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Advances in Breeding of Jackfruit Crop: A Review

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ABSTRACT

The improvement of jackfruit is required to make it amenable for intensive cultivation and make it suitable for a variety of value-added products. There is a significant variation for various traits such as plant phenology, leaf shape, leaf size, fruit shape, fruit size, number of fruits per plant, flake colour, number of flakes per fruit *etc*. The jackfruit crop has long juvenility, high clonal heterozygosity, recalcitrant type of seeds make it difficult to improvement of jackfruit varieties or hybrids, but on the other hand ease of vegetative propagation of hybrids or varieties is advantageous for the jackfruit breeder. The development of jackfruit is again based on the selection of clones especially for small-sized quality fruits, dwarf, less gum type, disease and pest resistance *etc.* The detailed knowledge on phenology, inheritance pattern and advanced techniques for hybrid/variety development will be useful to overcome the problems of jackfruit breeding *viz* fruit size, gummier fruits, susceptibility to disease and pests *etc*. The development of genetic markers has further reduced the uncertainty in the breeding of jackfruit and maintains the hybrid/varietal populations with desirable characteristics.

Key words: Breeding, Genetics, Inheritance pattern, Jackfruit.

Importance

Jackfruit (*Artocarpus heterophyllus*) is native to India, now it has been spread across the tropics. In Asian, African and South American countries one can find more cultivation of this crop. It is popular because of its large-sized fruits, weighing up to 65 kgs. India, Myanmar and Sri Lanka are the countries where this crop is commercially cultivated. Both the pulp and the seed are edible. On ripening the bulbs of yellow or cream flesh are eaten fresh or added to fruit salad, incorporated into the ice creams. The bulbs are also added in small quantities to bring g agreeable flavour in any food products. The seeds are boiled or roasted and being flavorous like a chestnut are worth using. The unripe fruits are used as a vegetable or incorporated in stews or curries and also made into pickles. The rind and leaves are fed to livestock. The tree may be used to shade for growing coffee or areca and as living support for pepper. The resinous latex is used to mend earthenware and utensils; yellow heartwood is used in furniture making and is popular. Breadfruit (*Artocarpus altilis*) is a close relative of jackfruit which is used as a staple food. Improvement of such a tremendous and important crop has not been taken seriously due to its perennial nature and heterozygosity (Anonymous 2011).

Taxonomy

Jackfruit has a chromosome number of 2n=4x=56. It belongs to the family Moraceae, genus *Artocarpus* contains 50 species of monocious trees. Through several species bear edible fruits only two are economically important. Monkey Jack -*Artocarpus lakoocha* widely grown in India and the Bread fruit-*Artocarpus altilis* grown commercially worldwide (Priyadevi *et al.,* 2014).

Differences between jackfruit and breadfruit

It is easy to distinguish between jackfruit and breadfruit, these two species don't hybridise freely. The leaves of jackfruit are small in size, with smooth margins, 5-20 cm size, it is tetraploid with 2n= 4x=56. Whereas the breadfruit leaves are deeply lobed, having cut margins, with large size, 30-60 cm, it is reported to be diploid with chromosome number 2n=28. *Artocarpus elasticus* is a progenitor of bread fruit. Some seedless breadfruit cultivars (2n=3x=42) are considered to be a hybrid of *Artocarpus altilis and Artocarpus mariannensis.*

Genetic resources

There is rich genetic diversity in India and across the tropics, in addition to *Artocarpus heterophyllus,* the wildtypes such as *Artocarpus chaplasha, Artocarpus hirsutus, Artocarpus lakoocha* are grown in forests of Kashmir, Tripura and Nagaland. Being cross-pollinated and mostly seed propagated, the heterozygosity and heterogeneity are built-

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Important *Artocarpus species* grown for edible fruits

Species	Common name	Description
Artocarpus heterophyllus or Artocarpus integra or Artocarpus integrifolia	Jackfruit	Big sized fruits, edible pulp and seed, having attractive fruits
Artocarpus altilis	Breadfruit	The tree is ornamental in appearance, fruits are smaller in size, pulp and seeds are edible, seedless types are more starchy.
Artocarpus chempeden	Chempeden fruit	Slimy pulp, seeds have a very strong stench (unpleasant smell), small fruits and leaves and twigs are hairy.
Artocarpus elasticus	Elasticus fruit	Edible for pulp and seed
Artocarpus odoratissimus	Marang fruit	Edible pulp and seeds but having a pervasive smell.
Artocarpus lakoocha	Monkey jackfruit	Small fruits, edible pulp, irregular fruit shape
Artocarpus chaplasha	Chaplash jackfruit	Wild type, poor quality fruits with a stench
Artocarpus hirsutus	Aini fruit	Wild type, used as rootstock for jackfruit
Artocarpus mariannensis	Mariannensis type	Wild type, might have contributed to the evolution of the domestic species

in the populations of jackfruit trees. There is an innumerable type of jackfruit trees differing widely with respect to the density of spines/studs on the fruit, rind thickness, bearing intensity, size, shape, quality and period of maturity of fruits. The wide range of various traits has been documented by Shyamalamma *et al.* (2008). Factors directly and indirectly affecting the genetic diversity and breeding of jackfruit crop is presented in the Table 1.

Variability of breadfruit-*Artocarpus altilis* is wide with respect to tree and leaf morphology, considerable variation in internal and external features, soft flesh and firm flesh type *etc*. Both the species are commercially propagated by seed (breadfruit often by root cuttings), seedlings are highly variable. These variability need proper documentation and exploitation through modern breeding strategies.

Floral biology

All cultivated jackfruits are monoecious types having separate male and female flowers; here the individual flowers are crowded on the outer periphery of the cylindrical, rachis (receptacles). The inflorescence ie all the tiny flowers on the rachis is called spike. The tiny flower bud has taken 25-40 days to develop and reach the stage when the sex of the spike are separated, female inflorescence arises from the trunk and older thick branches either single or in pairs, a distance away from male spikes. They can be found on the protruding roots at ground level. The female spikes are borne on fruit stalks or peduncles while male spikes appear on the footstalks as well as on the apices of the branchlets. The fruit stalk bearing female spikes are much more vigorous than those carrying only the male or both male and female spikes. Female spikes often appear in the central region of the trees, while male spikes are found both in the interior and peripheral regions of the tree. The sex of spike can be easily identified by its size and appearance, the length and diameter of female spikes are more than those of males. The surface of the young male spike is smooth while in the case of the female spike is granular. Each flower is a tubular perianth (undifferentiated or fused calyx and corolla). The perianth is dense shaped with glandular hairs on its apices (Azad 1989).

Table 1: Factors directly and indirectly affecting the genetic diversity and breeding of jackfruit crop.

Traits	Range
The yield	14-525 fruits/tree
Fruit weight	2.1-60.0 kgs/fruit
Fruit shape	Oblong, roundish and conical
Skin colour	Greenish, light brown, dark brown, yellow, yellowish-brown
Number of tubercles in skin	5-27/cm^2
Pulp colour	Yellow, whitish, reddish, pinkish yellow
Number of segments	34-380/fruit
Number of stones	32-362/fruit
Texture of pulp	Soft, moderately soft and hard
Pulp weight	361-3648 g or 0.36-3.6 kg
Total soluble solids	15.4-32.0%
Total sugar	12.9-28.6%
Acidity	0.10-0.31%

Male flower

Stamens are enclosed in a green leathery tubular perianth, during anthesis the stamens protruding out of the perianth tube appear on the surface of the spike. After 4-6 days the first stamens appear. In a couple of days, the whole surface of the spike is covered with non-dehisced yellow anthers or ashy grey dehisced one held on filaments. After dehisce open and the male spike gradually turn into black colour due to the growth of the mould on it and drops down in another week time, peak anthesis is at 1-2 pm, peak dehiscence is at 3-4 pm.

Female flower

Perianth encloses the ovary and style. The creamy white stigma protrude out of the surface of the female spike within 4-6 days the whole surface looks woolly, the stigma receptivity for 36 hours, pollination and fertilization complete within 3-6 days after anthesis.

Breeding objectives

Since yield is not similar every year, therefore to develop a variety ie regular bearing and prolific in bearing with high-quality forms important objective. For quality, there are two types of flakes with firm sweet pulp (high quality) and tender mushy pulp -inferior quality (Jagadish *et al.,* 2007). The flesh should be crispy, sweet, yellowish or creamy in colour and possess a good aroma at least to avoid a strong unpleasant smell.

Ideotype breeding

According to Haq (1995), the following are the model traits that are considerable for ideotype breeding in jackfruit *viz* easy to manageable type plants, vigorous and prolific plants, good quality fruits with acceptable flesh colour and text, fruits with symmetrical size, resistance to pests and diseases, wider adaptability, off-season bearing type, long post-harvest life fruits and high yielding types.

Inheritance pattern

The texture of edible flesh, sweetness, seed size, number of fruits per tree, size of fruits, the thickness of rind, for all these knowledge of genetic variation helps decide the parents (APAARI 2012).

Breeding methods

Selection

Varietal improvement is limited, Rudrakshi, south Indian jackfruit grown from seed, its fruits are much smaller (like pummel), it comes to bearing sooner and used as rootstock. Flakeless jack has been reported in Assam. Its fruits are completely devoid of flakes but full of false buds.

Hybridisation

Need to exploit heterosis for yield gain and improvement in the fruit quality. The jackfruit and breadfruit have considerable potential, planned breeding with the aid of biotechnological skills is required to exploit their potential.

Biotechnology

Breeding for seedlessness, disease resistance, insect resistance, salt tolerance and for germplasm storage the biotechnological tools can be utilised. The biotechnological approaches like cell hybridization, organelle transfer, genetic transformation, protoplast fusion, anther culture (haploid production), embryo culture (rescue techniques), micropropagation (Abdel Zaher 2009) are needed to be employed for jackfruit crop improvement.

The details of observations to be taken for improvement of jackfruit

Tree characters

1) Crown shape: It is recording visually for pyramidal, obovate, oblong circular, elliptical irregular *etc*. types of crowns.
2) Growth habit: Visually (erect, semi, spreading).
3) Branching density: visually (dense, medium, sparse).
4) Branching pattern: Visually (erect, opposite, verticulate, horizontal, irregular).

Leaf characters

1) Leaf blade shape: It is recording visually for elliptic, oblong, lanceolate.
2) Leaf apex shape: Visually (acuminate, acute, obtuse).
3) Leaf base shape: Visually (oblique, rounded, alternate).
3) Leaf colour: Visually (green, light green).
4) Leaf pubescence based on intensity (glabrous, sparse, intermediate, dense).

Flower characteristics

1) Flowering season: Early, mid, late.
2) Flowering to fruiting period: Days difference from initiation to harvest.

Fruit characteristics

1) Season of fruiting: Visually.
2) Fruit bearing position: Regular or irregular.
3) Fruit clustering habit: Visually (solitary or clusters)
4) Fruit shape: Spheroid, elliporoid, clavate, oblong, irregular.
5) Junction of stalk attachment to fruit: Visually recorded, depressed, flattened.
6) Fruit rind colour: Taken for matured fruit: Green, greenish yellow, yellow, greenish.
7) Fruit surface: Visually (smooth, rough).
8) Latex exudation: Visually (low, medium, high).
9) Flake shape: From middle region of fruit, visually and grouped (spheroid, cordate, *etc*).
10) Fruit length (cm): Taken for matured fruit, from stalk to tip.
11) Fruit girth (cm): At middle of tree, it is recoding for fruit bearing plants.
12) Fruit weight (kg): It is taken five fruits in a plant at all the branches latter average the values.
13) Fruit rind weight (kg): First separate the bulbs, seeds, perigones then weight of rind recorded.
14) Fruit rind thickness (mm), at maximum point of fruit mend, thin (less than 1 mm).
15) Number of flakes/ fruit : Number of flakes/kg of fruit weight counted × weight of fruit.
16) Weight of flakes/fruit (g), weight of 10 flakes from each fruit × number of flakes.
17) Weight of fresh flakes with seed (g): 10 flakes weight with seed, take average.
18) Flakes to fruit ratio: Total weight of fruit/ total weight of flakes.
19) Flake length (cm): Length of 20 flakes from each plant
20) Flake colour: Visually like yellow, white, golden yellow, light red *etc*.
21) Total soluble solids: TSS of ripened flake directly estimated.

Seed characters

1) Shape: Taken visually and grouped spheroid, ellipsoid elongate, oblong reniform, irregular *etc*.
2) Seed coat colour: Taken visually as white, creamish, dull brown, brown.

3) Seed weight: Weight of 10 seeds, from each plant, averaged and expressed in grams.
4) Yield: Yield per year, per tree shall be recorded and expressed in number of fruits/plant.

Varieties

The champedak (*Artocarpus integra* Merr.)

The tree is native and grows wild in Malaysia up to an altitude of 1300m and is cultivated in Malaysia, Indonesia, Thailand. It is distinguished from jackfruit by long, stiff brown hairs on young branches, leaves, buds and peduncles. The fruit is borne on a deciduous tree, reaching about 18 m in cultivation and 30-45 m in the wild. The fruits are cylindrical or irregular, mustard yellow to a golden brown, reticulated, warty and highly odoriferous.

Lakoocha (*Artocarpus lakoocha* Roxb.)

It is also known as monkey jack or lakuchi in India, tampang in Malaysia and as lokhat in Thailand. It is a native of the humid- Himalayan region of India up to 1200 m and Malaysia and Sri Lanka. The tree grows up to 6-9 m in height with deciduous, large, leathery leaves, downy on the underside. Orange-yellow male flowers and reddish female flowers are borne on the same tree.

The Kwai Muk (*Artocarpus lingnanensis* Merr. Or *A. hypargynaeus*)

The tree is slow-growing, slender, erect ornamental, 6-15 m tall and native to china and Hong Kong. Male and female flowers are tiny and yellowish, borne on the same tree. Fruits are more or less oblate and irregular with velvety, brownish thin tender skin.

Singapore (or) Ceylon jack

It was introduced in Tamil Nadu from Sri Lanka. Fruits are medium in size each weighing 7-10 kg. The carpels are crisp, sweet and yellow with a strong pleasant aroma. It is a precocious bearer.

Muttam varikka

It is a locally selected variety producing medium-sized fruit with sweet flesh. It produces the fruit of about 7 kg with 46 cm length and 23 cm width.

PLR-1 (Palur-1)

It is a high yielding variety developed at Vegetable Research Station, Palur of Tamil Nadu Agricultural University. A single plant section isolated from Panikkankuppam village near Panruti of Cuddalore district of Tamil Nadu.

PPI-1 (Pechiparai-1)

It was developed at Horticultural Research Station, Pechiparai of Tamil Nadu Agriculture University by clonal selection from Mulagummoodu local. Trees are medium tall, maximum bearing in the tree trunk.

Hybrid jackfruit

It is a cross between Singapore Jackfruit × Velippala, developed at Fruit Research Station, Kallar, Trivandrum, Kerala. Trees are Precocious in bearing; carpels are bigger in sweeter than the parents.

Burliar-1 (T Nagar selection)

It was developed at fruit Research Station, Burliar, Coimbatore district of Tamil Nadu by crossing Singapore jackfruit and Velippala. The trees are medium in height and prolific in bearing.

Exotic cultivars

The Fairchild Tropical Garden, Florida introduced and evaluated a collection of 22 superior jackfruit cultivars developed in different countries. Black gold, gold nugget, J-31, honey gold and lemon gold have been most precocious. The cultivars vary greatly in their size, shape flesh characteristics and taste.

Swarna

It was released by UAS Bengaluru, India is a very good bearer all around the branches and trunks, having medium-sized fruits weighing 6-8kg/fruit with golden brown coloured flakes, TSS 25-26°brix, thick flakes with thin rind.

Gumless variety

It was released from IIHR, Bengaluru, India having medium latex with an average weight 6.4-9.0 kg/fruit, oblong fruit shape, 120-140 flakes/fruit, yellow coloured flakes.

Konkan prolific

It was released from KKV Dapoli Maharashtra India, having 450-550 kgs of fruits/tree with an average 420.56 kg /tree, 5.7 kg/fruit with golden yellow flakes.

GI Thubagere

A superior quality fruit, with ellipsoid or elongate weighing 20-25 kg having 300-350 flakes/fruit, the flakes are deep coppery red coloured and possess very high TSS 30°brix.

CONCLUSION

The genetic improvement of jackfruit can be explored by utilising great variability present across the regions where it is cultivated. The establishment of field gene banks will go a long way to conserve the genetic resources of this crop besides serving as starting material to undertake systematic breeding. While there is greater scope for simple selection to breed this crop, hybridisation followed by clonal propagation of superior hybrids is a possibility: both approaches have been seldom applied in this crop and there exists a greater opportunity. Comprehensive knowledge of genetic diversity prevailing in different regions for flower traits, fruit traits and breeding behaviour is expected to accelerate the breeding efforts in this crop. Further, whole-genome sequencing and the development of genomic resources in terms of molecular markers is expected to marker-trait association studies.

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