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Standardization of harvest maturity of jackfruit (*Artocarpus heterophyllus lam.)* by morpho-physical investigation

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ABSTRACT

An experiment was carried out to investigate the standardization of harvest maturity indicators in Jackfruit (*Artocarpus heterophyllus Lam.*)The mean number of spines/cm^2 was lowest in tree 1 (8.0), the mean metallic sound (hedonic scale) was highest in tree 1 (2.8), the mean fruit length was significantly increasing and reaching its maximum in tree 1 (39.00 cm), and the mean fruit circumference was significantly increasing and reaching its maximum in tree 1 (39.00 cm) (41.48 cm).The experiment's data were considered non-replicated, and the recorded data were statistically analyzed using a one-way ANOVA design in the computer software MS Excel. Considering morphological analysis the characters *viz.*, fruit circumference(39.00 cm), low spine density(8.0), moderate to high spreading of spines, presence of sensible hollow metallic sound could be used as the maturity indices of jackfruit. It is also noted that jackfruit could be harvested after 100 days of fruit set.

Introduction

The jackfruit (*Artocarpus heterophyllus Lam.*) is a tropical and subtropical fruit crop that is grown in tropical and subtropical climates, especially in South and Southeast Asia. The tree is an important part of subsistence and small-scale farmers' farming systems, and the fruit serves as a secondary staple meal as well as a source of income for the impoverished. India has been growing jackfruit since ancient times. It was most likely brought to the East African coast by Arab traders, and it has since spread throughout the tropics (Mijin *et al.,* 2021). In Hindi, the fruit is known as 'Kathal,' and in Kannada, it is known as 'Halasu.' Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer. Maturation is the stage of development leading to the attainment of physiological or horticultural maturity (Mijin *et al.,* 2021). For maturity measurements to be carried out by producers, handlers and quality control personnel they must be simple, readily performed in the field or inspection point, and should require relatively inexpensive equipment. The index should preferably be objective (a measurement) rather than subjective (an evaluation) and ideally the index should be non-destructive There are many different ways for determining maturity. Different maturity or harvest indices have been devised. For these indices to be useful, they must objective, easy to use and interpret, be unambiguous and have generality so that data obtained can be compared between farms, regions and years. Also, they should measure what is important. Attainment of a specific size is one possible index of maturation, but it cannot be used

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alone since fruit size for any variety can be influenced by crop load, climatic conditions, and cultural practices. Fruit shape and/or fullness of cheeks in mango indicate maturity (Rana and marapana , 2019).

Since fruit quality of jackfruit cannot be improved after harvest, selecting the fruits at proper maturity is very much important. Hence, the present investigations will be focusing on harvest maturity indices of jackfruit with the specific objective of assessment of harvest maturity indices by morphological traits (Rana *et al.,* 2018). During the maturation and ripening process, jackfruit undergoes many morphophysical changes. Evaluation of these changes during maturity allows making the best use of jackfruit in different applications. The aim of this study was to determine the variations of morphophysical properties in jackfruit in order to use this knowledge to utilize the most suitable stage to harvest jackfruit.

Material and Methods

A jackfruit orchard was chosen at the College of Horticulture, Kolar, Karnataka. Trees 1–10 were chosen from ten different jackfruit accessions of uniform age. The labelling was finished at the same time as the blossoming. Tagging selected flower buds in all ten trees yielded all of the parameters. The number of spines/cm^2, fruit length (cm), fruit circumference (cm), and hollow metallic sound were recorded as observations for assessing harvest ripeness indices by morphological features. The number of spines/cm^2 was calculated by counting the number of spines on 10 tagged fruits in each tree at 30 day intervals. Every 30 days, the length of the fruit was measured and the average in cm was recorded.

The circumference (cm) of 10 fruits tagged in each tree was measured at 30 day intervals and the average was expressed in centimetres. The metallic sound of ten fruits tagged in each tree was measured on a hedonic scale of 1 to 4, with 1 equaling not sensible and 4 equaling sensible. The study was carried for 120 days. The experiment data was considered non-replicated, and the recorded data were statistically analysed using a one-way ANOVA design in the computer software MS Excel (Rana and marapana ,2019).

Results and Discussion

Number of spines/cm^2

The data in Table 1 show the number of spines per square centimetre in ten jackfruit trees. The number of spines/cm2 of jackfruit varied significantly up to 118 days after harvest. At 30 DAF, there was no significant difference between trees, but T_1 (21.4) and T_3 (23.4) had the highest number of spines/cm^2 (21.4). However, in T_5, it was kept to a bare minimum (19.1), T_{10} (15.2) had the most spines/cm^2 at 60 DAF; followed by T_6 (12.6) and T_2 had the fewest spines/cm^2 (8.5). T_8 (6.8) had the most spines/cm2 at 90 DAF, followed by T_{10} (5.9), and T_2 had the fewest spines/cm2 (4.4). At 104 DAF highest number of spines/cm^2 was recorded in T_8 (5.2) which was followed by T_6 (4.7) and minimum number of spines/cm^2 was found in T_2 (1.4). Observations were taken before harvesting jackfruits of T_2, T_3 and T_5 at 104 DAF. At 110 DAF, highest number of spines/cm^2 was recorded in T_7 (3.7) which was followed by T_8 (3.5) and minimum number of spines/cm^2 was found in T_4 (2.0). Observations were taken before harvesting jackfruits of T_4, T_7, T_8 and T_9 at 110 DAF. At 118 DAF, highest number of spines/cm^2 was recorded in T_1 (2.9) and T_{10} (2.9) and minimum number of spines/cm^2 was found in T_6 (2.1). Observations were made prior to harvesting T_1, T_6, and T_{10} jackfruits at 118 DAF. This is because the surface area of the fruit increased during its growth stage, increasing the distance between spines and resulting in a decrease in the number of spines per square metre. Saha *et al*. (2016) also found that at 100 DAF, the spine number per sq-cm was less than 2, indicating that the spine density of jackfruit was lower in the advanced mature stage. According to Rahman *et al*. (2019), AH Joy-090 (151) had the most dense spine (per five squire centimetre), followed by AH Joy-089 (134), and AH Joy-017 had the least dense spine (per five squire centimetre) (38) (Saha *et al.,* 2019).

Fruit length (cm)

Table 2 shows the results of fruit length measureme nts on ten jackfruit trees. Up to 118 days after harve st, significant disparities in jackfruit fruit length we re detected. At 30 DAF, there was no significant dif ference across trees; however, T_7 (21.98cm) had the longest fruit, followed by T_5 (21.3cm). In T8, thou gh, it was at a bare minimum (18.56cm). T_7 had the longest fruit length (33.67 cm) at 60 DAF,

Table 1: The effect of Number of spines/ cm^{2}in trees after flowering of jackfruit at different intervals.

Treatment (trees)	Number of spines/ cm^2						
	Number of days						
	30DAF	60DAF	90DAF	104DAF	110DAF	118DAF	Mean
T_1	21.4	11.2	5.3	3.9	3.0	2.9	**8.0**
T_2	19.5	8.5	4.4	1.4	*	#	**8.5**
T_3	21.4	10.4	4.6	3.9	*	#	**10.1**
T_4	20.2	10.0	4.7	4.1	2.0	#	**8.2**
T_5	19.1	9.5	5.5	4.0	*	#	**9.5**
T_6	20.0	12.6	6.6	4.7	2.6	2.1	**8.1**
T_7	20.8	12.3	5.4	4.1	3.7	#	**9.3**
T_8	19.8	11.4	6.8	5.2	3.5	#	**9.3**
T_9	20.1	10.3	5.2	4.3	3.3	#	**8.6**
T_{10}	21.2	15.2	5.9	4.4	3.3	2.9	**8.8**
Mean	**20.4**	**11.1**	**5.6**	**4.0**	**3.1**	**2.6**	
S.E.m±	1.79	1.01	0.62	0.50	0.45	0.37	
CD(5%)	NS	3.00	1.83	1.2	1.32	1.1	

Table 2: The effect of fruit length (cm) in trees after flowering of jackfruit at different intervals.

Treatment (trees)	Fruit length(cm)						
	Number of days						
	30DAF	60DAF	90DAF	104DAF	110DAF	118DAF	Mean
T_1	20.7	28.21	44.45	45.89	47.55	47.21	**39.00**
T_2	19.64	32.61	45.35	46.58	*	#	**36.05**
T_3	20.48	31.82	43.14	45.24	*	#	**35.17**
T_4	18.57	31.4	42.48	43.14	47.31	#	**36.58**
T_5	21.3	29.31	40.86	43.51	*	#	**33.75**
T_6	20.62	29.24	41.12	44.87	46.87	48.95	**38.61**
T_7	21.98	33.67	42.35	43.47	45.76	#	**37.45**
T_8	18.56	28.99	39.76	40.76	44.21	#	**34.46**
T_9	18.71	27.51	39.07	40.19	42.32	#	**33.56**
T_{10}	21.06	32.42	40.82	43.17	45.59	47.08	**38.36**
Mean	**20.16**	**30.52**	**41.94**	**43.68**	**45.66**	**47.75**	
S.E.m±	2.21	1.27	1.21	1.86	1.87	2.13	
CD(5%)	NS	3.79	3.43	5.54	5.60	NS	

Table 3: The effect of fruit circumference in trees after flowering of jackfruit at different intervals.

Treatment (trees)	Fruit circumference (cm)						
	Number of days						
	30DAF	60DAF	90DAF	104DAF	110DAF	118DAF	Mean
T_1	10.04	21.01	53.2	53.66	54.86	56.08	**41.48**
T_2	10.69	31.35	46.76	48.56	*	#	**34.34**
T_3	11.59	27.99	38.87	41.41	*	#	**29.97**
T_4	11.1	25.68	39.96	40.34	42.97	#	**32.01**
T_5	12	23.39	35.87	38.23	*	#	**27.37**
T_6	11.9	23.41	34.47	35.07	35.85	37.23	**29.66**
T_7	11.34	23.52	33.26	36.96	38.17	#	**28.65**
T_8	12.35	23.88	33.93	34.6	37.05	#	**28.36**
T_9	15.43	25.77	36.55	37.19	39.73	#	**30.93**
T_{10}	12.79	24.59	38.85	39.68	40.58	41.98	**33.08**
Mean	**11.92**	**25.05**	**39.17**	**40.57**	**41.31**	**45.09**	
S.E.m±	0.82	0.98	1.35	1.31	1.37	1.71	
CD(5%)	2.32	2.77	3.81	3.69	3.90	5.14	

NS-Non significant
DAF-Days after flowering
***-fruits harvested at 104 days   #- fruits harvested at 110 days**
T_1=Tree 1 T_2=Tree 2 T_3=Tree 3 T_4= Tree 4 T_5=Tree 5
T_6=Tree 6 T_7=Tree 7 T_8=Tree 8 T_9=Tree 9 T_{10}= Tree 10

Table 4: The effect of metallic sound in trees after flowering of jackfruit at different intervals.

Treatment (trees)	Metallic sound (Hedonic scale)						
	Number of days						
	30DAF	60DAF	90DAF	104DAF	110DAF	118DAF	Mean
T_1	1.0	2.0	3.5	3.9	4.0	4.0	3.1
T_2	1.0	2.0	3.0	3.1	*	#	2.8
T_3	1.0	1.6	2.6	2.7	*	#	2.5
T_4	1.0	1.6	2.6	2.8	3.4	#	2.6
T_5	1.0	1.6	2.7	3.0	*	#	2.6
T_6	1.0	2.0	2.5	3.1	3.3	4.0	2.7
T_7	1.0	2.0	2.9	3.0	3.1	#	2.7
T_8	1.0	1.7	2.7	3.0	3.3	#	2.6
T_9	1.0	1.7	2.7	3.2	3.4	#	2.7
T_{10}	1.0	2.0	3.0	3.1	3.4	4.0	2.8
Mean	1.0	1.8	2.8	3.0	3.4	4.0	
S.E.m±	0	0.15	0.16	0.5	0.45	0.37	
CD (5%)	0	0.43	0.46	1.3	1.34	1.10	

The degree of metallic sound was quantified through hedonic scale of 1 to 4,
as: 1= not sensible (Absent).
2= slightly sensible,
3= moderately sensible
4= clearly sensible (hollow metallic sound)
***-fruits harvested at 104 days #- fruits harvested at 110 days**

followed by T_2 (32.61 cm), and T9 had the shortest (27.51cm). The length of fruit was highest in T_2 (45.35cm) at 90 DAF followed by T_1 (44.45cm) and minimum fruit length was found in T_9 (39.07cm). At 104 DAF, highest length of fruit was recorded in T_2 (46.58cm) which was followed by T_1 (45.89cm) and minimum fruit length was found in T_9 (40.19cm). Observations were taken before harvesting jackfruits of T_2, T_3 and T_5 at 104 DAF. At 110 DAF, highest length of fruit was recorded in T_1 (47.55cm) which was followed byT_4 (47.31cm) and minimum fruit length was found in T_9 (42.32cm). Observations were taken before harvesting jackfruits of T_4, T_7, T_8 and T_9 at 110 DAF. At 118 DAF, highest length of fruit was recorded in T_6 (48.95cm) which was followed by T_1 (47.21cm) and minimum fruit length was found in T_{10} (47.08cm). Observations were taken before harvesting jackfruits of T_1, T_6 and T_{10} at 118 DAF. The difference in the mean fruit length may be attributed to the difference in their genotypes. Fruit lengths ranged from 20.00 to 47.00 cm, with a mean of 31.40 cm, according to Akter *et al*. (2017) . AHJ05 produced the longest fruit (47.00 cm), foll owed by AHJ19 (46.00 cm), while AHJ04 produce d the shortest fruit (43.00 cm) (20.00 cm). Accordin g to Rana *et al*. (2018), the GM and AM of the soft variety were lower than those of the hard variant, al though both kinds showed a similar trend. As the st age changed from 1 to 4, the GM and AM for soft v arieties increased from 5.15 to 10.11 cm and 5.75 to 11.12 cm, respectively (Saha *et al.,* 2016).

Fruit circumference (cm)

The results pertaining to fruit circumference in ten trees of jackfruit is presented in Table 3. Significant difference was observed with respect to fruit circumference of jackfruit up to 118 of harvest. At 30 DAF, there was significant difference among trees, the maximum fruit circumference was noticed in T_9 (15.43cm) which was followed by T_{10} (12.79cm). However, it was minimum in T_1 (10.04cm). At 60 DAF, highest circumference of fruit was recorded in T_2 (31.35cm) which was followed by T_3 (27.99cm) and minimum fruit circumference was found in T_1 (21.01cm).The circumference of fruit was highest in T_1 (53.2cm) at 90 DAF followed by T_2 (46.76 cm) and minimum fruit circumference was found in T_7 (33.26cm). At 104 DAF, highest circumference of fruit was recorded in T_1 (53.66cm) which was followed byT_2 (48.56cm) and minimum fruit circumference was found in T_8 (34.6cm). Observations were taken before harvesting jackfruits of T_2, T_3 and T_5 at 104 DAF. At 110 DAF, highest circumference of fruit was recorded in T_1 (54.86cm) which was followed byT_4 (42.97cm) and minimum fruit circumference was found in T_6 (35.85cm). Observations were taken before harvesting jackfruits of T_4, T_7, T_8 and T_9 at 110 DAF. At 118 DAF, highest circumference of fruit was recorded in T_1 (56.08cm) which was followed byT_{10} (41.98cm) and minimum fruit circumference was found in T_6 (37.23cm). Observations were taken before harvesting jackfruits of T_1, T_6 and T_{10} at 118 DAF. The difference in the mean fruit circumference in all the trees may be attributed to the difference in their genotypes. Akter *et al*. (2017) also reported fruit length ranged from 20.00 to 47.00 cm with the mean of 31.40 cm respectively. The longest fruit was obtained from AHJ-05 (47.00 cm) followed by the AHJ-19 (46.00 cm) and shortest fruit in AHJ-04 (20.00 cm). Rana *et al.* (2018) found the GM and AM of the soft variety were lower than those of the hard kind, but both varieties showed a similar pattern. The GM and AM for soft varieties grew from 5.15 to 10.11 cm and 5.75 to 11.12 cm, respectively. As the stage progresses from one to four.

Ruby Khan *et al*. (2010) discovered this using morphological standardized descriptors (IPGRI 2000), and it's the first large-scale in situ assessment of jackfruit diversity in several locales (900 trees) (nine villages). It is expected that jackfruit populations will exhibit genetic diversity reflected in phenotypic variation as a result of various local environmental (i.e., location) and human selection pressures. We anticipate that jackfruit grown on homesteads will be subjected to positive selection pressure for marketable traits, and that the position of a tree reflects its origin storey as much as human selection.

Metallic sound

The result pertaining to metallic sound in ten trees of jackfruit is presented in Table 4. At 30 DAF, there was no characteristic metallic sound heard from the fruits as hedonic scale score was 1. At 60 DAF, slightly sensible hollow metallic was heard from fruits of T_1, T_2, T_6, T_7 and T_{10} as hedonic scale score was 2.0, followed by T_8 and T_9 (1.7). At 90 DAF, moderately sensible hollow metallic was heard from fruits of T_1 (3.5) followed by T_2 and T_{10} (3.0). At 104 DAF, moderately sensible hollow metallic was heard from fruits of T_1 (3.9) followed by T_2 and T_{10} (3.0). Observations were taken before harvesting jackfruits of T_2, T_3 and T_5 at 104 DAF. At 110 DAF, clearly sensible hollow metallic was heard from fruits of T_1 (4.0) followed by T_4, T_9 and T_{10} (3.4). Observations were taken before harvesting jackfruits of T_4, T_7, T_8 and T_9 at 110 DAF. At 118 DAF, clearly sensible hollow metallic was heard from fruits of T_1, T_6 and T_{10} (4.0). Observations were taken before harvesting jackfruits of T_1, T_6 and T_{10} at 118 DAF. The reason behind this could be that in initial stages of growth and maturity of fruit, the bulbs and seeds were not fully developed, thus hollow metallic sound was completely absent because there was more space inside the fruit but with advances in growth and maturity, the bulbs and seeds were fully developed and hence produce clear hollow metallic sound because there was no more space inside the fruit among the trees studied. Saha *et al.* (2016) also reported that no characteristic metallic sound was heard from the fruits of 80 and 90 DAF. It was heard from the fruits of 100 DAF and it was slight to moderately sensible. With the advances of maturity the metallic sound was heard progressively. It was moderately to clearly sensible at 120 DAF and clearly sensible at 130 DAF.

Conclusion

The following conclusions can be drawn based on the aforesaid discussion of results obtained in above investigation. In this experiment, maturity indices were judged upon morphological characters of fruits. The mean fruit length was found significantly increasing and maximum in tree 1 (39.00 cm), followed by tree 6 (38.61 cm) and it was least in tree 9 (33.56 cm). The mean fruit circumference was found significantly increasing and maximum in tree 1 (41.48 cm), followed by tree 2 (34.34 cm) and it was least in tree 9 (30.93 cm). The mean number of spines/cm^2 was maximum in tree 3 (10.1), followed by tree 5 (9.5) and it was least in tree 1 (8.0). The mean number of spines/cm^2 was decreasing significantly but at 30 days, mean number of spines/cm^2 were non significant. The degree of metallic sound was quantified through hedonic scale of 1 to 4, as: 1= not sensible (Absent), 2= slightly sensible, 3= moderately sensible and 4= clearly sensible (hollow metallic sound). At 118 DAF, the characteristic metallic sound was clearly sensible as hedonic scale score was 4.0. The mean metallic sound (hedonic scale) was maximum in tree 1(2.8), followed by tree 2(2.8) and it was least in tree 3(2.5). The analysis of variance for morphological characters of fruit revealed existence of considerable variation among the genotypes for the characters studied. Fruit circumference, low spine density, moderate to high spine spreading, and the presence of a sensible hollow metallic sound could be used as jackfruit maturity indices based on morphological analysis of the characters. It's also worth noting that jackfruit can be harvested after 100 days of fruit development.

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Conflict of interest
The authors declare that they have no conflict of interest.

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