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Fruit Growth Dynamics in Jackfruit (*Artocarpus heterophyllus* Lam.) Genotypes

Mahalakshmi, Shyamalamma S., Nache Gowda V., Vasudevu K. R., Aravind J. S.

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Abstract Fruit growth dynamics was studied in seven jackfruit genotypes viz., Swarna, Lalbagh Madura, Muttam Varika, HMT Jack, Horticulture Veg-1, Horticulture Veg-2 and Tissue culture Jackfruit at an interval of 30, 60, 90, 120, 150 days after fruit set (DAFS) and up to ripening stage. Fruit weight, length, diameter and volume of jackfruits increased continuously from the initial stage of fruit development till maturity in all the genotypes. However, HMT Jack, Lalbagh Madura showed higher growth in terms of fruit weight and length up to 150 DAFS. Genotype, Swarna showed slower growth in fruit weight, length, diameter and volume initially and it was rapid from 150 DAFS to maturity. Spine density decreased in all genotypes with maturation of fruits from 139.09 to 84.24 per 5 cm^2. Least number (8.33) of flakes per kg of fruit with higher width (4.95 cm) and flakes size (59.10 g) was observed in Lalbagh Madura followed by Horticulture Veg-I. Jackfruit genotypes studied followed single sigmoid pattern of fruit growth with respect to all the growth parameters such as fruit weight, length, diameter and volume.

Keywords Fruit set, Genotypes, Growth dynamics, Jackfruit, Maturity.

Shyamalamma S.[1]*,
Prof. University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

Mahalakshmi[2], Nache Gowda V[3], Vasudevu K. R.[4], Aravind J. S.[5]
[2]M.Sc. Student, [3]Director of Research, [4]Associate Professor, [5]Asst. Prof.
University of Horticultural Sciences, Bagalkot, Karnataka, India
e-mail: shyamala_reddyrs@yahoo.co.in
*Corresponding author

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae. It also comprises of other economically important cultivated genus like, Fig (*Ficus carica* L.) and Mulberry (*Morus alba* L). The genus *Artocarpus* includes some economically important species such as, Bread fruit *(A. altilis)*, Chempedak *(A. integer),* Wild jack *(A. hirsutus)* and Lakoocha *(A. lakoocha)* (Elevitch and Manner 2006). Jackfruit is an evergreen tree, grows well in wide range of soil and climatic conditions. Being nutritious, it serves as a food for millions of poor people in the country side during the season; therefore this fruit is regarded as "poor man's fruit" in Eastern and Southern parts of India (Jagadeesh et al. 2007; Prakash et al. 2009). It is considered as national fruit in Bangladesh and highly appreciated in India due to low price and availability in pre monsoon season, when food is scarce (Schnell et al. 2001).

The juicy bulbs are eaten fresh or preserved in syrup and have wide potential for preparing jam, jelly and as vegetable. The fruit has high nutritive and medicinal value, but information about fruit growth, development is limited. An understanding of the pro-

cess of fruit development is an important prerequisites for rational development and exploitation of this crop. Knowing the changes in growth parameters and physical parameters during fruit growth and development is important and this helps to know the days taken for maturity. The information pertaining to the changes in growth parameters and physical parameters in jackfruit genotypes at different stages of fruit growth is very scanty in India. Such information are required for determining the optimum stage of fruit harvesting for better quality. Therefore, keeping these facts in view a comprehensive study was carried out on changes in various growth and physical parameters at different stages of fruit development to determine the appropriate maturity standards so as to harvest the fruits in appropriate time for better quality.

Materials and Methods

An experiment was conducted at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka during 2016-2017. Seven jackfruit genotypes viz., Swarna, Lalbagh Madura, Muttam Varika, HMT Jack, Horticulture Veg-1 (HV-1), Horticulture Veg-2 (HV-2) and Tissue culture Jack were selected for this study. The experiment was laid out in randomized block design with three replications with three plants per replication. Flowers were tagged at the time of spathe opening in all genotypes. Fruits from the tagged flowers were harvested at specified interval for various analysis till they reached harvestable maturity. The observations recorded at 30 days interval after fruit set or spathe shedding. Representative fruit sampling was made in each genotype at 30 days after fruit set (DAFS), 60 DAFS, 90 DAFS, 120 DAFS, 150 DAFS and ripening stage.

Growth parameters

Fruit weight, length, diameter, volume and spine density were studied. The weight of the fruits was calculated on the basis of three representative fruits and the mean was expressed in kg. The fruit length was measured from stalk end to bottom of the fruit by using measuring tape and average was recorded in centimeter. The fruit diameter was measured using measuring tape at the point where the diameter was maximum and expressed in centimeter. The core diameter was measured at the widest point by using measuring scale and expressed in centimeter. Thickness of the fruit rind at the maximum point was measured and expressed in centimeter. The spine density was observed in 5×5 cm^2 area at the base of fruit at different intervals during growth and development.

Physical parameters

Physical parameters such as number of flakes per kg fruit, flake length, flake width, edible and non edible portion per fruit were studied. One kg fruit was weighed out separately and number of flakes present in one kg fruit were counted and recorded. Flake characters such as length, width, weight and TSS were recorded on five flakes from each fruit and the average was worked out. Weight of the edible portion was taken after separating the rind, core and seeds. The weight of flakes from three individual fruits were recorded and expressed in kg

Results and Discussion

Fruit growth and development

The data on fruit growth parameters (Table 1) shows

Table 1. Fruit weight (kg) of different jackfruit genotypes during various stages of fruit growth.

Jackfruit types	Fruit weight (kg)					
	30 DAFS	60 DAFS	90 DAFS	120 DAFS	150 DAFS	Mature stage
Swarna	0.25	0.48	1.02	2.27	4.23	6.30
Lalbagh Madura	0.24	1.17	2.32	4.20	6.29	8.23
Muttam Varika	0.37	0.69	2.17	3.57	4.83	5.05
HMT Jack	0.53	1.18	2.47	5.90	8.66	8.68
Horticulture Veg-1	0.66	1.14	2.27	4.05	5.68	5.79
Horticulture Veg-2	0.41	1.01	2.29	4.15	5.75	5.82
Tissue culture jack	0.38	1.05	1.47	3.28	4.24	5.13
Mean	0.40	0.96	2.00	3.92	5.53	6.43
SEm ±	0.02	0.32	0.05	0.08	0.07	0.48
CD @ 5%	0.08	0.1	0.16	0.25	0.2	1.49

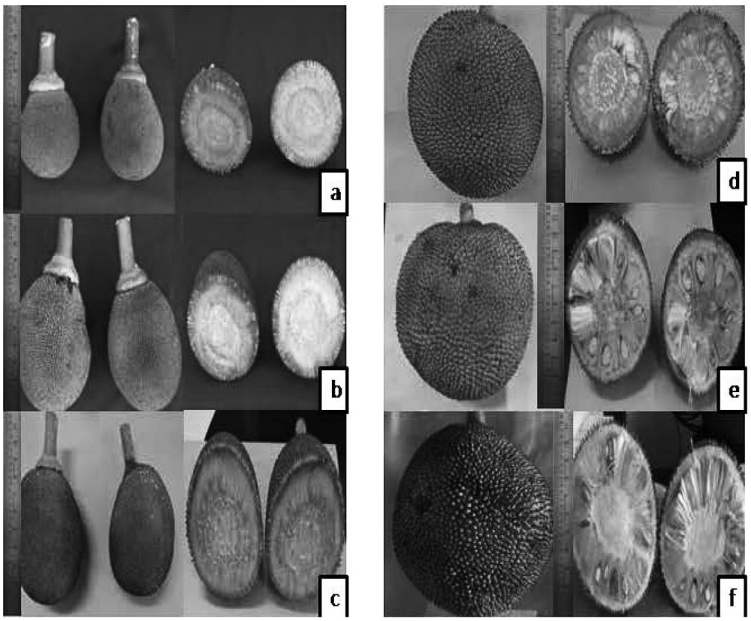

Fig. 1. Growth and development of fruits at defined intervals in jackfruit genotype Swarma. a. Fruit growth at 30 DAFS, b. Fruit growth at 60 DAFS, c. Fruit growth at 90 DAFS, d. Fruit growth at 120 DAFS, e. Fruit growth at 150 DAFS, f. Fruit growth ripe stage.

that, the fruit weight increased gradually in all the genotypes at defined intervals till maturity. The mean fruit weight increased from 0.40 kg at 30 DAFS to 6.43 kg at mature stage. Fruit weight varied largely at various stages of fruit growth. There was a significant difference among the genotypes in fruit weight at mature stage (Fig. 1). The genotype HMT Jack showed significantly higher fruit weight (8.68 kg) followed by Lalbagh Madhura (8.23 kg). Swarna possessed medium sized fruits with an average fruit weight of 30 kg followed by the genotypes, HV-1 (5.79 kg) and HV-2 (5.82 kg) which were on par with each other. The fruit length (Table 2) also increased gradually in all the genotypes at defined intervals till maturity. The mean fruit length increased from 15.03 cm at 30 DAFS and reached the maximum of 36.34 cm at mature stage. Significant differences were found among the genotypes for fruit length at mature stage. The genotype, HMT Jack showed significantly higher fruit length (46.07 cm) followed by Lalbagh Madura (42.17 cm),

Table 2. Fruit length (cm) of different jackfruit genotypes during various stages of fruit growth.

Jackfruit genotypes	Fruit length (cm)					
	30 DAFS	60 DAFS	90 DAFS	120 DAFS	150 DAFS	Mature stage
Swarna	13.83	14.93	15.57	19.23	23.00	26.50
Lalbagh Madura	12.40	19.17	26.33	32.83	39.50	42.17
Muttam Varika	14.80	18.77	20.33	26.10	18.07	39.67
HMT Jack	16.07	20.63	28.67	38.83	44.37	46.07
Horticulture Veg-1	15.80	19.63	23.07	31.83	34.50	36.17
Horticulture Veg-2	15.50	19.30	24.83	31.67	34.23	35.80
Tissue culture Jack	16.83	20.5	21.67	23.90	28.00	31.67
Mean	15.03	19.01	22.92	29.20	34.52	36.86
SEm ±	0.27	0.31	0.48	0.59	0.44	0.45
CD @ 5%	0.84	0.97	1.49	1.82	1.38	1.4

Table 3. Fruit diameter (cm) of different jackfruit genotypes during various stages of fruit growth.

Jackfruit genotypes	Fruit diameter (cm)					
	30 DAFS	60 DAFS	90 DAFS	120 DAFS	150 DAFS	Mature stage
Swarna	6.87	8.50	10.71	15.00	18.03	21.14
Lalbagh Madura	5.38	10.07	10.73	13.42	19.15	19.42
Muttam Varika	6.80	8.02	13.02	17.00	19.06	19.14
HMT Jack	8.13	11.22	13.13	17.20	19.95	20.73
Horticulture Veg-1	8.25	11.20	13.16	15.96	17.45	19.15
Horticulture Veg-2	6.89	10.34	12.79	17.73	19.41	20.30
Tissue culture Jack	6.77	8.51	11.73	14.24	19.01	19.85
Mean	7.01	9.69	12.32	15.79	18.87	19.96
SEm ±	0.20	0.12	0.29	0.14	0.14	0.37
CD @ 5%	0.64	0.36	0.89	0.43	0.42	1.13

whereas Swarna variety exhibited lower fruit length (26.5 cm).

The mean fruit diameter increased from 7.01 cm at 30 DAFS and reached the maximum of 19.95 cm at mature stage (Table 3). The genotype Swarna showed significantly maximum fruit diameter (21.14 cm) which was on par with HMT Jack (20.73 cm), while., HMT Jack was on par with HV-2 (20.30). Muttam Varika variety exhibited minimum fruit diameter of 19.14 cm. Fruit volume also increased gradually in all the genotypes at defined intervals till maturity. The mean fruit volume was increased from 190.58 cc at 30th day and reached the maximum of 4299.19 cc at mature stage (Table 4). At mature stage, genotype Swarna showed higher fruit volume of 4929.79 cc, followed by HMT Jack (4638.16 cc) and lower fruit volume (3661.52 cc) was observed in Muttam Varika (Fig. 2.).

From the above data, the results can be inferred that, the fruit growth and development largely depends on the genetic potential of a particular genotype or variety. The genotypes with larger fruit size exhibited higher fruit weight, fruit length (HMT, Lalbagh Madura), whereas the fruit diameter was directly correlated to fruit volume. Swarna with higher fruit diameter recorded higher fruit volume, indicating maximum accumulation of metabolites. Thus, the irreversible increase in weight, length, diameter and volume of the fruits occurs due to cell division (increase in number), cell differentiation, cell enlargement (increase in size) and accumulation of biosynthesized substances in the intercellular spaces in fruit (Patel et al. 2015) and also the ability of these genotypes to mobilize photosynthetic compounds to fruit growth during the fruit developmental stages.

Spine density

The spine density decreased gradually in all the geno-

Table 4. Fruit volume (cc) of different jackfruit genotypes during various stages of fruit growth.

Jackfruit genotypes	Fruit volume (cc)					
	30 DAFS	60 DAFS	90 DAFS	120 DAFS	150 DAFS	Mature stage
Swarna	169.59	322.91	647.13	1762.55	3040.78	4929.79
Lalbagh Madura	81.74	532.61	652.95	1242.53	3331.75	3763.45
Muttam Varika	164.68	269.84	1153.28	2565.7	3613.98	3661.52
HMT Jack	289.31	738.33	1187.52	2657.4	4149.46	4638.38
Horticulture Veg-1	293.21	733.73	1190.16	2125.61	2777.81	3668.16
Horticulture Veg-2	173.27	577.55	1370.44	2898.06	3826.78	4391.25
Tissue culture Jack	162.23	321.67	850.42	1509.36	3591.85	4140.34
Mean	190.58	499.52	1007.42	2108.74	3476.06	4170.41
SEm ±	20.13	15.03	62.77	57.81	156.12	219.71
CD@ 5%	62.042	46.31	193.42	178.13	481.05	676.99

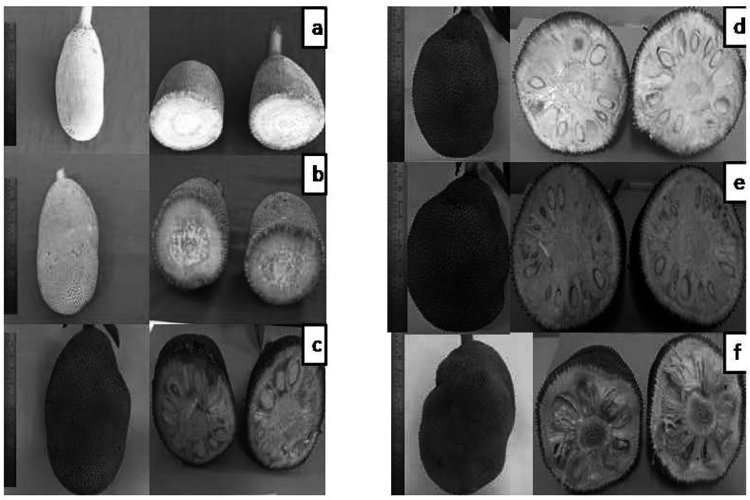

Fig. 2. Growth and development of fruits at defined intervals in jackfruit genotype Muttam Varika. a. Fruit growth at 30 DAFS, b. Fruit growth at 60 DAFS, c. Fruit growth at 90 DAFS, d. Fruit growth at 120 DAFS, e. Fruit growth at 150 DAFS, f. Fruit growth at ripe stage.

types till maturity. The average spine density at 60 DAFS was 139.09 and at mature stage, it decreased to 84.57 per 5 × 5 cm^2 area. At mature stage, Swarna showed significantly lower (75.67) spine density followed by Lalbagh. Madura (79.00) Table 5. The higher (93.33) spine density was observed in HV-2. The decrease in spine density towards maturity may be attributed to increase in fruit size. As the fruits grow, widening of the space between the spines helps to reduce the density of spines for a specific area. However, again this character is also genotype and fruit shape specific. Fruits with round to oval fruit shapes enlarge in size, thus the spines also enlarge and become broad and consequently the number of spines gets reduced at maturity, which also serves as one of the maturity indices in jackfruit. Similar opinions have been expressed by Sabiha et al. (2006) and Maiti et al. (2002).

Physical parameters

Number of flakes per kg of fruit

Number of flakes per kg of fruit varied (Table 6) from

Table 5. Spine density of different jackfruit genotypes during various stages of fruit growth.

Jackfruit genotypes	Fruit diameter (cm)				
	60 DAFS	90 DAFS	120 DAFS	150 DAFS	Mature stage
Swarna	141.00	121.33	101.67	81.00	75.67
Lalbagh Madura	142.00	123.67	110.67	89.33	79.00
Muttam Varika	138.67	123.33	114.67	91.33	86.33
HMT Jack	136.67	125.33	110.00	89.33	85.00
Horticulture Veg-1	136.33	122.33	110.33	98.00	82.67
Horticulture Veg-2	136.33	120.33	113.00	97.67	92.33
Tissue culture Jack	142.67	126.33	113.33	91.00	88.67
Mean	139.09	123.24	110.52	91.09	84.24
SEm ±	0.85	0.78	0.73	0.76	0.92
CD @ 5%	2.62	2.39	2.25	2.36	2.84

Table 6. Flake and other characteristics in various jackfruit genotypes at ripe stage.

Jackfruit genotypes	Number of flakes per kg of fruit	Flake length (cm)	Flake width (cm)	Weight of edible portion per fruit (kg)	Weight of non-edible portion per fruit (kg)	Number of days taken for maturity
Swarna	15.5	4.43	3.48	4.11	2.18	174.67
Lalbagh Madura	8.33	6.39	4.95	4.32	3.88	162.67
Muttam Varika	20.00	4.39	3.50	2.51	2.54	154.00
HMT Jack	21.00	6.07	3.74	4.41	4.27	158.00
Horticulture Veg-1	12.67	6.21	4.10	3.18	2.41	152.00
Horticulture Veg-2	11.67	7.31	4.15	2.10	3.72	152.33
Tissue culture Jack	20.33	6.07	3.38	3.23	1.91	157.67
Mean	15.64	5.84	3.90	3.41	2.99	158.76
SEm ±	0.50	0.25	0.05	0.14	0.09	1.27
CD @ 5%	1.54	0.78	0.14	0.44	0.27	3.92

a minimum of 8.33 to a maximum of 32.67 and the mean number of flakes per kg of fruit was 18.81. Maximum number of flakes per kg of fruit was noticed in HMT Jack (21), followed by Muttam Varika (20.00). In genotype Swarna the number of flakes per kg fruit was 15.50, While, the least number of flakes per kg of fruit was recorded in Lalbagh Madura (8.33). The lower number of flakes per kg fruit would be more preferable, as the number is less, individual flake size will be much bigger. In the present case also, the individual flake weight in Lalbaugh Madhura was around 60 to 70 g, followed by Swarna with a flake weight of 35 to 40 g. Similar findings were observed by Reddy et al. (2004); Nipe (2013) and Murugan (2007).

Flake and other characters of fruits

The mean flake length observed was 5.84 cm, while it ranged from a minimum of 4.29 cm to a maximum of 7.31 cm (Table 6). The longer flake length was observed in the genotypes HV-2 (7.31 cm) and the shorter flake length was observed in genotype Muttam Varika (4.39 cm) and Swarna (4.43 cm).

Among the genotypes, the flake width was higher in Lalbagh Madura (4.95 cm) and lower in Tissue culture Jack (3.38 cm) and Swarna (3.48 cm). Variation in the flake length and width were because of the genotypic characters and it could also be attributed to highly heterozygous condition of the seedling progeny (Jagadeesha et al. 2010; Singh and Srivastava 2000).

The significant difference among the genotypes for weight of edible portion per fruit were observed. The average weight recorded was 3.41 kg. The weight of edible portion varied from a minimum of 2.10 kg to 4.41 kg. The higher amount of edible portion per fruit weight was recorded in HMT Jack (4.41 kg), followed by Lalbagh Madura (4.31 kg) and Swarna (4.11 kg) per fruit. With respect to non edible portion, the lesser amount of non edible portion per fruit was recorded in Tissue culture Jack (1.91 kg), followed by Swarna (2.18 kg). Higher amount of non edible portion per fruit was recorded in HMT Jack (4.27 kg).

Conclusion

The study helped to understand the following facts on fruit growth and development in seven jackfruit genotypes grown under Bengaluru, Southern Karnataka region, India. 1. All the genotypes studied exhibited single sigmoid pattern of fruit growth with respects to growth parameters such as fruit weight, length, diameter and volume. 2. All the genotypes required minimum of five months growth for maturity and ripening from the date of anthesis. 3. Seed formation was observed between 90 to 120 days after anthesis, whereas the seeds matured around 120 days after anthesis. 4. Flakes developed color pigmentation only after 150 days after anthesis. Above observations are helpful in deciding the right maturity stage for use the fruits in various value added products preparation in jackfruit starting from tender jackfruit for vegetable purpose to mature fruits for chips ; papad and ripe fruits for table purpose.

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