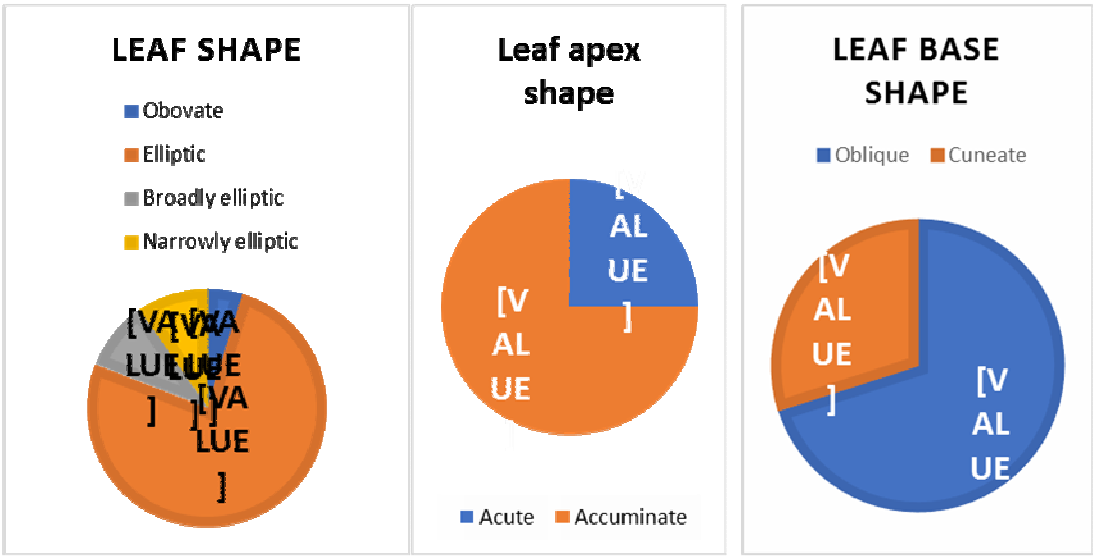

Fig. 2 : Diversity in leaf shape, leaf apex shape and leaf base shape in twenty Jackfruit genotypes

Inflorescence and fruit morphological traits

The female inflorescence density was found to be dense in eight genotypes and intermediate in 12 genotypes. Most of the genotypes were regular in fruit bearing habit. The dominant fruit bearing position was on main trunk and primary branches (12 genotypes), followed by only on primary branches in seven genotypes. All 20 genotypes showed fruit in clusters and green fruit rind colour being dominant (11 genotypes) followed by greenish yellow (7 genotypes) fruit rind colours. The fruit surface was spiny in 18 genotypes. External appearance or attractiveness of the fruit was excellent in two genotypes *viz.,* HV-2 and KV-2 and it was good in eight genotypes followed by moderate in eight genotypes. The predominant fruit shape was ellipsoid (15 genotypes) and stalk attachment to fruit was depressed in 14 genotypes, followed by flattened in 6 genotypes. The spine density was sparse in two genotypes (HV-2 and GTC-3) and dense in the remaining twenty genotypes. In maximum genotypes (17), the spine shape was sharp pointed and it was flat in HV-2 (Table 3). Latex exudation was low in seven genotypes, medium in five and high in eight genotypes. Six genotypes showed less browning while most of them (12 genotypes) were categorised under medium browning and two genotypes *viz.,* Muttamvarikka and NSP-3 exhibited high browning. Presence of seed was noticed in eleven genotypes and it was not seen in remaining nine genotypes (Table 3).

Dey and Baruah (2019) evaluated twenty-four local Jackfruit genotypes in Assam to study the morphological characters. They noticed that, the fruit bearing position was predominantly on main trunk (18 accessions, 75%) followed by primary branch. Phaomei *et al.* (2017) conducted survey in Rongram block of West Garo Hills district of Meghalaya and found that all trees showed a regular bearing habit. They also reported that, out of twenty genotypes studied, eleven genotypes borne fruits in clusters; seven was solitary bearing and remaining two were both solitary and clusters bearers. They also reported that all of the fruit surface was spiny; shape of the spine was 'sharp pointed' in eight genotypes and intermediate in twelve genotypes. Spine density was sparse in fourteen genotypes and dense in six genotypes. Akter and Rahman (2017) reported that, the stalk attachment to fruit was depressed in all the 23 genotypes studied.

Kavya *et al.* (2019) reported that green fruit rind colour was dominant in twenty Jackfruit genotypes, the major fruit shape was 'ellipsoid'. Dey and Baruah (2019) also reported that the fruit shape 'ellipsoid' was prominent (33.33%), rest being oblong, spheroid, clavate and obolid. These findings support the present results of ellipsoid fruits being predominant.

Roy *et al.* (2018), Singh *et al.* (2018), Ullah and Haq (2008), Reddy *et al.* (2004), Mitra and Maity (2002) have reported similar kind of variations in inflorescence and fruit morphological traits in Jackfruit genotypes.

Table 3 : Qualitative characters pertaining to inflorescence and fruit morphological traits

Sl. No.	Character	Category	Genotypes	Total
1.	Female Inflorescence density	Intermediate	LM, BC, MV, GL, HV-1, KV-1, GA-20, NSP-1, NSP-2, GH-9, GH-11 and GH-15	12
		Dense	SW, HV-2, KV-2, KV-3, GTC-1, GTC-3, GA-18 and NSP-3	8
2.	Fruit Bearing Habit	Regular	LM, BC, SW, MV, GL, HV-1, HV-2, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	20
3.	Fruit Bearing Position	Main trunk and Primary branch	LM, BC, SW, HV-1, KV-1, KV-3, GTC-1, GTC-3, NSP-1, NSP-3, GH-11 and GH-15	12
		Primary branch	MV, GL, HV-2, KV-2, GA-18, GA-20 and GH-9	7
		Main trunk, Primary and Secondary	NSP-2	1
4.	Fruit clustering habit	Clusters	LM, BC, SW, MV, GL, HV-1, HV-2, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	20
5.	Fruit rind colour	Green	BC, MV, GL, KV-1, KV-2, KV-3, GTC-1, GTC-3, GH-9, GH-11 and GH-15	11
		Greenish yellow	LM, SW, HV-1, HV-2, GA-18, GA-20 and NSP-1	7
		Reddish yellow	NSP-2 and NSP-3	2
6.	Fruit surface	Smooth	HV-2 and NSP-1	2
		Spiny	LM, BC, SW, MV, GL, HV-1, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, NSP-2, NSP-3, GH-9, GH-11 and GH-15	18
7.	Fruit attractiveness	Poor	KV-2 and GTC-1	2
		Moderate	MV, HV-1, GA-18, GA-20, NSP-1, NSP-3, GH-11 and GH-15	8
		Good	LM, BC, SW, GL, KV-3, GTC-3, NSP-2 and GH-9	8
		Excellent	HV-2 and KV-1	2
8.	Fruit shape	Obloid	SW	1
		Ellipsoid	LM, MV, GL, HV-1, KV-1, KV-2, KV-3, GTC-3, GA-18, GA-20, NSP-2, NSP-3, GH-9, GH-11 and GH-15	15
		Clavate	NSP-1	1
		Oblong	BC and HV-2,	2
		Irregular	GTC-1	1
9.	Stalk attachment to fruit	Depressed	LM, BC, GL, HV-1, HV-2, GTC-1, GTC-3, GA-18, GA-20, NSP-3, GH-9, GH-11 and GH-15	14
		Flattened	MV, KV-1, KV-2, KV-3, NSP-1 and NSP-2	6
		Inflated	SW	1
10.	Spine density	Sparse	HV-2 and GTC-3	2
		Dense	LM, BC, SW, MV, GL, HV-1, KV-1, KV-2, KV-3, GTC-1, GA-18, GA-20, NSP-1, NSP-2, NSP-3, GH-9, GH-11 and GH-15	18
11.	Shape of spine	Sharp pointed	LM, BC, SW, MV, GL, KV-1, KV-2, KV-3, GTC-1, GTC-3, GA-18, GA-20, NSP-1, NSP-3, GH-9, GH-11 and GH-15	17
		Intermediate	HV-1 and NSP-2	2
		Flat	HV-2	1
12.	Latex Exudation	Low	BC, GL, HV-2, NSP-1, NSP-2, GH-15, and GTC-3	7
		Medium	NSP-3, GH-9, GH-11, GA-18 and GA-20,	5
		High	LM, SW, GTC-1, MV, HV-1, KV-1, KV-2 and KV-3	8
13.	Browning	Low	LM, BC, HV-2, KV-1, KV-3 and GTC-1	6
		Medium	SW, GL, HV-1, KV-2, GTC-3, GA-18, GA-20, NSP-1, NSP-2, GH-9, GH-11 and GH-15	12
		High	MV and NSP-3	2
14	Seed development	Present	LM, BC, SW, KV-2, GTC-1, GA-18, GA-20, NSP-1, NSP-2, GH-11 and GH-15	11
		Absent	MV, GL, HV-1, HV-2, KV-1, KV-3, GTC-3, NSP-3 and GH-9,	9

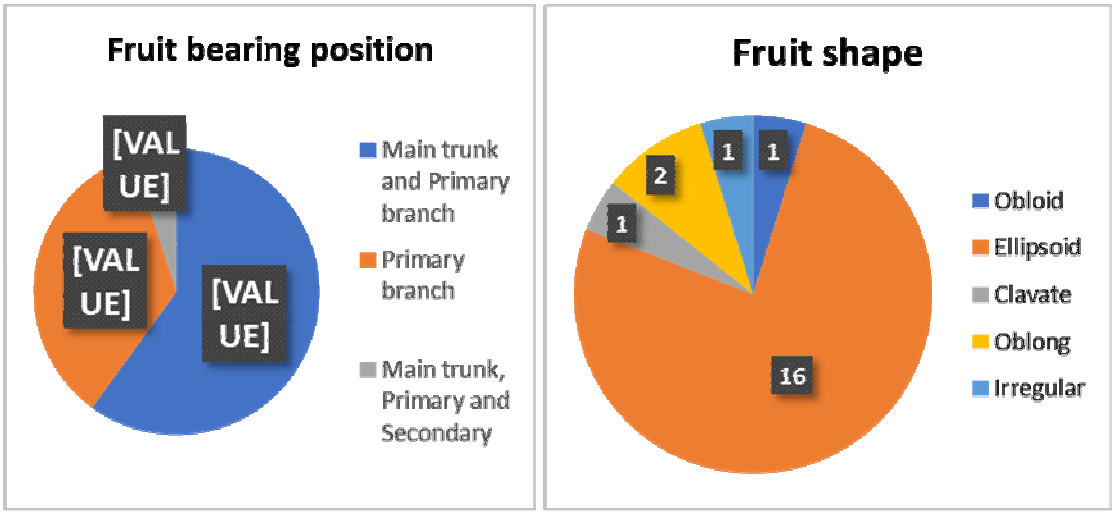

Fig. 3 : Diversity in fruit bearing position and fruit shape in twenty Jackfruit genotypes

Conclusion

The study revealed considerable morphological diversity among the twenty jackfruit genotypes examined. The traits such as tree canopy structure, leaf morphology, inflorescence density and fruit characteristics showed significant variation, reflecting both genetic heterogeneity and environmental influence. Genotypes with desirable features such as dense female inflorescence, regular bearing habit, green rind colour, moderate latex exudation and reduced browning were identified as promising candidates for tender fruit utilization. The presence of seedless types further enhances their potential for commercial exploitation as a vegetable alternative. Overall, the findings highlight the importance of morphological characterization in identifying superior genotypes for breeding and conservation programs, thereby supporting the sustainable utilization and genetic improvement of jackfruit for future market and industrial needs.

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