



# Jackfruit

Improvement in the  
Asia-Pacific Region

– A Status Report



# Jackfruit Improvement in the Asia-Pacific Region

## A Status Report

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c/o FAO Regional Office for Asia and the Pacific

Bangkok, Thailand

*Citation:* APAARI. 2012. Jackfruit Improvement in the Asia-Pacific Region – A Status Report. Asia-Pacific Association of Agricultural Research Institutions, Bangkok, Thailand. 182 p.

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Printed in June, 2012

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## Foreword

The jackfruit is native to parts of South and Southeast Asia and is believed to have originated in the rainforests of Western Ghats of India and is cultivated throughout the low lands in South and Southeast Asia. Major jackfruit producing countries are Bangladesh, India, Myanmar, Nepal, Thailand, Vietnam, China, the Philippines, Indonesia, Malaysia and Sri Lanka. Jackfruit is also found in East Africa e.g. Uganda, Tanzania and Mauritius as well as throughout Brazil and Caribbean nations such as Jamaica. Jackfruit is the national fruit of Bangladesh and is one of the three auspicious fruits of Tamil Nadu in India along with mango and banana.

The jackfruit is a multi-purpose species providing food, timber, fuel, fodder, and medicinal and industrial products. The primary economic product of jackfruit is the fruit which is used both when mature and immature. When unripe (green), it is remarkably similar in texture to chicken, making jackfruit an excellent vegetarian substitute for meat. In fact, canned jackfruit (in brine) is sometimes referred to as “vegetable meat”. Jackfruit seeds (nuts) can be roasted like chestnuts, or boiled. The fruit pulp is sweet and tasty and used as dessert or preserved in syrup. The fruits and seeds are also processed in a variety of ways for food and other products. Jackfruit value added products include chips, papads, pickles, icecream, jelly, sweets, beverages like squash, nectar, wine and preserved flakes, etc. Additionally, jackfruit leaves, bark, inflorescence, seeds and latex are used in traditional medicines. The wood of tree is also used for various purposes.

It is a nutritious fruit rich in carbohydrates, proteins, potassium, calcium, iron, and vitamin A, B, and C. Due to high levels of carbohydrates, jackfruit supplements other staple foods in times of scarcity in some regions. The flesh of the jackfruit is starchy and fibrous, and is a source of dietary fibre. The presence of

isoflavones, antioxidants, and phytonutrients in the fruits indicate that jackfruit has cancer-fighting properties. It is also known to help cure ulcers and indigestion.

In spite of such a vast potential and usefulness, jackfruit remains an underutilized fruit species and deserves to be given the needed thrust for research and development. This publication entitled “Jackfruit Improvement in the Asia-Pacific Region-A Status Report’ is an attempt to draw the attention of researchers and policy makers. The publication describes the production status of jackfruit in Asia-Pacific region; germplasm collection, characterization, conservation and utilization; varietal improvement; package of cultivation practices; diversified uses and value added products, and economics and marketing. It also highlights the future prospects and strategy for jackfruit production and utilization.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) has been publishing status reports and success stories on various aspects of research and development that have large scale impact and have brought tangible benefits to both the farmers and consumers alike. So far, 49 such success stories and reports from the region on diverse topics have been published, details of which are available on APAARI website: [www.apaari.org](http://www.apaari.org). It is expected that wide dissemination of this status report will help in promoting both research and development of this important, yet underutilized, tropical fruit species.

We are highly thankful to Dr A.S. Sidhu, Director, Indian Institute of Horticultural Research, Bangalore for synthesizing this valuable information on jackfruit. It is our expectation that this publication will be of immense benefit to all members and various stakeholders in the Asia-Pacific region.



**Raj Paroda**

*Executive Secretary*  
APAARI

## Acronyms and Abbreviations

ABTS	2,2'-Azino-bis (3-Ethylbenzothiazoline-6-sulphonic acid)
ACP	Acid Phosphatase
ADH	Alcohol Dehydrogenase
AFLP	Amplified Fragment Length Polymorphism
AICRP	All India Coordinated Research Project
Anti-HIV	Anti- Human Immunodeficiency Virus
Anti-HSV	Anti- Herpes Simplex Virus
APEDA	Agricultural & Processed Food Products Export Development Authority
BA	Benzyladenine
BAP	Benzyl Adenine Purine
BARI	Bangladesh Agricultural Research Institute
BCA	Biological Control Agents
CARD	Christian Agency for Rural Development
CDH4 <sup>+</sup>	Cluster of Differentiation 4 <sup>+</sup>
CFTRI	Central Food Technological Research Institute
COX-2	Cyclooxygenase
CPA	p-Chlorophenoxy Acetic Acid
cpDNA	Chloroplast DNA
DFID	Department for International Development (UK)



DMPD	NN-dimethyl-1,4-phenylenediamine
DMSO	Dimethyl Sulfoxide
DPPH	Diphenylpicrylhydrazyl
EDDHA	Ethylenediamine di-(o-hydroxyphenylacetate)
DTPA	Diethylene Triamine Penta Acetic Acid
FRAP	Ferric Reducing Antioxidant Power
FYM	Farm Yard Manure
GA	Gibberellic Acid
GDH	Glutamine Dehydrogenase
GI	Geographical Indication
GOT	Glutamate Oxalacetate Transaminase
GRAMA	Group Rural Agricultural Marketing Association
HORDI	Horticultural Crop Research and Development Institute
2-HSG	2-Heremans Schmid Glycoprotein
IAA	Indole-3-Acetic Acid
IBA	Indole-3-Butyric Acid
IBPGR	International Board for Plant Genetic Resources
ICAR	Indian Council of Agricultural Research
ICRAF	International Center for Research in Agroforestry
ICUC	International Center for Underutilized Crops
IgA1	Immunoglobulin A1
IIHR	Indian Institute of Horticultural Research
INM	Integrated Nutrients Management

iNOS	Inducible Nitric Oxide Synthase
IPB	Institute of Plant Breeding (University of the Philippines, Los Baños)
IPDM	Integrated Pest and Disease Management
IPGRI	International Plant Genetic Resources Institute
ISSR	Inter-Simple Sequence Repeat
IU	International unit
KAU	Kerala Agricultural University
KMS	Potassium Metabisulfite
KVK	Krishi Vigyan Kendra
LAF	Laminated Aluminium Foil
Leu	Leucine
LPS	Lipopolysaccharides
MDH	Malate Dehydrogenase
Met	Methionine
MPP	Modified Polypropylene Packets
MS Media	Murashige and Skoog Media
NAA	Naphthalene Acetic Acid
NABARD	National Bank for Agriculture and Rural Development
NBPGR	National Bureau of Plant Genetic Resources
NOS	Nitric Oxide Synthase
NRC	National Research Center
PGE2	Prostaglandin E2

PGR	Plant Genetic Resources
Phe	Phenylalanine
PLR	Palur
PPI	Pechiparai
RAP	Reducing Antioxidant Power
RDA	Recommended Dietary Allowance
REN	Rural Enterprises Network
RFLP	Restricted Fragment Length Polymorphism
RFRS	Regional Fruit Research Station
RIFAV	Research Institute of Fruits and Vegetables
RTS	Ready-to-Serve
SCUC	Southampton Center for Underutilized Crops
SS	Seed Suspension
TDZ	Thiadiazuron
TNAU	Tamil Nadu Agricultural University
UP	Uttar Pradesh
UAE	United Arab Emirates
UAS	University of Agricultural Sciences
UTFANET	Underutilized Tropical Fruits in Asia Network

# 1. Production Status of Jackfruit in the Asia-Pacific Region

## 1.1 Introduction

The jackfruit is indigenous to the rain forests of the Western Ghats of India and is cultivated throughout the tropical lowlands in South and Southeast Asia, parts of central and eastern Africa and Brazil. Major jackfruit producers are Bangladesh, India, Myanmar, Thailand, Vietnam, China, the Philippines, Indonesia, Malaysia and Sri Lanka. It is a popular and relatively cheaper fruit in Southern Asia and other warm countries of both the hemispheres. In Europe, the fruit is sold canned with sugar syrup. Away from the Far East, the jackfruit has never gained the kind of acceptance that is accorded to the breadfruit (except in settlements of people of East Indian origin). This is largely due to the odour of the ripe fruit and traditional preference for breadfruit.

Jackfruit (*Artocarpus heterophyllus* Lam.) is the largest tree-borne fruit in the world, reaching up to 50 kg in weight and 60-90 cm in length (recently 81 kg fruit also reported from Panrutti, India). A mature tree produces up to 700 fruits per year, each weighing 0.5 to 50 kg. On an average, 50-80 tons of fruits can be harvested from a hectare of land. The tree is monoecious, producing male and female flowers. Stem of this plant is straight and rough whereas bark is green or black, 1.25 cm thick and exudes milky latex; leaves broad obovate, elliptic, decurrent, glabrous, entire; inflorescence solitary axillary, cauliferous and ramflours on short leafy shoots. It has also been reported that

the evergreen leaves are oblong, oval or elliptic in shape, 10-15 cm in length, alternate, glossy and dark green in colour. The juvenile leaves are lobed.

*Artocarpus heterophyllus* Lam., belongs to the family Moraceae, along with *Ficus* spp. (fig), *Morus* spp. (mulberry), and *Maclurapomifera* Schneid (osage orange or hedge apple) (Chandler, 1958; Popenoe, 1974). This family encompasses about 1,000 species in 67 genera, mostly tropical shrubs and trees, but also a few vines and herbs (Bailey, 1949; Merrill, 1912).

The word *Artocarpus* is derived from the Greek words artos (bread) and carpos (fruit) as reported by Bailey (1949). The name "Jackfruit" is derived from the Portuguese jaca, which in turn, is derived from the Malayalam language term, chakka. The fruit is popularly known as, kathal or kata-hai in Bengali and in Hindi. The Malayalam name chakka was recorded by Hendrik van Rheede (1678-1703) in the Hortus Malabaricus, vol. iii in Latin. Henry Yule translated the book in Jordanus Catalani's (1678-1703) *Mirabilia Descripta: The Wonders of the East* (Yule and Jordanus, 2011). The common English name jackfruit is the name used by physician and naturalist Garcia De Orta in his 1563 book *Coloquios dos simples e drogas da India*. The world's largest fruit is called by a variety of names, viz., kathal, panasa, jaca, nangka, kanoon, mit or *Artocarpus heterophyllus*, its scientific name.

The jackfruit is also commonly named as jak or jack, English adaptations of the Portuguese jaca (Popenoe, 1974). This name is in turn taken from the Malayan term tsjaka or chakka. It is also known as jacque or jacquier in French and jaca in Spanish. Table 1 lists the common names of *Artocarpus heterophyllus* in different countries and Table 2 indicates the area, production and productivity of jackfruit in Asia.

**Table 1. Common names of *Atrocarpus heterophyllus* in different countries**

Country	Name
Cambodia	Khnor or khnao
China	Po-lo-mi
India	Kanthal, kathal, penasa or kantaka
Indonesia	Nangka or nongko
Malaysia	Nangka
Myanmar	Peignai
Papua New Guinea	Kapiak
Philippines	Langka or nangka (Tagalog, Bisaya, Ilocano) Nanka or lanka (Tagalog, Bisaya) Sagakat (Mountain Province) Badak (Cagayan) Ananka (Ilocano) Yanka (Kapampangan) Ubiyen (Ibanag)
Thailand	Khanun, makmi or banun
Vietnam	Mit

Source: Liu 1987; Popenoe, 1974; Soepadmo, 1992

## 1.2 Production status of jackfruit in the Asia-Pacific Region

**Table 2. Area, production and productivity of jackfruit in Asia**

Country	Area (‘000 ha)	Production (‘000 t)	Productivity (t/ha)
Bangladesh	10.00 (2006)	926.00	8.20
India	102.00 (1992)	1436.00	11.40

Contd...

Table 2 (Contd...)

Country	Area (‘000 ha)	Production (‘000 t)	Productivity (t/ha)
Indonesia	50.00 (1987)	340.00	9.00
Malaysia	5.00 (1987)	13.00	10.00
Nepal	1.60 (2009-10)	18.97	11.89
	2.17 (2002-03)	17.16	11.60
Sri Lanka	50.00 (2011)	*	*
Thailand	37.00 (1987)	392.00	10.00

Source: Haq (2006), Ghosh (1996), AEC (2003) and Haq (2003b)

\*Information not available

**1.2.1 India :** India is the second biggest producer of the fruit in the world and is considered as the motherland of jackfruit. Chakka, its Malayalam name, according to some, has given birth to the English name jackfruit. In India, it has wide distribution in Assam, Tripura, Bihar, Uttar Pradesh, the foothills of the Himalayas and South Indian States of Kerala, Tamil Nadu and Karnataka. Jackfruit plays a significant role in Indian agriculture and culture. It was cultivated in India 3,000-6,000 years ago. Jackfruit is widely grown as an important tree in Kerala’s homesteads and also as a shade crop in coffee plantations. It is popularly known as poor man’s fruit in the eastern and southern parts of India. The tender fruits of the tree are used as vegetables and the ripe ones as table fruits. The traditional varieties bear fruits once in a year. Usually, the flowering starts from mid-November and extends till mid-February, depending on the location and the variety. The tender fruits come to market from March onwards and continue till August. The fruits begin to ripe in the month of June. However, the late varieties may ripen in October. Fresh and tender fruits are usually not available from November onwards. The region comprising Assam and

Tripura produces major share of jackfruit in India and the total annual production in Assam is estimated to be in the vicinity of 1,75,000 tons.

Commercial cultivation of jackfruit is still at a primitive stage in India, primarily because of the difficulty in procuring elite planting materials. Jack is easily propagated through seeds. The seedlings take 8-10 years to bear fruits. Due to the highly cross pollinated nature of the crop, vegetative propagation is essential in order to get true to type plants. In India, the total area under jackfruit cultivation is approximately 1,02,552 hectares, of which, an estimated 1,00,000 trees are grown in back yards and as intercrop in other commercial crops (betel nut, coffee, pepper and cardamom plantations) in south India. In India, the major area under jackfruit is in Kerala state (Table 3) and it was regarded as heavenly fruit in the ancient periods. It is grown in an area of 97,536 ha with annual production of 348 million fruits and productivity of 3,568 fruits per ha. In Assam, though the area and production has not shown any change, but the productivity has been improving (Table 4). The value of jackfruit in Karnataka has been calculated to Rs. 12,718 lakhs (Anonymous, 2011).

**Table 3. Area, production and productivity in different jackfruit growing states of India**

States	Area (000' ha)	Production (000' mt)	Productivity (t/ha)	Year
Arunachal Pradesh	1.06	8.52	8.03	2005
Jharkhand	4.10	41.00	10.01	2008
Karnataka	6.78	231.57	34.17	2005
	5.25*	213.82*	36.71*	2009-10*
West Bengal	10.42	143.47	13.76	2005

Contd...



Table 3 (Contd...)

States	Area (000' ha)	Production (000' mt)	Productivity (t/ha)	Year
Kerala**	97.54	348 million fruits	3,568 fruits/ ha	2010
Assam	18.00	170.00	9.49	2003-04

Haq, 2006; \*Hort. Crop statistics, Government of Karnataka 2009-10;

\*\* Shree Padre (2011): <http://panasamwonders.blogspot.in/>

**Table 4. Area, production and productivity of jackfruit during the period from 1998-99 to 2004-05 in Assam**

Year	Area (000' ha)	Production (000' mt)	Productivity (t/ha)
1998-99	17.0	154.0	8.82
1999-2000	17.0	154.0	8.92
2000-01	17.0	156.0	9.01
2001-02	17.0	159.0	9.14
2002-03	17.0	156.0	8.97
2003-04	18.0	170.0	9.49

Source: Directorate of Agriculture (Assam)

**1.2.2 Bangladesh :** Jackfruit is the national fruit of Bangladesh where the tree has great socioeconomic importance and ranks second in production among the fruits after mango. It is important all over the country and widely grown fruit tree, but grown especially in central districts. Fruit distribution and diversity is in the homestead of a Southern Island of Bangladesh. In Bangladesh, both area and production in jackfruit has increased during the period from 1971-72 to 2001-02 with no significant change in yield per unit area. However, during the period from 2004-05 to 2006-07, there was an increasing trend in area under jackfruit (orchards) with a significant increase in total production (orchards + isolated

trees). As per 1996 data, it occupied an area of 26,000 ha having a production of 0.257 million tons (Anonymous, 1996), However, in 2010, Bangladesh produced 1.5 million tons of fruits from 1,60,000 hectares of land, with about 30% of fruits being produce from jack plantations (Tables 5 and 6).

**Table 5. Area, production and yield of jackfruit in Bangladesh**

Year	Area under orchard (ha)	Average yield per tree (kg)	Production (000' mt)		Total
			In orchard (mt)	Outside orchard	
2005-06	8,245.5	136.0	228.0	596.1	824.2
2006-07	8,430.8	146.0	253.7	672.2	925.9
2008-09	9,232.4	138.0	260.0	714.7	974.8
2009-10	10,184.3	135.0	256.6	748.5	1,005.2

Source: Siddique and Azad, 2010

**Table 6. Area, production and productivity of jackfruit in Bangladesh (1971-2008)**

Year	Area (000' ha)	Production (000' mt)	Productivity (t/ha)
1971-72	17.4	187.0	10.75
1976-77	19.0	203.0	10.68
1981-82	20.6	205.0	9.85
1986-87	23.5	254.0	10.91
1991-92	25.1	256.0	10.20
1996-97	26.3	265.0	10.08
2001-02	27.1	276.0	10.14
2004-05	7.4	745.0	*
2005-06	9.2	720.0	*
2006-07	10.0	926.0	*

\* Data not available

**1.2.3 Pakistan :** The local production of jackfruit is almost negligible. The tree is grown out of curiosity in and around Karachi. The fruit is either brought by the people who visit this part of the country from across the border or from Bangladesh as a gift. The fruit is also sold in the Empress Market or the new *Subzi Mandi* (vegetable market), Hence, there is no systematic data on productivity and the extent of jackfruit distribution.

**1.2.4 Nepal :** The jackfruit (*ruk-katahar*) is a large, oblong tree-borne fruit with bumpy, dark green skin. It is eaten as a vegetable when green and a dessert when it is ripe. In this recipe, the young green fruit is cut into bunks and simmered with yogurt and spices. Fresh jackfruit is available at Asian food stores, but it is available canned at Indian, Asian, and specialty food markets. This recipe can be prepared from the canned variety, but these need to be rinsed in several changes of water before using. In Nepal, green jackfruit is considered a festive vegetable. In the Hindu marriage ceremonies of some *Brahmin* families, the bride's family does not serve meat. Instead, unripened jackfruit is substituted during the wedding feast. It is believed that the texture and flavour of cooked jackfruit is similar to meat. The data (Table 7) indicates that, though the productivity in Nepal has not recorded any significant change, the area under this crop has been increasing.

**Table 7. Area, production and productivity of jackfruit in Nepal**

Year	Area (ha)	Production (mt)	Productivity (t/ha)
2001-02	1,449.0	16,782.0	11.58
2002-03	1,479.0	17,160.0	11.60
2008-09	1,581.0	18,861.0	11.90
2009-10	1,594.6	18,971.5	11.89

Source: Statistical Information on Nepalese Agriculture

**1.2.5 Sri Lanka :** Jackfruit is one of the most common fruit tree species in Sri Lanka (Hitinayake *et al.*, 1996; Senaratne and Amarashinge, 1996). Improved jackfruit cultivars have been developed and several varieties and cultivars are now known in Sri Lanka (Medagoda and Tennakoon, 2001). In general, jackfruit growers distinguish two major types, namely, firm-fleshed varieties and soft-fleshed varieties, which are called *Waraka* and *Wela*, respectively. The tree is grown mainly in home gardens or forest plantations (Watanabe and Dassanayake, 1997) in the humid zone of the island. The main fruiting season is during March to June with a minor season from November to January (Medagoda and Tennakoon, 2001). Because of its high content of carbohydrates, jackfruit is also called “rice tree” or “poor man’s food”. It is a good substitute of staple food in periods of shortage of rice or other main staple crops (Nissanka and Marambe, 1996). Jackfruit in Sri Lanka is also known as ‘*Bath Gasa*’ reflecting its prime value as a food which is similar to that of the staple food rice known as *bath* in Sinhala. Jackfruit is also grown commercially in Sri Lanka over of an area of about 4,500 hectares, primarily for timber, although the fruit is also much appreciated as a by-product.

## 2. Germplasm Collection, Characterization, Conservation and Utilization

### 2.1 Introduction

Plant genetic resources (PGR) represents the raw materials that farmers and plant breeders use to improve the quality and productivity of their crops. There is worldwide concern over the ever increasing loss of PGR diversity, especially in underutilized crops (Williams and Haq, 2002). A major reason for this is the replacement of diverse, genetically variable landraces with a few genetically uniform modern varieties (Brush, 1991; Harlan, 1992; Hawkes, 1983; NRC, 1993, Oldfield and Alcorn, 1987; Brush, 1991; IPGRI, 2000). However, in the case of underutilized crops like jackfruit, these activities have been overlooked by scientists, possibly due to lack of knowledge of the crop or being neglected and underutilized. The primary and secondary gene pools of *Artocarpus heterophyllus* have not been identified. Jackfruit is largely a cultigen found only under cultivation. Due to its spread over very wide areas of Asia long ago it is important that an assessment is made for the patterns of genetic diversity that exist so that genetic resources can be identified for conservation and utilization. For sustainable use, the genetic diversity of jackfruit is a valuable resource for the present and future. Therefore, the documentation and conservation of genetic resources of jackfruit is necessary. Several investigators reported on jackfruit germplasm (Ullah and Rahman, 2007-08a; Ullah and Rahman, 2007-08b; Firoz and Rahman, 2007-08; BARI, 2007-08).

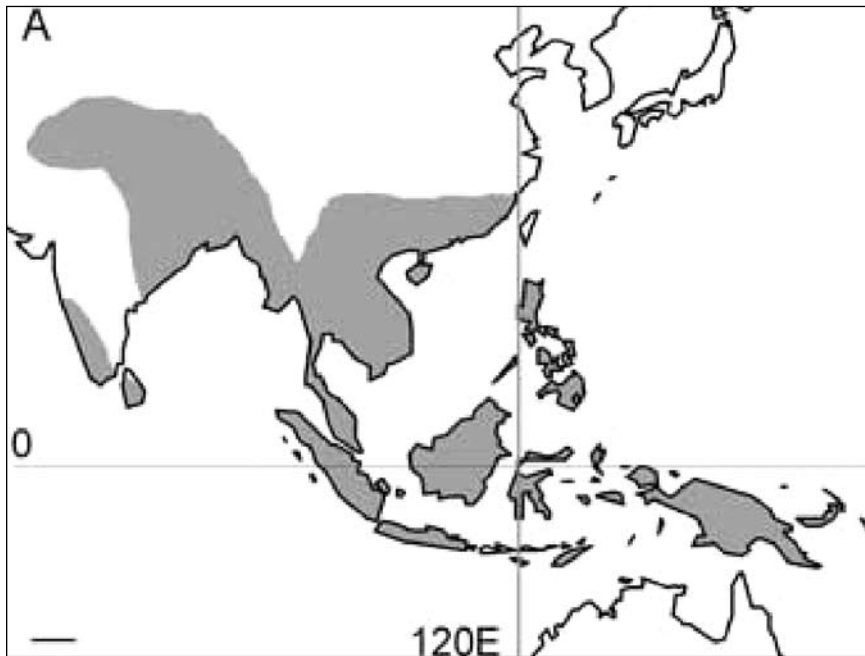
Jackfruit has a wide range of genetic variation, in particular in South and Southeast Asia, which aids in the selection of superior

and desirable types. Recently, some progress been made on assessment of germplasm of *A. heterophyllus* around the world but very little assessment of this diversity has been done in both the primary and secondary genepool (Haq, 2006). This chapter assesses status of information available on the genetic resources and its use in breeding and crop improvement.

## 2.2 Origin and geographic distribution

*Artocarpus* (c. 45 – 59 spp.) is the third largest genus in the Moraceae family. It is distributed from Southeast Asia to Oceania and includes several economically important species such as breadfruit (*A. altilis*) and jackfruit (*A. heterophyllus*) that are cultivated throughout the tropics. The jackfruit has only one identified center of origin (Harlan, 1987): the Indo-Malayan region (Barrau, 1976; Zielenski, 1955). More specifically, the species reportedly originated in the rainforests of the Western Ghats of India (Chandler, 1958; Popenoe, 1974; Purseglove, 1968) and in Malaysia (Brown, 1941; Hensleigh and Holaway, 1988; Merrill, 1912; Wester, 1921). It then spread to neighboring Sri Lanka, southern China, Southeast Asia, and farther to tropical Africa, including Kenya, Uganda, Zanzibar, Mauritius, and Madagascar (Fig. 1) (Barrau, 1976; Hensleigh and Holaway, 1988; Morton, 1965, 1987; Purseglove, 1968; Soepadmo, 1992).

From the mid-seventeenth century to the late nineteenth century, the species spread further to tropical and subtropical America (Brazil, Suriname, Jamaica, and Florida) and Australia (Morton, 1965, 1987; Popenoe, 1974; Purseglove, 1968). From these countries, the jackfruit may have dispersed even further, to other tropical and warm subtropical regions where it is now widely cultivated at low and medium elevations (Harlan, 1987; Purseglove, 1968).



**Fig. 1.** Distribution of *Artocarpus* (cultivated species span in the tropics)

### 2.3 Taxonomy and nomenclature

*Artocarpus heterophyllus* Lam., belongs to the family Moraceae, along with *Ficus* spp. (fig), *Morus* spp. (mulberry), and *Maclurapomifera* Schneid (osage orange or hedge apple) (Chandler, 1958; Popenoe, 1974). This family encompasses about 1,000 species in 67 genera, mostly tropical shrubs and trees, but also a few vines and herbs (Bailey, 1942; Merrill, 1912). The Philippines is the home to about 150 species representing 13 of these genera (Merrill, 1912).

The genus *Artocarpus* comprises about 50 species, 11 of which are known to produce edible fruits. Even at the species level, a high degree of genetic variability exists. This is true in the case of jackfruit (*A. heterophyllus*), breadfruit (*A. altilis*) and marang (*A.*

*odoratissimus*). At least two species, jackfruit and champedak (*A. integer*) hybridize freely in nature. Furthermore, some species are graft-compatible. The seedless breadfruit, for example, is graft-compatible not only with the seeded strains but also with the kamansi (*A. camansi*) and pedalai (*A. sericicarpus*). The monkey jackfruit (*A. rigidus*) is another promising species because it is very productive, produces perhaps one of the smallest fruits in the genus, has sub-acid taste and possesses good flavour, better than jackfruit, champedak and marang.

The genus *Artocarpus* includes about 50 species with a milky latex in the Asiatic tropics and Polynesia (Barrau, 1976; Campbell, 1984; Corner, 1988), 18 of these species are found in the Philippines (Merill, 1912). The complete taxonomic classification of *A. heterophyllus* is as follows (Stanton, 1970; Zielenski, 1955):

Kingdom	: Plantae (planta, plantes, plants, vegetal)
Sub-kingdom	: Tracheobionta (vascular plants)
Super-division	: Spermatophyta
Division	: Magnoliophyta (angiosperms, flowering plants, phanerogames)
Sub-division	: Angeospermae
Class	: Magnoliopsida (dicots, dicotyledones, dicotyledons)
Sub-class	: Hamamelididae
Order	: Urticales
Family	: Moraceae
Genus	: <i>Artocarpus</i>
Species	: <i>Artocarpus heterophyllus</i> Lam.

The species' botanical or scientific name was coined by the botanist Lammarck (Abbreviated usually as Lam. or sometimes



Lamk.) (Corner, 1988). Its legitimate synonyms are: *A. heterophylla* Lam., *A. philippinensis* Lam., *A. maxiiija* Blanco; *Soccus arboreus* major Rumph., *Polyphema jaca* Lour., and *A. brasiliensis* Gomez (Corner, 1988; Soepadmo, 1992). Erroneously used synonyms include: *A. integrifolius* Auct., *A. integrifolia* L. f., *A. vintegra* (Thunb.) Merr., *A. jaca*, and *Rademachia integra* Thunb. All of these refer to a related species, *A. integer* (Thunb.) Merr., or chempedak (Corner, 1988; Morton, 1987). Other edible fruit-bearing species related to jackfruit are *A. altilis* (Park.) Fosb. (rimas), *A. blancoi* (Elmer) Merr. (antipolo), *A. camansi* Blanco (camansi), *A. odoratissima* Blanco (marang), *A. lanceaefolia* Roxb. (kledang), and *A. rigidus* Blume (mandalika) (Coronel, 1983; Hensleigh and Holaway, 1988).

Very little information is available on the cytology of *A. heterophyllus* genepool. Darlington and Wylie (1956) and Habib (1965) have reported that it is tetraploid with a somatic chromosome number of 56 ( $2n=4x=56$ ), thus the basic chromosome number ( $x$ ) is 14. It crosses freely with *A. integer*, *A. lanceaefolius* and *A. rigidus* and Kanzaki *et al.* (1997) believed that these species are close relatives of *A. heterophyllus*.

The male flowers are produced amongst the leaves above the female flowers, and when mature, become covered in pollen that falls rapidly after flowering. Male head is sessile or on short peduncles, sometimes born on the ultimate twig. The female flowers are borne on short twigs that develop from the trunk, branches and sometimes from below the soil level at the base of older trees. Female heads are oblong, ovoid receptacle, syncarpus, cylindrical. The rind of the compound fruit is greenish yellow when fully ripe. Inside, the fruit is made up of large, yellow bulbs enclosing an oval light brown seeds. There are 100-500 seeds in a single fruit. Seeds are separated horny endocarpus enclosed by sub-gelatinous exocarpus (1 mm thick) oblong ellipsoid in nature. The sweet yellow sheaths around the seeds are about 3-5 mm thick and have a taste

similar to that of pineapple, but milder and less juicy when fully ripe fruit is opened. All parts of the tree produce sticky, white latex, but latex-free genotypes have been identified in India.

## 2.4 Genetic diversity

Jackfruit shows a considerable range of variation in morpho-agronomic characters and this may be because jackfruit trees are cross-pollinated and are mostly propagated by seed. A considerable variation between trees has been observed for the traits such as growth habit, canopy structure, leaf size, fruit shape, size, colour, fruit bearing (age and seasonality) and maturity. (Table 8). The International Plant Genetic Resources Institute (IPGRI; now Bioversity International) in 2000 issued a list of descriptor and descriptor states both for characterization of germplasm, and for further evaluation. Variation also exists in density, size and shape of spines on rind, fruit bearing sensory quality, flesh types, sweetness, flavour and taste (Azad, 2000). Table 9 shows variation in flake types of fruits and Table 10 shows variation in fruit characteristics (Haq, 2011).

**Table 8. Variation in morpho-agronomic characters**

Trait	Range of variation
Tree habit	Open, spreading, low spreading, sparse upright
Tree growth rate	Fast, moderate, slow
Canopy	Dense mostly dome-shaped, slightly pyramidal or flat topped. It ranges from 3.5-6.7 m
Leaf shape	Elliptic., elliptic-obovate, obovate, oblong, lanceolate, oval
Leaf size	4-25 cm in length; 2-12 cm in width
Leaf petiole	1.2-4.0 cm long
Fruit maturity	Variable

Contd...

Table 8 (Contd...)

<b>Trait</b>	<b>Range of variation</b>
Fruiting seasons	Variable
Fruit shape	Oblong, ellipsoid , triangular, spheroid, claviform, round
Number of fruits/tree	15-1450
Fruit weight (kg)	1.2-22.0
Fruit thickness	Thin, medium, thick
Fruit texture	Fibrous, firm, coarse, melting, crisp
Seed shape	Oblong. ellipsoid, irregular, reniiform, elongate, spheroid
100 - Seed weight (g)	250-1230

Source: Haq (2006)

Table 9. Variation in flakes types

<b>Trait</b>	<b>Range of variation</b>
Flakes aroma	Mild, strong
Flakes colour	Creamy white, light yellow, deep yellow, yellow, reddish, red golden
Flakes texture	Crisp, coarse, fibrous / coarse, fibrous, smooth
Quantity of fibre	Scarce, medium, abundant
Juiciness of pulp	Very juicy, juicy, medium juicy, less juicy, dry

Source: Haq (2006)

Table 10. Variation in fruit characteristics

<b>Characteristics</b>	<b>Range</b>
Fruit weight (kg)	1.2-22.0
Fruit length (cm)	20.5-60.6

Contd...

Table 10 (Contd...)

Characteristics	Range
Fruit diameter (cm)	16.4-29.5
Fruit girth (cm)	50.5-95.8
No. of bulbs/fruit	24.2-580.2
Pulp (%)	18.3-60.9
Seed (%)	2.6-23.1
Rachis (%)	1.5-21.4
Rind (%)	20.6-72.0
Brix (°)	13.8-25.3

Source: Haq (2006)

Soepadmo (1992); Rey (2002); Haq (2006); Azad *et al.* (2007); Jagadish *et al.* (2007) reviewed the current information on the diversity of jackfruit. Some attempts have been made to understand the extent of genetic diversity from the study of morphological characters with an aim to identify superior types for cultivation. The germplasm of jackfruit was evaluated and selections were made in Asia (Mitra and Mani, 2000; Reddy *et al.*, 2001; Susilodi *et al.*, 2002; Mitra and Maity, 2002; Azad *et al.*, 2007).

A few attempts were also made to understand the extent of genetic diversity for morphological characters and to select superior types of jackfruit. There has been limited germplasm of jackfruit for evaluation and selection in India, Indonesia, Nepal, Malaysia, Thailand, the Philippines, Sri Lanka, Vietnam and Bangladesh (IPGRI, 2000; Bhag Mal *et al.*, 2001; Haq, 2002) and thus limited information is available on the performance of the accessions. Hossain and Haque (1979) studied the morphological characteristics of a few selected jackfruit trees in one location in Bangladesh. Azad (1989) reported on the variation of fruit characteristics in different jackfruit trees which originated from seeds. Saha *et al.* (1996) also studied the morphological variability

of some selected lines from one location in Bangladesh but these studies did not consider environmental factors. Bashar and Hossain (1993) carried out a survey in Bangladesh to identify diversity in jackfruit through farmers' interviews. In Nepal, the variation estimated was based on early, mid season and late season flowering, and fruiting all the year round. Mitra and Mani (2000), Susilodi *et al.* (2002), Mitra and Maity (2002), Reddy *et al.* (2001), Crane *et al.* (2003) and Haq (2003) summarized information on the diversity of jackfruit in South Asia and Southeast Asia and also for the introduced accessions in Florida.

Thus, the information on morphological characteristics of a limited germplasm is now available. However, in recent years, further evaluation of morpho-agronomic characters have been done in some other countries. Evaluation of landraces was also carried out in several Pacific island countries (Cambell *et al.*, 2004). Diversity in all fruit trees and in jackfruit studied at two locations in Sri Lanka has been given in Table 11 and similarity in the diversity of all fruits and jackfruit is given Table 12.

**Table 11. Diversity in jackfruit assessed at two locations in Sri Lanka**

Site	Simpson index	Shannon index	No. of species/cultivars
Kandy-Kegalle (Farmer)	0.53	0.93	4
Galle (Farmer)	0.64	1.21	6
Kandy-Kegalle (Nursery)	0.81	1.51	5
Galle (Nursery)	0.81	1.72	6

**Table 12. Similarity of jackfruit diversity kept by farmers and nurseries at Kandy-Kegalle and Galle, Sri Lanka**

Site	Sorensen index
Kandy-Kegalle and Galle (Farmer)	0.60
Kandy-Kegalle and Galle (Nursery)	0.73

Germplasm movement of selected underutilized multipurpose tree species in Sri Lanka was reported by Hillmann *et al.* (2006). They compared data for over 40 fruit tree species in the home gardens and slightly fewer in the nurseries by using both Shannon and Simpson indices. It was concluded that Shannon index is a better measure to show the differences in diversity among different sites and groups (Table 11). The species composition between the groups of all species in almost identical, whereas farmers in Gale and Kandy-Keggale do not share many cultivars of *Artocarpus heterophyllus* as noticed in Forenson index (Table 12).

## 2.5 Germplasm collections

Only a few national programmes in Asia have attempted sporadically to collect, characterize and evaluate jackfruit germplasm. There has been no systematic effort by regional or international institutions to collect and evaluate germplasm other than two regional programmes: i) Underutilized Tropical Fruits in Asia Network (UTFANET) (Haq, 2003) and ii) Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia (Bhag Mal *et al.* 2001). There is a need to collect germplasm from targeted areas from Indian sub-continent and Southeast Asia in particular from the origin and center of diversity. There is a need for systematic collection of germplasm from Western Ghats and Andaman Islands where wild jackfruit germplasm may be present (Haq, 2006). The collections held by different countries are listed in Table 13.

**Table 13. Jackfruit collections in different countries**

Country	No. of accessions
Bangladesh	130
India	947

Contd...

Table 13 (Contd...)

Country	No. of accessions
Indonesia	155
Nepal	350
Pakistan	10
Sri Lanka	77
Thailand	87
Vietnam	202
Other Pacific Islands	30

### 2.5.1 India

So far, there is no well-defined variety in jackfruit and different types are known differently in different localities. Local selections have been named as Gulabi (rose scented), Champa (flavour like that of *Michelia* sp.), Hazari (bearing more number of fruits in a tree).

As a result of local survey, some better types have been collected. Since raw jackfruits have good demand in India as vegetable for culinary purpose, emphasis is also given on fruit characters like thickness of rind and softness of flesh at premature stage of fruit development. New selections, namely, NJT1, NJT2, NJT3 and NJT4 with large fruits and excellent pulp quality have been identified for table purpose, while types like NJC1, NJC2, NJC3 and NJC4 were found better for culinary purpose.

Survey conducted in Assam showed that both soft flesh (Pakikhua) and firm flesh (Khoja) varieties are available. Commonly, jackfruit ripens during March-May in Barak Valley, while in the Assam Valley, fruits ripe during May-July. Certain trees with fruiting 2-3 times a year, (January-February, April-May and June-July) known as "Baromahia" were located during the survey.

From the Western Ghats, a variety Muttam Varikka producing fruits weighing 7 kg each (46 cm long × 23 cm wide) has been reported (Sreenivasan, 1970). A jackfruit variety known as Rudrakshi having fruits of the size of a large pummelo with smooth rind and less spikes has been reported to produce off-season crop between September to December.

In South India (Kerala, Tamil Nadu and Karnataka), different forms of jackfruit (Varikka, Koozha, Navarikka) are available and the maximum diversity has been reported from Wynad Plateau of Western Ghats of Kerala. The Guinness world record for the biggest jackfruit (34.4 kg) stands in the name of a Hawaiian farmer. However, the jackfruit grown in the orchard of Karunakaran, a farmer in Melmambattu village of Tamil Nadu in India, recorded 81 kg fruit. In Melmambattu and Maligaipattu villages of Tamil Nadu, the huge jackfruit trees grown have wide variability with respect to size, taste and bearing habit.

At Kallar and Burliar Fruit Stations in Tamil Nadu, a total of 30 seedlings and 20 clonal progenies were assembled from Myanmar, Indonesia, Sri Lanka, Philippines and Malaysia. Among the collections, Burliar Jack seedlings followed by Singapore and Velipala seedlings yielded better and are now being grown by jack lovers.

The studies on pollination and hybridization between jackfruit and breadfruit were undertaken at Kallar. Further, the performance of jackfruit varieties under Burliar conditions was studied and results showed that the selections Virudhachalam and Singapore were tall types. The Tamil Nadu Agricultural University (TNAU), Coimbatore (India) has developed two improved varieties, viz., Palur-1 and PPI Jack which have shown good performance in the state and further efforts are needed to popularise these varieties.



A jackfruit variety known as Singapore or Ceylon Jack, introduced from Sri Lanka is a popular variety. Certain other varieties named as Velipala, Hybrid Jack, Panruti Selection, Burliar I and Muttam Varikka are also popular in different localities. Ceylon Jack variety produces fruits from 3rd year of planting and fruit weighs 5-20 kg. In Uttar Pradesh (U.P.), a small fruited (2-8 kg) jackfruit variety known as Barka and a large fruited variety Kapa are grown. The Kapa variety locally known as Kathal in U.P. produces fruits as big as 40 kg in weight and the fruit is very sweet in taste on ripening.

The work on collection and conservation of jackfruit started at Indian Institute of Horticultural Research (IIHR), Bangalore (India) during 2000-01 under Underutilized Tropical Fruits in Asia Network (UTFANET) project funded by International Center for Underutilized Crops (ICUC) for promotion of research on underutilized fruit species. During the same time, Indian Council of Agricultural Research (ICAR) also initiated collection and conservation of jackfruit under the All India Coordinated Research Project (AICRP) as one of the mandate crops. The objectives of these programmes are to survey, collect and characterize jackfruit diversity available in different parts of the country.

### **2.5.2 Bangladesh**

Jackfruit is the second most important fruit in Bangladesh after banana with about 17% of total fruit production of the country. The cultivars are classified into three categories (i) those with soft edible pulp known as Gala, ii) those with crispy bulbs known as Khaja, and iii) others of intermediate types. Being of seedling origin, large variability exists among the jackfruit trees. There are certain trees which bear fruits more than once a year, almost throughout the year. *Artocarpus lakoocha* Roxb., a related semi-domesticated species, is also found in Bangladesh. It is known as Barta in Chittagong and Bon Kathal in Rajshahi

districts. Another species, *Aritocarpus chaplasha* Roxb., locally known as Chaplash in Chittagong, Cham in Sylhet, and Chambal in Dhaka and Mymensingh districts, having greater timber value, is also found to grow in wild to semi-wild conditions.

Bashar and Hossain (1993) reported that wild jackfruit relatives inhabit the Andaman Islands and are found only under cultivation in Bangladesh. However, it is often found in forests in Bangladesh away from human habitation (Haq, 2006). In many districts like Tangail, Mymensingh, Dhaka, and adjoining areas, many jackfruit trees grow in the wild near and in forest edges and fallow lands. Many of these trees grow tall and bear relatively small but numerous fruits that are, in most cases, inedible or of very poor quality. The local people call these "*jangli kathal*" (wild jackfruit). A wide diversity of jackfruit has been observed throughout Bangladesh, but little attention has been paid to its documentation and conservation. The documentation of this diversity is crucial to better understand the history of jackfruit domestication. If Bangladesh is a secondary center of diversity for jackfruit, this implies that it was domesticated elsewhere and subsequently introduced to Bangladesh, where the crop was then diversified. If there are truly wild jackfruit trees in Bangladesh, then it is possible that Bangladesh is part of a broader center of origin of the crop (Harlan, 1971). On the other hand, perhaps the trees growing in forests and fallow lands that exhibit wild characteristics are not truly ancestrally wild, but rather represent naturalized feral populations of trees that in the absence of human selection evolved back toward wild characteristics after the crop was introduced to the area millennia ago. Before these questions can be addressed, a better understanding of the morphological diversity of Bangladeshi jackfruit is necessary.

Khan *et al.* (2010) in his survey with the villagers demonstrated the importance of jackfruit and the recognition of wild diversity of

the jackfruit (*kathal*) tree. Villagers used several names to describe this variation, e.g. *Chaila kathal* (hard, tasteless jackfruit), *Roachhara kathal* (jackfruit without *roa* or pulp), *Hazari kathal* (bearing a thousand small fruits), *Khokra kathal* (wavy, irregular shaped, hard fruit), and *Neisha kathal* (very soft, sweet, small-sized pulp). These names indicate plants that trees are somewhat wild or not entirely domesticated. These are considered inferior in quality and generally are not preferred or fetch a low price in the market. However, such trees are still kept for timber and wood, and poor people use these inferior fruits as green vegetables before they reach maturity.

Mannan *et al.* (2004, 2006) reported that in south western region of Bangladesh, jackfruit trees bear flowers during August-October and fruiting age was found less than 20 years.

## 2.6 Characterization using morphological characters

### 2.6.1 India

#### a) North-Eastern India

In North-Eastern region of India, jackfruit is very popular among the tribals and the crop is grown almost in a semi-wild condition. Soft-flesh varieties predominate the market.

A survey was conducted in 1996 in the lower Brahmaputra Valley of Assam (25°30' N latitude and 89°40' E longitude). The climate of the zone is humid subtropical with an annual rainfall of 2,789 mm. The cultivated types identified are named as KJF (Kahikuchi jackfruit). Twelve distinct types were identified, with fruit ripening period varying between early June to late July coinciding with rainy season. Significant variations in fruit bearing habit and fruit quality were recorded. Wide variation was noted in number of fruits ranging from 4-60 per tree per season. Viviparous seed germination was observed in certain genotypes.

**b) Eastern India**

i) *West Bengal* : Identification of superior clones by evaluation and subsequent maintenance/multiplication of the selected clones by vegetative propagation were initiated at the Bidhan Chandra Krishi Viswavidyalaya, West Bengal (India) in 1991. Surveys were conducted to identify superior clones possessing one or more of the following characters: i) regular bearing, ii) early flowering to use as vegetable in December-January, iii) bearing more than once a year, iv) high yield potentiality, v) higher fruit weight, vi) acceptable fruit size with good quality to use as table fruit, and vii) resistance to biotic or abiotic stress. More than 3,000 trees were studied during seven years in different districts of West Bengal which resulted in the identification of promising types for use as vegetable (T6, T12), tree bearing twice a year (T17), very high yield potential (T23, T24), types suitable for use as table fruit (T28, T33), big sized fruit (T13, T14), resistant to saline and alkali soil (T31, T32), fruit having red pulp that are suitable for vegetable (T6) and salt tolerant types (T31, T 32). Variation among the selected types included medium to tall (tree size), irregular/regular/thrice a year bearing habit, greenish/brown/brownish fruit colour, fruits weighting 2.5-10 kg, 25-240 fruits/plant, 35-380 segments/fruit, segment weight of 12-38 g, TSS of 15.4-29.6 °Brix, 12.4-26.7% total sugar content having an acidity of 0.10-0.37%. In another study, Mitra and Mani (2000) evaluated over 1,460 fruit trees in West Bengal. Wide variability was noticed in several tree characteristics, viz., yield (15-1,450 fruits/tree), fruit wt. (1.22-17.3 kg), fruit shape, peel colour, flake colour, number of flakes (30-380/fruit), number of seeds (30-365/fruit), TSS (9.1-28°Brix), total sugar (7.6-23.6%) and fruit acidity (0.10-0.33%) among the genotypes. Variation was also observed in growth and fruit bearing among genotypes. The genotypes were selected for dessert use, high juice content for processing and drought tolerance.

*ii) Bihar and Jharkhand* : From the Eastern India, some collections were made and the seedling selections were evaluated at the Regional Station of the ICAR Research Complex for Eastern Region at Ranchi (Jharkhand, India). Superior clones of firm flesh type Khajwa were identified based on their growth habit, fruit yield and quality (Reddy and Rai, 1999). Based on the performance of the seedling selections, a budded Khajwa selection (Accession No.3/2) was identified and is being cultivated.

### ***c) South India***

Detailed survey was conducted in major jackfruit growing areas of Kerala, Tamil Nadu and Karnataka states and based on tree and fruit characters, 200 different types were selected. The seeds were sown and seedlings were selected based on seedling vigour and planted at the Mannuthy Campus of Kerala Agricultural University at Thrissur, Kerala. The plants have started fruiting and have been characterized. Based on characterization, the promising types, were selected.

In South India, the jackfruit is classified into two general types : Type 1 jackfruit having firm flesh is called Varikka is more important commercially and possesses crispy carpels/flakes of high quality. On the other hand, Type 2 jackfruit has soft flesh and are called Koozha. They have small fruits whose flesh is fibrous, soft, mushy, but it has very sweet carpels/flakes. The fruit of the Koozha variety is consumed mainly in the raw stage like preparing pickles or cooking different vegetable dishes. The fruits of the Koozha variety if allowed to ripen, do not taste as good as the Varikka variety because the flesh is soft or soggy. In contrast, the Varikka variety is used both in the raw (unripe) and ripe stages. If used in the unripe stage, it is usually made into curries and deep-fried chips. The Varikka types are preferred for canning in the processing industries.

Sreenivasan (1970) described a Varikka type of jackfruit from the seedling progeny of a type from Muttam in Alleppey district

of Kerala. This type is named as Muttam Varikka with fruits weighing 7.0 kg and flakes 3.6 g. The pulp is crisp, fleshy, non-fibrous, golden yellow and has very good edible quality.

Mathew (1995) described physical characteristics of 29 types jackfruit which exhibited a wide range of variation in edible and non-edible parts. Joseph and Kumaron (1996) studied the fruit set, fruit drop and fruit development in Varikka and Koozha types in jackfruit and did not find any significant difference among them in any of the above characters.

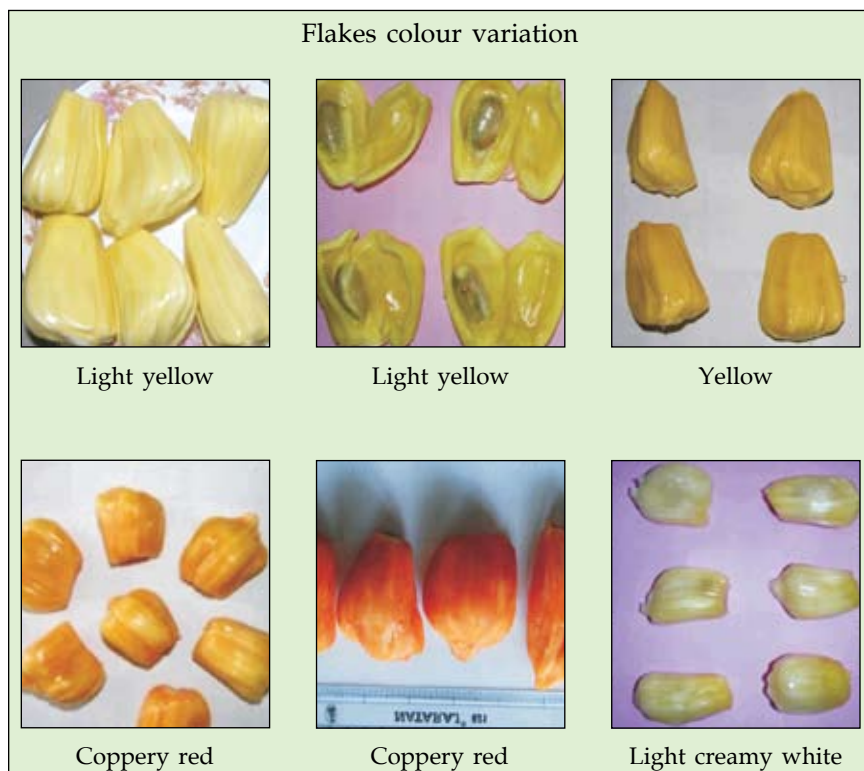
A total of 204 trees belonging to 67 accessions including wild and cultivated types from Kerala, Karnataka and Tamil Nadu are maintained at the National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur, Kerala. The seedlings generated through seed progenies are maintained in the field along with checks such as Singapore Jack and Muttam Varikka. Being seedling progenies, trees within the accession vary for fruit characters. Characterization and evaluation for 16 fruit characters in 12 trees have been completed. Results showed that all except one belonged to Varikka type with firm flesh. Trees numbering V-504-1A, IC 96152-1A, IC 9/624-1A and IC-91737-IA were excellent table fruit types. IC 93388-2A was the only Koozha type with soft bulbs used for fruit puddings. IC-99627-I A had very thin flakes, good for chips preparation.

OBL 8 was extra early (off-season) with fruit initiation in the month of August. IC-97624-IA though had early fruit ripening (March), but was highly susceptible to fruit borer (*Congethes punctiferalis*). IC 91665-2A and OBL-I (Undachakka) had small round fruits with single fruit weight ranging from 0.75-2.0 kg. These cultivars exhibiting early fruit maturity were desirable for vegetable purpose. IC 96148-3-A had coppery red flakes which are thick and crisp with good aroma.

From agroforestry point of view, promising lines, IC 97625-2A and IC 91126-IA having very small leaves and IC 91126-IA having pyramidal canopy were identified. Six accessions belonging to different species, namely, *Artocarpus lakoocha*, *A. communis* and *A. hirsuta* were also maintained.

Reddy *et al.* (2004) studied physio-chemical characteristics of jackfruit clones from South Karnataka and found diversity in several characters. Jagadish *et al.* (2007) analyzed 24 different firm type jackfruit clones from Western Ghats and found variation in total soluble sugars (TSS), acidity, TSS : acid ratio, sugars, starch and carotenoid contents in the bulbs. Jagadish *et al.* (2007) also found variability in fruit quality among 95 selected accessions from Western Ghats. They evaluated physio-chemical characters of fruits and found significant differences thus indicating wide genetic variability. However, the relative contribution of characters reflected that number of seeds per fruit contributed the maximum divergence followed by TSS: acid ratio, single bulb mass, percentage of edible portion, fruit length and TSS. Diverse types were selected based on desirable characters. Das and Das (2005) also observed wide diversity in jackfruit in homestead gardens in Assam.

At the Indian Institute of Horticultural Research, Bangalore, under UTFANET project, the diversity collected in jackfruit includes most of the common types and special types, viz., the trees bearing heavily and fruit weight ranging from 650 g - 35 kg. Fruits with low latex (gumless jack), firm flakes and colour ranging from creamy white, yellow, orange and coppery red (Fig. 2) were included in the field gene bank. Flakes with champak and rose scented collections were also found during surveys. Further, selections were made from these accessions for selecting the promising types supported by fruit quality attributes (Anonymous, 2004).



*Fig. 2. Flake colour variation in jackfruit accessions*

### 2.6.2 Bangladesh

The Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI) undertook programmes in germplasm collection and evaluation in a systematic way. Hossain (1996) described the fruit characteristics of some of the selected types and some important horticultural traits of 18 selected types occurring in Bangladesh.

### 2.7 Characterization using molecular markers

The genetic diversity of the plants is commonly determined by



their morphological characteristics. Most of the morphological traits are influenced by environmental factors and many of qualitative traits which are of polygenic inheritance are expressed only after several years of growth (Hamrick *et al.* 1992). As a result, the level and pattern of genetic diversity determined only by morphological traits are less accurate and questionable. Therefore, in recent years, the use of biochemical markers has been employed to assess the genetic diversity more accurately. This prompted the scientists to use isozyme and molecular techniques to measure the genetic diversity more accurately in jackfruit (Schnell *et al.* 2001; Azad, 2007; Shyamamma *et al.* 2008). The genetic diversity of jackfruit is a valuable resource for the present and future. Bangladesh is expected to be the home for rich morphological and genetic variability, and possibly also harbours wild jackfruit diversity. The documentation of this genetic resource is a necessary first step in understanding and conserving the diversity for long-term sustainable use.

Azad *et al.* (2007) reported variation in enzymatic patterns in jackfruit populations in Bangladesh and indicated genetic differences from the study on four isozymes, viz., Alcohol dehydrogenase (ADH), Glutamate oxaloacetate transaminase (GOT), Malate dehydrogenase (MDH) and Acid phosphatase (ACP). They discovered that morphological traits such as weight, length, girth of the fruits and percentage of pulp correlated poorly with environmental factors, suggesting that these characters are more likely genetically controlled. However, isozyme markers are also known to be affected by both environment and post-translation modification, and their practical use is limited (Akashi *et al.* 2002).

A comprehensive understanding of genetic diversity and molecular characterization of jackfruit cultivars is needed for formulating appropriate sampling and management strategies.

A detailed analysis of a large number of genetic markers will help in developing useful gene conservation strategies and help in popularizing this species as a commercial crop. Schnell *et al.* (2001) looked at the genetic diversity of 26 accessions from 8 countries for assessment of genetic diversity, using amplified fragment length polymorphism (AFLP) markers, and provided an actual picture of diversity and genetic relatedness in jackfruit. This study included only two accessions from India, and they scored a small number of markers (187), of which 92 (49.2%) were found to be polymorphic. A recent study revealed that varieties used for making chips have high dry matter content indicating a direct relationship between these characters (Jagadeesh *et al.* 2008). Further studies revealed that majority of jackfruit selections (91 accessions), irrespective of their ecogeographic origin were grouped in one cluster, while 4 other selections were solitary in each cluster (Jagadeesh *et al.* 2007a). The chemical composition of bulbs from 24 different firm-type jackfruit clones intended for dessert purposes was analyzed to determine the extent of variability (Jagadeesh *et al.* 2007b). The AFLP marker-based analysis of jackfruit germplasm indicated that there existed a limited genetic diversity. These observations are in agreement with the phenotypic evaluation conducted, suggesting that new jackfruit collections or accessions need to be obtained from the center of origin of species to increase genetic variability in the germplasm (Schnell *et al.* 2001).

Shyamamma *et al.* (2008) has carried out evaluation of 50 accessions collected from the Western Ghats in India using AFLP markers. Sixteen primer pairs were evaluated and 8 were selected for screening of genotypes. Only 22% of bands were polymorphic, while 78% were monomorphic indicating modest variation. There was a strong correlation of AFLP based grouping with geographical localities (e.g. low, medium to heavy rainfall areas) and morphological characteristics.

Luke *et al.* (2007) compared the marker data with morphological data obtained from jackfruit accessions grown over three successive seasons at different locations in southern India. The maximum genetic distance was 7.9% between a clone of Mottavarica (M0), and Chandrahalasu from distant locations, while the minimum genetic distance (5%) was between the genotypes (M0) and Kerala, indicating their similar geographical origin. Chemical composition of bulbs from 24 different firm-type jackfruit clones was analyzed to study the variability. Sane *et al.* (2009), distinguished 18 accessions of jackfruit (*Artocarpus heterophyllus* Lam.) maintained in the field gene bank of Indian Institute of Horticultural Research Bangalore at the DNA level by ISSR analysis. Primers that generate accession specific profiles were identified and found useful for generating DNA profiles unique to the jackfruit accessions studied. The cluster diagram depicting genetic relationships between accessions showed that the accessions Gumless, Dorichandra and Tenvarike were the most divergent ones. This study revealed the ability of ISSR markers to detect polymorphism and also to evaluate genetic variability and differentiate accessions of jackfruit. The morphological characterization when collated with DNA profiles of these accessions showed that Tenvarike, which is a divergent accession, had desirable fruit characters like low latex exudation and low flake fiber content. Thus, molecular marker data together with morphological parameters could be effectively utilized for identifying trait specific germplasm to establish working collections in crop improvement programmes. Further studies are in progress to identify other unique traits, viz., earliness, low core thickness, higher number of flakes per fruit, flake thickness, higher total soluble solids, etc. integrating molecular analysis with morphological characterization data.

The phylogenetic relationship among eleven *Artocarpus* species was estimated by comparing 30 restriction site mutations

in an amplified region of chloroplast DNA (cpDNA). Close relationship between chempedak (*A. integer*) and jackfruit was confirmed. Breadfruit (*A. altilis*) and *A. elasticus* formed a mono phyletic group indicating that breadfruit was derived from *A. elasticus* or its close relatives. The results were in conformity with conventional classification of *Artocarpus* sp. except for the position of chaplasha (Kazaki *et al.* 1997). Using nuclear and chloroplast DNA sequence data and morphological characters, an *Artocarpus* phylogeny was reconstructed to study the evolution of inflorescence characters, address taxonomic issues and identify wild relatives of cultivated species in the genus (Zerega, 2003).

## 2.8 Conservation

Although germplasm resources of jackfruit are not threatened, there are some concerns of erosion of genetic diversity (Haq, 2002). It is felt that there is a need for attention to conserve the diversity of jackfruit genepool since the assessment of diversity is not extensive. Failure to conserve the important accessions possessing desired characters may result in loss of useful diversity.

### 2.8.1 *In situ* conservation

*In situ*/on-farm conservation of PGR is the continued cultivation and management of a diverse set of crop populations by farmers in the agro-ecosystems where the crop has evolved. It is dynamic and is aimed at maintaining the evolutionary processes that continue to shape diversity. *In situ* conservation has great importance in sustainably maintaining and managing the agro-ecosystems. Farmers know the nature and extent of diversity because of intimate knowledge of their trees.

As jackfruit is mostly grown in home gardens, *in situ* conservation is possible but rarely practiced. In Bangladesh, some farmers tend to select and conserve "straight stem" types

because of their potential use as wood. Farmers will need to be convinced of the value of the diversity and the usefulness to them for on-farm conservation to be effective. Once they are convinced, they can be persuaded to continue to grow trees in traditional agroecologies.

From the information available, the diversity of wild population of *A. heterophyllus* in forest habitats such as the Western Ghats of India, the Andaman Islands and the south eastern part of India is not enough to identify the location of precise areas of diversity. Once such information is available, these wild populations can form part of the large natural area of ecosystem and can be demarcated as biosphere reserve.

### **2.8.2 Ex situ conservation**

Jackfruit seeds are recalcitrant (IPB, 1990) and difficult to store as they lose viability quickly. The seeds cannot be dried and stored for more than about 5 weeks at low or ambient temperatures (Sonwalker, 1951).

Haq (2006) reported cryogenic storage of embryos of jackfruit. Low moisture content (16- 26%) of seeds is essential for cryogenic storage. Fu and Xia (1993) and Chandel *et al.* (1995) showed changes in physiological characteristics, desiccation and freezing sensitivity for embryonic axes with increasing seed maturity. However, they faced problems as the embryo size of jackfruit was not uniform. Embryos measuring 4-5 mm from mature, unripe seeds are the best for survival and can be regenerated repetitively. The selected fresh embryos have to be partially desiccated (60% moisture content) prior to treatment with dimethyl sulphoxide (DMSO) and 0.5% proline mixture. Freezing has to be carried out in stages i.e. pre-freeze slowly at 1°C per min down to -40°C after which they are plunged directly into liquid nitrogen at -196°C.

In theory, seeds under cryogenic storage are in a state of suspended animation and should survive indefinitely. However, long-term effects on future performance after storage need further study. Thamsiri (1999) reported a 50% survival rate of cryopreserved axes extracted from jackfruit seed. Rajasekharan and Yogesh (Per. communication) reported that the moisture content of the fresh embryonic axis was around 65%. Drying of embryonic axis to below 60% moisture was found detrimental for jackfruit as it did not germinate. However, embryonic axis with moisture content of above 60% could not survive cryostorage.

*In vitro* storage of vegetatively propagated clonal material can be done by using slow growth techniques for medium-term conservation. *In vitro* methods also help to eliminate pathogens and thus conserve disease-free samples. Mandal (1997) suggested that a systematic investigation is needed to standardize methods for *in vitro* storage of jackfruit.

### **2.8.3. Field gene banks**

The majority of jackfruit germplasm is maintained in field gene banks or orchards (also called repositories or collections of living plants). These face risks of disease and pest infestation and natural disasters. The advantage of field orchards is the accessibility of the germplasm because evaluation can be carried out on the growing plants. The disadvantages are the high cost of establishment and maintenance and the risks for long-term survival. Haq (2006) reported a number of field gene banks recently established at research fields of Horticultural Centers and the Universities across Asia. Cambell *et al.* 2004 reported a large collection maintained in the field of Fairchild Tropical Garden in Florida. Small collections are maintained in fields in several other countries including Australia, Hawaii and Fiji. These collections are used as the source of genetic materials to initiate improvement programmes or on-farm testing. Under

the UTFANET project, a total of sixty seven jackfruit accessions, including indigenous collections from Western Ghats and many other parts of south India, are conserved at IIHR field gene bank (Fig. 3) for further evaluation and release of the promising types for cultivation. Under AICRP, a total of 73 accessions are being conserved for further evaluation (Anonymous, 2011).



**Fig. 3.** Field view of jackfruit germplasm at IIHR, Bangalore

## 3. Varietal Improvement

### 3.1 Introduction

Jackfruit is important in many countries in South and Southeast Asia. Jackfruit trees are common in almost every household in Bangladesh. However, reports indicate that a moderate level of genetic erosion of jackfruit diversity has already occurred in Bangladesh (Khan, 2008). In addition to the loss of jackfruit trees due to logging and clearing land for agriculture, market demand for jackfruit may lead to the replacement of local diversity with uniform exotic genotypes and consequently to the replacement of local consumption with sales to large urban markets. As a cross-pollinated and seed-propagated species, jackfruit population diversity results from the breeding system and natural selection associated with local environmental differences (evolution) or from human selection and the preferences of the local community cultivating them (domestication). As an underutilized crop, jackfruit has escaped attention for intensive selection and cultivation. However, a wide range of genetic and morphological variation has been reported for jackfruit (Azad, 1999; Azad *et al.* 2007; Hossain, 1996; IPGRI, 2000; Jagadeesh *et al.* 2006; Saha *et al.* 1996; Schnell *et al.* 2001; Shyamamma *et al.* 2008; Ullah and Haque, 2008). All these studies indicate that both within and between population variations exist. These studies have, however, been limited in geographical scope and in the number of individuals examined, as very few germplasm collections of jackfruit are known (IPGRI, 2000).

For any crop improvement programme, it is important that ideotypes are selected for different uses and products that could



be marketed, either locally or internationally and for environmental adaptations and cultural practices. Haq (1995) believed that most important characteristics of a jackfruit ideotype are: (i) easy to manage and requiring less or no pruning for fruit production; in case of timber, long straight trunks for crop diversification and agroforestry systems, (ii) vigorous and prolific plants compatible with one or more rootstocks with early flowering and regular bearing, (iii) good quality fruits with acceptable flesh colour and texture, good flavour and sweetness, (iv) fruits with symmetrical form and acceptable size, (v) resistance to fruit borer, die-back and flood, (vi) wider geographical and environmental adaptation, (vii) wide range of fruit maturity period (viii) off-season fruiting, (ix) long post-harvest life, and (x) high yield.

Very little is known about breeding of jackfruit due to its status as a minor fruit, although it has high nutritive value and a wide range of uses. Farmers selected the clones from natural populations for desirable characters but the selection has not been rigorous. Hence, some trees produce sweet aromatic fruits; others are nearly dry and sour. Better selection and vegetative propagation of clones is practicable and efforts should also be made to extend the fruiting season. Although limited work has been done on rootstock and scion compatibility, the evidence so far is that there is a wide variability in scion performance with different rootstocks (Azad *et al.* 2006).

### **3.2 Breeding objectives**

In jackfruit, the trees are erratic in bearing and the fruit yield varies every year. Hence, the first objective is to develop a variety that is regular and prolific in bearing high quality fruits. According to Bhatia *et al.* (1955), the edible pulp (bulbs) forms 29% of the ripe fruit, the seeds 12% and the outer rind 59%. The outer rind consists of soft structural matrix (non-edible

internal tissues) and fleshy yellow-green spines on the skin. The content of this mass in a fruit needs to be reduced through breeding. Sincere breeding efforts are required to enhance the weight of edible pulp from about 30% to 45% of the fruit. The seeds should constitute about 5% of the fruit and the outer rind along with internal structural matrix should not exceed 50% of the total fruit weight. Usually big size fruits are inconvenient to handle. Thus, to improve yield, number of fruits per tree should be increased instead of getting lower number of bigger sized fruits.

Jackfruit tree has a long juvenile phase (7-8 years). Reducing this period is another important breeding objective. According to Richards (1950), Singapore variety comes into bearing in about 18 months under favourable conditions in Sri Lanka. Nangka Salak is an early bearing variety in Java (Yaacob and Subhadrabandhu, 1995). Such varieties can be used as one of the parents for inducing precocity. Reduction in tree height is desired for high density plantings and also for convenience in cultural operations.

### **3.3 Inheritance pattern**

Very little work has been done on varietal development in jackfruit through hybridization. Hence, there is hardly any information on heritability of economic characters like texture of edible flesh, sweetness, seed size, and number of fruits per tree, size of fruit and thickness of rind. In breeding for improvement of qualitative traits, the knowledge of genetic correlations between traits is helpful in deciding the parents to be used in the breeding programme. Genetic investigations, particularly mode of inheritance of important characters and identification of gene(s) for seedlessness, dwarfness, resistance against fruit fly, fruit rot and soil salinity, need to be initiated on priority.

### 3.4 Selection

Varietal improvement in jackfruit is limited to selection of high yielding, better quality genotypes. The varieties grown commercially are selections made by enlightened growers or enthusiasts based on their own perceptions of suitability.

Jackfruit has a high nutritive value and a wide range of uses but it is still recognized as a minor and underutilized fruit. As a result, research investment to improve this crop has been very limited and appropriate breeding strategies have not been developed. The genetic improvement of a tree species is time consuming as it requires 15-20 years to produce a cultivar for use by farmers. There are two reasons for this, firstly, jackfruit trees require 4-8 years to reach the fruiting stage and secondly the germplasm has to undergo several stages of screening, including on-farm evaluation. Farmers' participation must also be considered during the screening process because the farmers are the producers as well as the consumers. Jackfruit trees are cross pollinated and are propagated through seeds, the progeny segregates and produces diverse types and hence, heterozygous trees are found in homestead farms and small orchards. Farmers want uniform and good quality planting materials. Several authors (Cambell *et al.* 2004; Reddy *et al.* 2004; Haq, 2006; Jagadish *et al.* 2007) have reported the selection of desirable types through germplasm characterization and evaluation. Table 14 shows a list of cultivars which have been selected through evaluation (Haq, 2006). Azad *et al.* (2007) has evaluated the diversity of jackfruit in five regions of Bangladesh and selected 10 trees as potential superior types based on farmers' criteria which include high yield, fruit quality, sweetness, early fruiting and off-season types. These types were recommended for cloning.

**Table 14. List of selected cultivars in different countries**

Country	Cultivars
Bangladesh	Topa, Hazari, Chala, Goal, Koa, Khaja
India	Khujja or Karcha, Ghila, or Ghula, Hazari, Rudrakshi, Gulabi, Hazar, NJT 1, NJT 2, NJT 3 NJT 4, Koozha Navarikka or Pazam Varikka, Safeda, Khaja, Bhusila, Bhadaiyan, Handia, Mammoth, Everbearer, Rose-scented, Kooli, Varika, Gerissal, Barica, Ghila, Karcha, Rudrakshi, Champa, Safeda, Khaja, Bhusila, Bhadaiyan, Handia, T-Nagar, Jack, Velipala, Ghulabi, Champa, Singapore or Ceylon Jack
Myanmar	Talaing, Kala
Sri lanka	Vela, Varaka (Waraka), Peniwaraka, Kuruwaraka, Singapore Jack/Ceylon Jack

*Source: Haq (2006)*

Farmers also propagated clones from selections made from natural populations for their desirable characters but the selection was not rigorous. However, as the tree is heterozygous any improvement requires a basic understanding of the existing clones. An effective selection of clones with desirable characters and vegetative propagation of these clones is practicable (Haq, 2006). Although, a little work has been done on rootstock and scion compatibility, the evidence so far is that there is a wide variability in scion performance when grafted to different rootstocks (Haq, 2006). The selection of superior mother trees and their clonal development is expected to be faster and will have greater impact than conventional breeding.

Haq (2006) reported that a major effort was made in 9 countries in Asia for characterization, evaluation and identification of trees with desirable characteristics through farmer participation. Table 15 shows the selection of superior mother plants in the second

column. These were propagated by grafting to produce relatively large number of plants for home gardens and commercial use. These trees can be grown with ease and with little or no care and it should prove to be profitable for farmers.

**Table 15. Characterization, evaluation and selection of promising lines of jackfruit**

Country	Accessions characterized and evaluated	Promising lines selected
Bangladesh	70	10
India	281	54
Nepal	350	47
Pakistan	10	5
Sri Lanka	77	3

Source: Haq (2006)

A few reports are available on the varieties of jackfruit developed through breeding programmes in different countries. The cultivars are broadly classified on the basis of a few characteristics of the fruit. The classifications was done on the basis of aroma of pulp, yield of trees, and seasonal availability of fruits. However, the other important characters were overlooked and not used for this classification due to other local names of cultivars of jackfruit (Azad, 2000; Haq, 2006).

Local selections were named as Gulabi (rose scented), Champa (flavour like that of *Michelia* sp.), Hazari (bearing more number of fruits in a tree). As a result of local survey, some better types were collected. Since raw jackfruits have good demand in India as vegetable for culinary purpose, emphasis is also given on fruit characters like thickness of rind and softness of flesh at premature stage of fruit development.

Samaddar (1985) reported that there was no distinct cultivar of jackfruit. Hossain (1996) also reported that there was no recommended variety of jackfruit for cultivation. Different types of jackfruit have come into commercial cultivation with different local names. There is very little comprehensive or reliable information on any true variety of jackfruit which has been developed through breeding programme. However, the cultivars Rudrakshki and Singapore Jack (Ceylon Jack.) in India are known to breed more or less true to type from seed (Soepadmo, 1992). These cultivars produce fruits weighing 5-20 kg within 2-5 years of planting the seedlings. In most jackfruit producing countries, there are many local names given to clonal selections which are propagated (e.g. Gulabi, Chamoora, Hazari in India; Gala, Khaja, Hazari, etc. in Bangladesh), but how these are to be distinguished from each other is not yet established. Selections that moved from one country to another were given separate names which caused confusion. In Sri Lanka, a variety called Vela with soft pulp is the same as described by de Costa as Gerisssa in India. Under these two names, there are many subtypes which differ in taste, colour, fibre content and sweetness and they have their local names. Many of the local names relate to attributes rather than places e.g. Gulabi (rose scented); Champa (taste like champedak), Hazari (producing large number of fruits) (Samaddar, 1990). Manjunath (1948) also classified jackfruit into two types on the basis of fruit size, (i) Barka - a smaller fruit type and (ii) Kapa - large fruit type. The Barka is locally called Katahali (in Uttar Pradesh) and yields small fruits (2-8 kg each) which are somewhat sour in taste. Kapa is called Kathal in Uttar Pradesh and neighbouring states, yields large fruits weighing up to 40 kg and at ripening has fleshy sweet bulbs. Sreenivasan (1970) reported a local cultivar, Muttam Varikha, with an average weight of 7 kg in Tamil Nadu (India) produced at ground level and with a large fruit weighing up to 55 kg. Singh (1986) also reported local selected strains, Hairialyalva,

Bhadunha, Zarda and Bhusala from Northern India. Morton (1987) reported selected cultivars of jackfruit which included Safeda, Khaja, Bhusila, Bhadaian, Handa, T-Nagar Jack and also Velipala a local selection from the forest having large fruits with superior quality large bulbs.

Recently, a crop improvement programme at the University of Agricultural Sciences, Dharwad, India has been initiated (Jagadish *et al.* 2007) and 65 types from the hill zone and 30 from the coastal zone were evaluated and promising types selected. Further breeding work involving these selected materials is in progress.

Farmers participatory methods are useful for the varietal selection of any crop because farmers are best placed to know the preferences of the market. The farmers also play an important role as retailers in the local market. Therefore, awareness of farmers about market preference has made the selection process more acceptable, because the farmers are involved as producers, consumers and retailers of jackfruit. However, farmers use seeds of the mother trees for propagation which fail to maintain trueness to type. Therefore, a little impact of this selection was found in the development of cultivars. Selection will only be effective by propagating from superior mother trees using asexual means. The farmer preferences are for high fruit yield/plant, longer fruiting season, desirable flesh colour and texture and sweetness of the fruit, which should be kept in view in the selection/breeding programmes.

Gunasena *et al.* (1996) stated that hybridization in jackfruit is cumbersome and time consuming and hence is not considered suitable. Therefore, selection of superior mother trees from the existing population is more successful and convenient as it saves time, money and effort. Jackfruit can live up to 100 years and has a very long juvenile period before coming into bearing. The large number of varieties now available have apparently evolved through

natural crossing. These varieties are selected by professional tree breeders principally based on fruit characteristics. Varieties or hybrids of jackfruit selected for their timber characteristics have not been reported. But, selections have been made from the characterized germplasm and have been released in different regions.

### 3.5 Improved varieties

#### 3.5.1 India

***Palur 1 Jack or PLR, 1*** : Tamil Nadu Agricultural University (TNAU) in India developed this improved variety (Fig. 4) in 1992. It is a clonal selection from Panikkankuppam local of Panruti taluk, in South Arcot district of Tamil Nadu. It is high yielding with medium height, less spreading and suitable for high density planting. In addition to regular bearing season (March-June), it produces fruits during off season (October- December) also. The annual yield per tree is about 80 fruits weighing around 900 kg. The average fruit weight is 12 kg containing 115-120 flakes. The



**Fig. 4.** *PLR 1 variety of jackfruit*



off season bearing is a unique trait of this variety and the fruits fetch premium market price. The fully ripe fruits have flat stigmatic surface instead of spiny surface. The fruit quality is good with attractive golden yellow firm flakes. The flakes are very sweet with high consumer appeal and good keeping quality. The seeds are also edible with high palatability. TSS is 19°brix.

***PPI 1 Jack*** : Tamil Nadu Agricultural University (TNAU) has developed this improved variety (Fig. 5) in 1996. It is a clonal selection from Ulagumoodu Local near Pechiparai. It is a medium tall tree, yields 105 fruits per tree per annum (each weighing 17 kg) which accounts for 40.8% more yield than local. The fruit bearing occurs twice annually (April-June and November - December) and produces high quality crisp carpels with high TSS and ascorbic acid content. The flakes are sweet and tasty



**Fig. 5.** PPI 1 variety of jackfruit

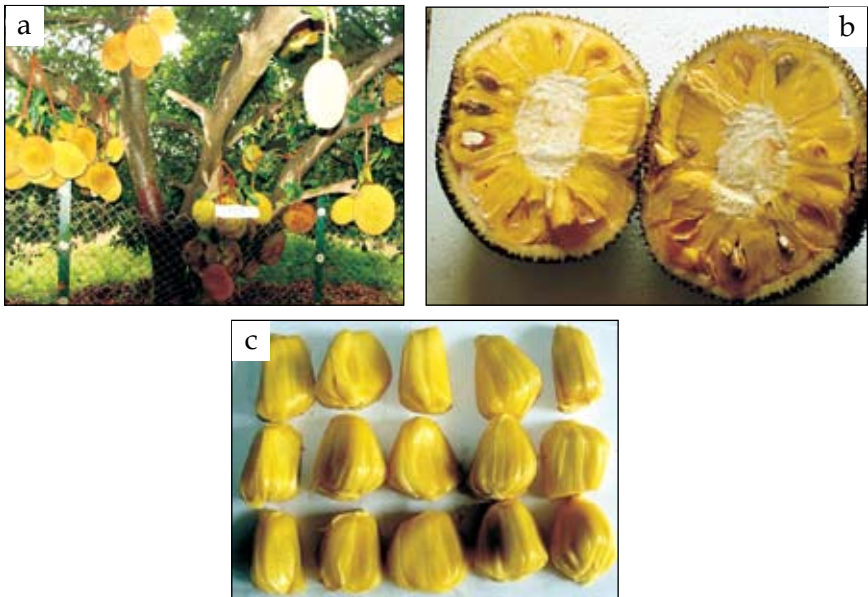
with pleasant aroma. The maximum bearing takes place on tree trunks. This variety is suitable for commercial planting and home gardens.

**PLR (J) 2:** Tamil Nadu Agricultural University (TNAU) developed this improved variety (Fig. 6) during 2007. It is a clonal selection from Pathirakkotai Local. It possesses good quality and bigger size fruits, and highly palatable and edible flakes and fetch more price due to attractive characters and better keeping quality resulting in increased income to the farmers. This is having less incidence of major insect-pests and diseases. This can be planted during June–December. This is suitable for growing in tropical climates of deep well drained loam soils. This variety yields 95–110 fruits/tree/year weighing an average of 1600–1950 kg. This is suitable for growing in tropical climates and deep well drained loam soils.



**Fig. 6.** PLR (J) 2 variety of jackfruit

**Swarna** : The University of Agricultural Sciences, Bangalore, Karnataka (India), released a jackfruit selection Swarna (Fig. 7) in 2010. Swarna is a very good yielder that bears fruits in bunches on the trunk, primary branches and also on the secondary branches. The medium sized fruits weigh 6-8 kg each. The fruitlets are golden brown in colour, juicy with a TSS of 25-26 °Brix, with thick flakes and a very thin rind (< 1.0 cm). Ten trees of this variety were planted at the university premises.



**Fig. 7.** Swarna variety of jackfruit : (a) fruiting branch, (b) cut fruit, (c) flakes

**Gumless Type (Pre-released)** : The gumless type (Fig. 8) developed at the Indian Institute of Horticultural Research (IIHR), Bangalore, India has medium to low latex with medium fruits (6.4-9.0 kg) having oblong fruit shape containing 120-140 flakes/fruit with



**Fig. 8.** Gumless jackfruit (Pre-released) : a) matured fruit, b) cut fruit, c) flakes

flakes: fruit ratio of 0.45-0.50. The flakes are light yellow, sweet in taste having TSS of 26-30°Brix has been found promising and is under the process of release.

**Konkan Prolific :** This variety (Fig. 9) was released in 2004 by the Regional Fruit Research Station (RFRS), Vengurle of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra. It is a seedling selection with a potential yield of 450-550 kg/tree and average yield of 420.56 kg/tree producing 73 fruits/tree/year with individual fruit weight of 5.70 kg, fruit length of 34.4 cm fruit breadth of 15.2 cm, medium sized fruit, oblong shape, firm flesh even in monsoon season, golden yellow colour of flesh, fruit bearing in bunches, spiny surface, flowering in January –



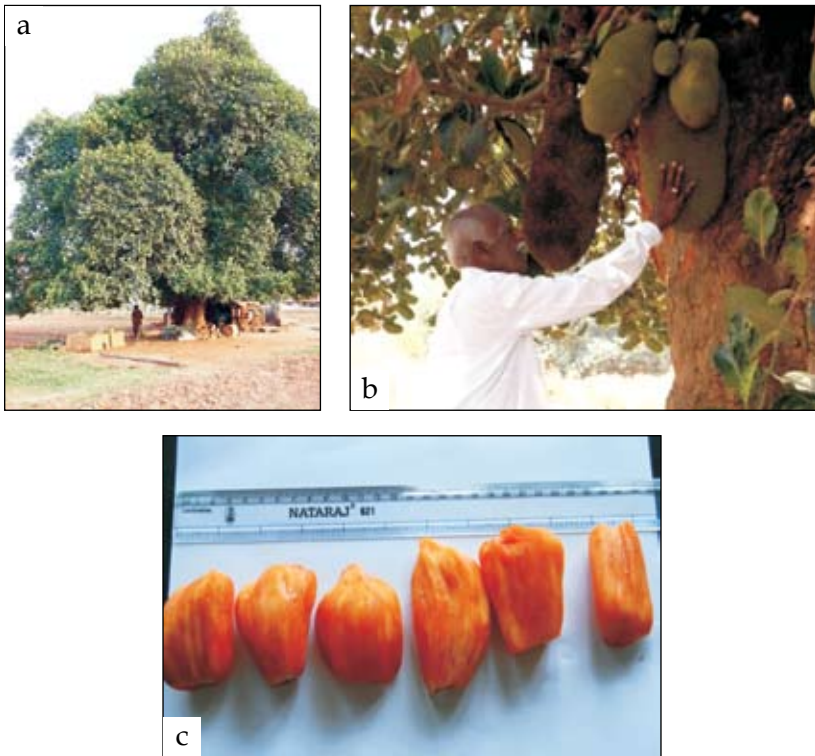
**Fig. 9.** *Konkan Prolific variety of jackfruit*

February, bearing after 6-7 years of planting. Fruits have TSS of 25 °Brix and seed weight of 132 g.

***Registration and GI facilitation for the jackfruit :*** A 300 year old elite jakfruit tree (Fig. 10) located in Kachahalli village Thubagere taluk of Doddaballapur district, Karnataka, India in has been documented for its excellent fruit qualities. The fruits are ellipsoid/elongate shaped weighing 20-25 kg and having 300-350 flakes per fruit. The flakes are deep coppery red coloured and possess very high TSS of 32°Brix.

### **3.5.2 Bangladesh**

***BARI Kanthal 1 :*** This variety was developed by Horticulture Research Center in 2008. This is high yielding, variety with regular bearing, early maturity, medium size fruit, uniform fruit shape weighing 9.5 kg. The pulp is medium soft, having very sweet (TSS 22°Brix) taste and less fibre content and is very juicy. The edible portion accounts for 55%. The variety yields 11,800,



**Fig. 10.** Kachehalli jackfruit : a) old tree, b) abundant fruiting, c) flakes

medium size fruits/ha. The fruit colour is light green. It is suitable all over Bangladesh and can be sown during June-September. The harvesting time is May-June. Further attention needs to be given to developing improved fruiting cultivars with good timber characteristics, especially for home gardens. In many cases, the use requirements can be in conflict since good timber types are not necessarily also good fruiting types.

### 3.6 Hybridization

There is hardly any published report on hybridization in jackfruit. As wide genetic variability exists in this crop, there is an

apparent need to exploit heterosis for yield gain and improvement in fruit quality. Interspecific hybridization also deserves attention in order to know the species that are compatible with jackfruit and their contribution in a particular direction, for example, tree size (dwarfness), precocity, hardiness for salt, low water stress, etc. The jackfruit and breadfruit have considerable potential. Planned breeding with the aid of biotechnological skills is required in order to exploit their potential.

The Fruit Experimental Station at Kallar started breeding work in 1952 with a view to developing short, compact, multi-branched trees; precocious and productive; bearing large, yellow, high quality fruits, 1/2 in the main season, 1/2 late. The variety Singapore Jack was chosen as the female parent because of its early and late crops and Velipala, a local selection from the forest having large fruits with large carpels of superior quality, and borne regularly in the main summer season was selected as the male parent. After 25 years of testing, one hybrid was rated as outstanding for precocity, fruit size, off-season as well as main season production, and yield excelling its parents. It had not been named when reported by Chellappan and Roche in 1982.

### **3.7 Biotechnology**

Biotechnological techniques could be useful in breeding for seedlessness, disease and insect-pest resistance, salt tolerance and germplasm conservation. Jaiswal and Amin (1992) reviewed the work done on this aspect and reported that so far selection from seedling population is the only breeding method used in jackfruit because this is monoecious in nature and commonly raised from seed. Biotechnological approaches like cell hybridization, organelle transfer, genetic transformation (i.e. generation of new genetic combinations), protoplast fusion, anther culture (haploid production) and embryo culture (rescue) are yet to be employed

to produce both intra and interspecific hybrids. Tissue culture techniques have been developed for faster multiplication of improved genotypes using nodal segments (Roy *et al.* 1990) and terminal and axillary buds (Roy *et al.* 1991) as explants. Dumet and Berjak (1995) suggested that cryopreservation of embryogenic axes can be helpful in establishing a genebank.

### **3.8 Current improvement efforts**

A major effort has been made to initiate selection by carrying out standard characterization and identification of trees with desirable characteristics. This was done under the auspices of Underutilized Tropical Fruits in Asia Network (UTFANET). The effort was intended to be participatory with farmers. Different participating countries of UTFANET characterized and evaluated the germplasm. Further, superior mother plants were selected and were used for vegetative propagation by grafting to produce relatively large number of plants for home gardens and commercial use.



## 4. Package of Cultivation Practices

Jackfruit is grown in homestead mostly without any management practices. As no fertilizer is applied to the homestead maintained jackfruit, it also has the potential to be identified as one of the promising fruits grown organically in Kerala by default. Although there is large number of indigenous varieties of jackfruit grown in the state, systematic documentation regarding the varieties is yet to be done.

### 4.1 Seed propagation/ sexual propagation

Jackfruit is a highly cross pollinated crop due to its monoecious habit, and plants raised from seed never bear fruits true to the type of the mother plant. The most common method of propagation of jackfruit is by seed which is easy and cost effective method and is suitable for cultivation of jackfruit trees for the purpose of fodder, timber, and shade where the quality of the fruit is not very important. However, the seeds may be selected from a well ripened jackfruit obtained from a plustree. Generally, 4-5 seeds are planted *in situ* so that the tap root can grow undisturbed and also as it has a fragile tap root. Seeds are sown 2-3 cm deep in pits of 50 cm × 50 cm × 50 cm, filled with cow dung or compost (20-30 kg/pit). Pits are covered with mulch and regularly watered. Germination starts within 10 days and 100% seeds germinate within 35-40 days. Shortly after germination, only the most vigorous seedlings are retained and the weaker ones are removed (Haq, 2006).

The seedlings can also be raised in pots or poly bags. After one or two years, the seedlings are planted in the field. Seeds should be sown immediately after extraction since they lose their viability during storage (recalcitrant). The germination percentage declines

to 40% after 30 days of storage. More than 70% seeds germinate within 15 days of extraction. However, the farmers of the Konkan region of Maharashtra (India) separate the seeds of jackfruit from the pulp and dry them under shade. Upon drying, they are coated with red soil, dried and stored in air tight containers in a cool place. Seeds stored in this manner retain viability until the next planting season. The seed viability of the species has been reported as 14 days. The need for prolonging the viability of *A. heterophyllum* seeds gains attention both due to being a recalcitrant species and for the purpose of germplasm conservation. The viability of seeds can be prolonged to 32 weeks (with 48% germination) when stored at 20°C (Rekha *et al.* 2009). Results at IIHR, Bangalore revealed that drying of embryonic axis to below 60% moisture was found detrimental for jackfruit as it did not germinate. However, embryonic axis with moisture content of above 60% could not survive cryostorage (Rajasekharan and Yogeesh, Personal communication).

Vivipary is also noticed in jackfruit under favourable conditions for germination. However, seeds can be stored for short periods if buried in dry sand or coir dust (Soepadmo, 1992). Seeds stored at 40% moisture content in airtight polythene containers at 20°C can remain viable for about three months. If the cotyledons start drying and shrivelling, the seeds will not germinate. Soaking seeds in 25 ppm NAA for 24 hours improves their germination and seedling growth.

Soaking of seed in water for 24 hours improves germination. The germination was reported to be 100% on soaking seed in GA upto 500 ppm for 48 hours. It takes 6-12 months to get the rootstock ready for grafting. Delayed transplanting beyond four-leaf stage causes seedling mortality upto 20%.

For raising seedlings to be used as root stocks, the seeds are sown in the nursery, in seed beds or containers/pots. When the seedlings reach four-leaf stage, they are transplanted to large poly bags.

## 4.2 Vegetative propagation

Vegetative propagation produces progeny which are genetically identical to the mother plant. The most common vegetative propagation methods include: cuttings, layering and air layering, budding and grafting onto seedling rootstocks and *in vitro* tissue culture. The success of the different vegetative propagation methods and the advantages and disadvantages vary and depend on the local climate, water availability and, in the case of grafting, on suitable rootstocks.

Vegetatively propagated plants tend to be relatively shorter in stature than those propagated from seed, which makes management and harvesting easier. Trees produced from physiologically mature vegetative material bear fruits earlier than trees grown from seed. Disadvantages of vegetative propagation may include trees which are shallow rooted and which form branches from a low level, thus affecting the trunk length if good quality timber is a major requirement for growing the tree. Vegetative propagation should be carried out at the end of the rest period of vegetative growth during spring and summer. The following vegetative propagation methods are being adopted in jackfruit:

### 4.2.1 Stooling or mound layering

Stooling or mound layering is successful in jackfruit and treatment with IBA improves rooting of layered shoots. Soil mounding upto 10 cm height around the basal shoots for 15-20 days is a pre-requisite. After that, the soil is removed and a ring of bark is removed from etiolated shoots. Indole butyric acid (IBA) with concentration of 5,000 ppm in lanolin paste is applied and callus formation will take place within 10 days. Earthing has to be done once again. After a month's time, rooting will take place.

### 4.2.2 Cutting

Propagation by cutting is not so common, pre-conditioning

(especially etiolation) or stock plant treatment with ethephon before taking cutting and treating the cuttings with IBA (5,000 ppm) and P-hydroxybenzoic acid (200 ppm) at the time of planting was found effective in inducing rooting of semi-hardwood cutting. Soft wood cuttings can also be rooted but with difficulty. Side branches as well as branches arising from stooled trees can be the source of cuttings. Mowry *et al.* (1941), Bailey (1949) and Morton (1965) reported successful propagation of jackfruit using cuttings. Rowe-Dutton (1985) recommended the most suitable stage for preparing cutting for faster rooting. The percentage of success for cuttings can be improved by special treatments and application on of growth regulator (Mukherjee and Chatterjee, 1978; Chatterjee and Mukherjee, 1980; Biswas and Kobayashi, 1989). Use of IBA at 500 ppm alone or in combination with ferulic acid (2,000 mg/l) and IAA (1,000 ppm) has been reported for induction of rooting. Biswas and Kobayashi (1989) observed that rooting of jackfruit stem cuttings was not possible without the use of IBA.

### 4.2.3 Air layering

It is another successful vegetative propagation method in jackfruit. However, the success rate depends on season and other agroclimatic conditions. Moist sphagnum moss, coir husk, coir dust, fine wood shavings or sand is used as rooting media for air layers. In this method, a ring of bark of about 5 cm wide is removed from two year old shoots and covered with moist rooting media. Three to four months old shoots of the current year's growth are ideal for layering. Polythene sheet is used to cover the rooting media and the ends are properly secured. The roots emerge in about 2-3 months. After rooting, a notch is made below the point of layering. Subsequently, this notch will be dependent gradually till the layer is finally separated from the mother plant. About 60-100% success has been observed for air layering (Sen and Bose, 1959; Madhav Rao, 1965). Etiolation and growth regulator application are helpful to improve the success rate of air layering.

Auxins like indole butyric acid (IBA), indole acetic acid (IAA) and naphthalene acetic acid (NAA) are useful in this regard (Madhav Rao, 1965). The cut surface of the stem has to be treated with growth regulator solutions at concentrations ranging from 250-7,500 ppm (Singh, 1951; Sen and Bose, 1959; Lavania *et al.* 1995; Singh and Sharma, 1995; Singh and Singh, 2004). Season has a profound influence in the success rate of etiolation. Lower rates are observed during rainy season. Sometimes, a combination of two auxins is useful for inducing better rooting. Black polythene sheet is preferred for covering the rooting medium. Etiolation for about one month increases the rooting (Dhua *et al.* 1983). Thus, treatment with IBA markedly improves the root formation in air-layering of shoots like girdling, etiolation and treatment with IBA, and NAA are more effective in rooting of air layers.

#### 4.2.4 Grafting

Grafting is the most reliable method of propagation. Grafted trees will bear fruits in 2-3 years after planting and have a more spreading and open canopy than seedling trees. Jackfruit grafting is now becoming a viable method of propagation. Today, grafted cultivars are common in India, Indonesia, Malaysia and Thailand and increasingly in South Florida. The grafting method is suggested as a pronounced traditional method for propagating the jackfruit as it maintains good characters, is easy and cheap procedure, produces disease free plants, trees start fruiting quickly and, it needs a few plant materials and less treatments than the other methods. In many cultivation areas, the seed is the major method of propagation and used in the rootstocks production.

Usually, the rootstock will be of any cultivated variety. Grafts of jackfruit can also be produced on the rootstocks of Rudrakshi variety or the wild species *Artocarpus hirsuta*. Rootstock has profound influence on the performance of the graft. Rudrakshi is considered as the best rootstock, resulting in earliness and high yields.

**4.2.4.1 Inarching :** In south India, inarching of jackfruit is successful using *A. hirsute* or Rudrakshi as rootstock. Epicotyl grafting with mature, plump, terminal scion shoot on germinating jackfruit seedling of about 8-10 weeks by wedge method during April-May could be successful. This method is widely practiced in Kerala for the large scale production of grafts of Muttom Varikka, a popular jackfruit variety that comes to bearing in the third year of planting. This is a cumbersome process and hence not so common though the success reported is better than other methods.

**4.2.4.2 Epicotyl grafting :** Epicotyl grafts attain saleable size within a year. The grafts become ready for planting in one or two years after grafting. Epicotyl grafting is reported to give 50-90% success in April-May. It was observed to give about 30% success in Bangladesh, while in India, the success rate was up to 90%. Age of the rootstock is critical in the success of epicotyls grafting. Epicotyl grafting on a 15 day old rootstock resulted in 46% sprouting but only 3% survival (BARI, 1990). Deshai and Deshai (1989) tried softwood grafting in jackfruit, with a success rate of 33-80%.

**4.2.4.3 Veneer grafting :** It is also adopted for jackfruit propagation (Reddy, 1998). It involves 4-5 month old terminal shoots and one year old rootstocks. Other methods of grafting have also been found successful in jackfruit. However, the success rate is not often satisfactory. A form of approach grafting known as suckle grafting is used in Thailand. In this method, the seedling rootstocks are decapitated and inserted in twigs of selected mother trees. Whip grafting is also successful in jackfruit. In this method, the cut ends of rootstocks and scion are cut again to form tongues which are interlocked and tied together tightly.

**4.2.4.4 Success in grafting :** The various methods of grafting in jackfruit have to be refined further for better results (Soepadmo,

1992). Considerable variability exists in the success rate of various grafting methods reported by various research workers. Naik (1952) achieved 60-70% success through inarching using rootstocks (Rajan, 2011) of *A. hirsutus* and *A. champedak*. Raman (1957) obtained 90% success in inarching using six superior varieties of jack. Kannan and Nair (1960) observed that inarching on rootstocks of *A. heterophyllus* was better, compared to other rootstocks. Quasem (1982) reported 90% success in modified inarching using 3-4 month old rootstocks. Quasem and Shakur (1984) reported that veneer grafting using one year rootstocks was successful during April. Swaminathan and Ravindran (1989) reported 60-90% success in inarching. Vijayakumar *et al.* (1991) observed that green wood cleft grafting was the easiest method. Dhar (1998) made a comparative study of epicotyl, cleft, splice grafting and veneer methods in jackfruit and recommended splice grafting as the best method. Azad (2000) compared veneer, cleft, splice and epicotyl grafting in Bangladesh and obtained 80% success with veneer in April and 70-73% success with cleft and splice grafting in November. Based on diverse results on the application of different grafting methods and differences exhibited between regions, Haq (2003) recommended specific methods of vegetative propagation suited to different countries as no single method is universal.

#### 4.2.5 Budding

Budding is another successful vegetative propagation method in jackfruit. However, the success rate varies drastically with season. Different types of budding like modified forkert budding, chip budding, patch budding, shield budding and ring budding are suitable for jackfruit propagation. These methods have been adopted with varying success in different countries.

Modified forkert budding is adopted for the propagation of jackfruit in Sri Lanka (Naik, 1952). Chip budding has low percentage

of success (Sammaddar and Yadav, 1970). Patch budding has been reported to be highly successful (Tonotia *et al.* 1963; Singh *et al.* 1982). In Bangladesh, ring budding found to yield upto 80% success (Biswas and Hossain, 1984). However, the success rate ranged from 20-80%, as influenced by season. The maximum success was in May, while the lowest rate was in June. Flute budding has been found to give 60% success in May and 40% in June. T-budding is not very much successful. Konhar *et al.* (1990) observed that the highest (80%) success for patch budding was during July-August. Kelasker *et al.* (1991) observed that retention of leaves on the rootsstock during budding had no effect on the success rate. They recommended polythene strips for tying the bud in place in order to maintain high humidity at the graft union.

#### 4.2.6 Recommended methods for vegetative propagation

Based on diverse results on the application of different grafting methods and differences exhibited between regions, Haq (2003b) recommended specific methods of vegetative propagation suited to different countries (Table 16).

**Table 16. Methods recommended for vegetative propagation of jackfruit in different countries**

Country	Recommended methods
Bangladesh	Veneer, cleft and epicotyl grafting
India	Softwood and epicotyl grafting
Indonesia	Top grafting
Nepal	Splice and cleft grafting
Pakistan	Stem cutting
Philippines	Modified cleft grafting
Sri Lanka	Wedge grafting
Thailand	Modified inarching grafting
Vietnam	Cleft, epicotyl grafting



### 4.3 Micropropagation

In jackfruit, new plantlets are successfully raised from nodal explants and shoot apices cultured on MS medium supplemented with various concentrations of cytokinin for shoot proliferation and sub-cultured on similar medium supplemented with different concentrations of auxin for root regeneration (Tables 17 and 18). Besides other advantages of *in vitro* propagation, it also helps in the production of uniform progeny from highly heterozygous plants like jackfruit and are reported to grow faster and mature earlier than the seed propagated plants. There are only a few reports on the tissue culture propagation of jackfruit. The first report was made by Rao *et al.* (1981). Rapid multiplication through enhanced release of axillary buds was successfully attempted in jackfruit by Rajmohan and Mohanakumaran (1988a). Selection of suitable explants is the pre-requisite and maturity barrier is a serious problem, affecting the *in vitro* response of explants from jackfruit. This maturity barrier in tissue culture can be overcome to a great extent by several techniques. Use of explant from the most juvenile part of the tree, stem sprouts and stump sprouts, serial grafting of mature scion on to juvenile rootstocks, etiolation of mother plants, spraying plant growth substances on mother plants, repeated rooting of shoots, frequent subculturing and stress treatment of the explants (providing heat shock, cold shock, centrifugation, etc.) are found effective (Peter *et al.* 2006). In spite of the several reports as reviewed by Peter *et al.* (2006), they opined that *in vitro* propagation of jackfruit from mature trees of known superior traits needs to be refined further to evolve reliable protocols, suitable for commercial adoption. Much more work is needed to establish the protocols for successful *in vitro* propagation.

**Table 17. Results of different *in vitro* methods for multiple shoot regeneration**

Explant	Media additives	Investigators
Axillary buds	BAP (30 mg/l) NAA (1.0 mg/l)	Rao <i>et al.</i> (1981)
Nodes	BAP (0.5 mg/l)	Rahman and Blake (1988a)
Nodes	BAP (1.0 mg/l) Kinetin (0.5 mg/l)	Roy <i>et al.</i> (1990)
Shoot tips and axillary buds	BAP (1.0 mg/l) NAA or IAA (0.5 mg/l)	Roy <i>et al.</i> (1991)
Shoot buds	BA (8.8 µM) NAA (2.7 µM)	Roy <i>et al.</i> (1993)
Shoot tips and axillary buds	BAP (1.0 mg/l) NAA (0.05 mg/l)	Roy and Hadiuzzaman (1991)
Shoot tips and apical buds	BAP (4.5, 9.0, 18.0, 36.0 µM)	Amin and Jaiswal (1993)
Shoot apices	BAP kinetin (1.0-2.0 mg/l)	Dhar (1998)
Shoot apices	TDZ (4.54 µM)	Murthy <i>et al.</i> (1998)
Shoot apices	BAP (2.0 mg/l) TDZ (0.5 mg/l)	Azad (2000)

Source: Haq, 2006

**Table 18. Results of regeneration using different methods for rooting of regenerated shoot**

Media additives	Rooting (%)	Investigators
IBA (2 mg/l), NAA (2 mg/l), sucrose (30 mg/l) and agar (6 g/l)	80	Rajmohan and Mohanakumaran (1988)

Contd...

Table 18 (Contd...)

Media additives	Rooting (%)	Investigators
½ MS+ kinetin (0.05 mg/l)+ IBA (1.5 mg/l)	98.6	Roy and Hadiuzzaman (1991)
IBA or NAA (10 µM)	60-80	Amin and Jaiswal (1993)

Source: Haq, 2006

#### 4.4 Planting

For planting jackfruit, 1 m<sup>3</sup> cube pits are dug at least 10 days before planting. About 30 kg well-rotted farmyard manure and 500 g superphosphate are mixed with the soil of each pit and the pit is refilled. Chloropyriphos may be applied in the pit to avoid insect attack. *In situ* planting of 3-4 seeds per pit and later retaining only one leads to stronger plant. After planting, the soil is pressed firmly to avoid water-logging in pits during rainy season as jackfruit cannot withstand water-logging.

The young plants should be protected from stray goats and cattle. The best time for planting vegetatively propagated plants or seedlings is at the beginning of the rainy season. Prolonged dry weather after planting may lead to the death of plants. The taproot should not be disturbed while planting to avoid damage to plants.

At maturity, jackfruit trees not periodically pruned become large trees. If little or no pruning is planned then jackfruit in the backyard gardens should be planted 7.5-9.0 m away from other trees and structures. If annual or semi-annual pruning is practiced, jackfruit trees may be planted 6.5-7.5 m away from other trees and structures. Trees planted too close to other trees or structures may not grow normally or produce abundant fruits due to shading (Haq, 2006).

#### 4.5 Training and pruning

Jackfruit does not respond well to indiscriminate pruning and

it is not commonly practiced. Young trees do not need pruning in the first year. However, when older trees are not pruned, a strong central leader usually develops which is desirable for its timber value. Nonetheless, where fruit production is the main purpose, pruning of the first lateral branches should be carried out in year two to slow upward growth and enhance the spreading of the canopy. One or two pruning of shoot tips during summer causes lateral bud break and makes the tree more compact. Grafted trees have a dwarfing tendency but produce a large number of branches from the beginning. These branches should be continuously pruned to get a reasonable trunk. Thereafter, branches may be allowed to remain but removal of vigorously growing upright shoots is recommended. Inner branches of the canopy should be removed to allow more light and air within the canopy. However, research results are warranted for further improving the productivity.

Regular pruning of weak, dead and diseased branches and removal of parasitic plants at the end of the rainy season is recommended. This prevents insect infestation and disease infection. Tree height and size may also be controlled, if desired, by pruning.

Old flowering shoots should be removed after harvesting and then the branches should be thinned out to increase light penetration to the inner canopy. The height of the tree should be maintained at about 4-5 m by periodic selective pruning. Selective pruning is also effective for equipment movement and other management operations. Trees may also be mechanically topped at about 4-5 m and hedged at a 5-10° angle from the vertical.

Fruit thinning is also recommended to prevent damage to branches as heavy fruit load breaks branches and can result in death or stunting of the tree. Limiting the number of fruits per limb may also improve the quality of the fruits and increase their size. However, not much research data is available on these aspects. A simple technique, thinning produces bigger fruits and is being

followed by the farmers of Panruti (coastal taluk) in Cuddalore district of Tamil Nadu, India. At a tender stage, excessive fruits are cut off allowing only selected ones to grow. Only two fruits are retained at one place. Consequently, only average size and big fruits flow into the market. This resulted in production of fruits not smaller than 15 kg (Padre, 2011).

#### **4.6 Aftercare**

Jackfruit leaves are a favourite feed for cattle and the young plants are frequently damaged by stray goats and cattle unless adequately guarded by providing gabions for about two years. Gabions need to be replaced after a year. Hand watering of young plants during summer is necessary for assured survival and good growth of plants during initial stage of crop. In cooler regions, protection against frost at least during the first few years is safe. Cleaning of basins by spading and ploughing of orchards should be followed as a routine measure. Frequent weeding and mulching are necessary to achieve normal plant growth. In Bangladesh, survey results revealed that dropping of flowers and fruits are a common problem in case of off-season jackfruit cultivation. The main cause of fruit and flower dropping was water deficiency as indicated by majority (77.14%) of the respondents. The other causes were diseases, insect-pests and nutrient deficiency as mentioned by 8.58%, 7.14% and 7.14% of the respondents, respectively (Manna *et al.* 2006).

#### **4.7 Integrated nutrient management**

Jackfruit is a homestead tree crop and not much work was done on determining the fertilizer requirement of jackfruit. Farmyard manure (FYM) or home produced compost is sometimes used to advantage, especially in home gardens. However, the trees need good nutrition to promote regular and good bearing. For quick growth of trees, manure should be applied twice a year, before and after monsoon. It is advisable to apply 20-30 kg of farmyard manure

per tree per year. The manures should be spread in the basin and thoroughly mixed with soil by spading. The manure should be applied in an area up to the leaf drop around each tree leaving a portion around the trunk. The quantity and type of fertilizer required depends on the vigour and age of trees, and the fertility of the soil. However, region specific nutrient needs of jackfruit need to be worked out. The recommended amounts of manure and fertilizers in Bangladesh are presented in Table 19. The Bangladesh Agricultural Research Council has other recommendations (Table 20).

**Table 19. Recommended doses of manure and fertilizers for jackfruit trees in Bangladesh**

Doses of manure and fertilizers/tree/year	Age of tree (years)				
	2-4	5-7	8-10	11-20	>20
FYM (kg)	10	15	20	25	30
Urea (g)	200	250	300	350	500
Triple super phosphate (g)	250	250	500	750	1000
Mauriate of potash (g)	100	200	250	300	500
Gypsum (g)	100	100	200	300	500

Source: Hossain and Haq (2006)

**Table 20. Recommended doses of fertilizers from planting to fruiting per plant**

Manure/nutrient	Before planting	Age of tree (years)					
		0-1	2-4	5-7	8-10	11-15	>20
FYM/cow dung/ compost (kg)	25-35	0-1	2-4	5-7	8-10	11-20	100
N (g)	0	20-30	30-40	40-50	50-60	60-75	920
P (g)	100	100	180	260	380	550	300
K (g)	125	60	100	150	200	250	500
S (g)	45	100	150	200	300	400	85

In India, University of Agricultural Sciences, Dharwad has recommended the doses of nutrients as per the package of practices (Table 21).

**Table 21. Recommended doses of nutrients for jackfruit in India**

Nutrient (g/tree)	Age of tree (years)		
	1 - 3	4 - 7	>7
N	200	400	600
P	120	240	300
K	60	120	240

Source: Anonymous (2007)

Further, Haq (2006) also reviewed the recommendations for application to bearing trees and is shown in Table 22 along with the spacing being adopted.

**Table 22. Application of fertilizers in four states of India (kg/tree)**

State	Spacing (m)	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	FYM
		g/tree/year	g/tree/year	g/tree/year	kg/tree/year
Assam	10 × 20	210	150	1000	20-30
Karnataka	10 × 10	600	300	240	50
Madhya Pradesh	10 × 10	800	430	1050	100
Tamil Nadu	6 × 6	750	400	500	50

Source: Tandon (1987)

Halder *et al.* (2008) reported the effect of boron for correcting the deformed shape and size of jackfruit, dropping of female spikes and irregular shaped fruits are cardinal problems in jackfruit production in Bangladesh. One of the reason might be that the female spikes generally appear on the trunk and main branches.

On the other hand, the male spikes appear in the periphery. Their anthesis period is also not synchronized. So, there is a possibility of improper pollination. If the flowers on all the sides are not pollinated, the fruit does not develop normally and as a result the size and shape may be small and irregular. Lack of pollination may also lead to dropping of the female spikes (Samaddar and Yadav, 1982; Tessa *et al.* 1996a). The number of fruits per tree is dependent on the number of female spikes and the ratio of male to female spikes (Sankar and Singh, 1965; Tessa *et al.* 1996b). The final size and the shape of the fruit depends on the number of flowers pollinated and fertilized and the pattern of pollination of flowers. Unfertilized flowers also lead to irregular shape of the fruits (Sharma, 1964).

It has been found that boron deficiency restricts the germination of pollen grains. Imbalanced fertilization sometimes enhances depollination. If pollination and fertilization fail to occur within 3-6 days after anthesis, the fruits become twisted and shrivelled in shape (Bose, 1990). Boron may stimulate the normal flow of hormone and enhance pollen grain and pollen tube formation. It also increases the stickiness of the stigma for receiving the pollen grains. In Bangladesh, an experiment was undertaken to find out the optimum dose of boron for correcting the deformed shape and size of jackfruit. The results revealed that 20 year old trees with 15 g boron/tree along with the blanket dose of N-P-K-S-Zn at 920:200:250:85:20 g/tree/year, respectively, along with 10 kg cow dung was optimum for increasing normal number of fruits and lowering the number of deformed fruits per tree. Considering the nutritional importance and epoch-making change in correcting the deformation of jackfruit, 15 g boron/tree for 20 years old trees along with the said blanket dose of fertilizers has been prescribed for boosting the jackfruit production in the hill region of Bangladesh.



## 4.8 Cropping systems

The jackfruit requires a long time to occupy fully the land provided during planting for future mature trees. It is desirable that the inter-spaces should not be left unutilized. Root distribution studies of the wild jackfruit tree revealed that most of the physiologically active roots were concentrated within the radius of 75 cm and 30 cm depth. Although tap root might reach even deeper, the tree roots seldom extend beyond 2.25 m laterally from the stem, hence the effect of overlapping root zones and the associated competitive effects may not be serious problem for intercropping during the first few years (<10 years after planting) of tree growth (Jamaludheen *et al.* 1997). When the soil moisture is not a limiting factor, vegetable crops like okra, brinjal, chilli, tomato and pulses like kalai, gram, etc. can be conveniently grown. When the trees come into bearing, pulses like gram and kalai can be grown as intercrops. These crops will also improve the nitrogen status in the soil.

## 4.9 Irrigation

The species is intolerant to poor drainage (Soepadmo, 1992) and roots fail to grow under flooded conditions. Unless drainage canals are constructed, waterlogged areas cannot be used for growing jackfruit. The soil at the base of the plant should be raised to prevent water stagnation. Irrigation during dry periods is considered essential in arid regions for normal growth. Costa *et al.* (2000) reported the effects of shade and water stress on growth in jackfruit. The trees are sensitive to drought. In order to economise use of water, ring system may be adopted for irrigation. Alternatively, drip irrigation may be followed so as to economise water use. For young orchards, hand watering is necessary during first 2-3 years till the root system has penetrated deep enough. The frequency of irrigation will depend on the soil moisture condition. Protective irrigations

are necessary initially at 12-15 days intervals depending on soil and climatic conditions. The frequency and quantity of irrigation will depend on the weather and soil moisture conditions, but jackfruit responds well to irrigation between flowering and fruiting.

#### **4.10 Weed management**

Weed is not a serious problem for jackfruit. But, for the proper utilization of nutrient and light, the field should be free from weeds. Manual weeding with *khurpi* or mechanical weeding by hoe is the best way to keep the field free from weed population. Inter-space may also be kept clean to avoid the harbouring of insect-pests and diseases. No research has been done on this aspect but general recommendation of weed management is being advocated.

#### **4.11 Fruiting**

Varieties of jackfruit trees differ widely in their bearing age. Early varieties such as Singapore Jack bear in 2-3 years in India and Sri Lanka. Other vegetatively propagated trees also bear in 4-5 years. In Bangladesh, tissue culture propagated plants bear fruits three years after transplanting (Azad *et al.* 1999). Some varieties, however, may take 8-10 years to bear fruits. Regional differences in the fruiting habit exist. In south India, trees mature in 6-7 years but in the cool weather of north India, fruiting is delayed and bearing is also delayed at higher elevations.

A well-grown tree will produce up to 200-250 fruits, each weighing 5-35 kg, but under good conditions, large fruits weighing 55 kg are produced (Ghosh, 1996). Because jackfruit is an underutilized species, there are no reliable statistical data on its production from producing countries. Hence, systematic documentation is warranted.

The yield of fruits per tree differs greatly on the basis of plant age, cultivars, season and localities. On an average 100-250 fruits/plant are harvested by most farmers. However, some cultivars give more fruiting because they grow through all seasons. In Nepal, 50-300 and sometimes 3,000 fruits per tree have been harvested, however, there is no improved/released cultivar in Nepal and fruits are mostly collected from the wild (Chaudhary and Khatari, 1997).

#### **4.12 Insect-pests of jackfruit and integrated management**

Insect-pests are not a serious problem in jackfruit. IPGRI (now Bioversity International) has issued a list of descriptors for characterization and evaluation of germplasm (IPGRI, 2000) and this list includes insect-pests and diseases. However, Gunasena *et al.* (1996) reported that the jackfruit is relatively free from serious diseases. Soepadmo (1992) stated that crop protection is not a major concern for growers of jackfruit. The reported insect-pests occurring on jackfruit in the major production countries (Table 23) are discussed below:

As many as 38 species of insects are known to attack jackfruit in India. Four mealy bugs including two pseudococcids *Nipaecoccus viridis* (Newstead) and *Ferrisia virgata* (CKLL) and two margarodids *Drosicha mangiferae* (Green) have been recorded earlier on jackfruit (Butani, 1979; Ghosh, 1998). Mani and Krishnamoorthy (1997) reported that the spherical mealy bug, *Nipaecoccus viridis* (Newstead), a sporadic but a severe pest on jackfruit was suppressed by the encyrtid parasitoid *Anagyrus dactylopii* (Howard) and the drosophilid predator *Cacoxenus perspicax* (Knab) within a month.

##### **4.12.1 Shoot and fruit borer (*Diaphania* sp)**

It is a major pest of jackfruit in India and Bangladesh. The reddish brown caterpillars bore into the shoots, buds and fruits. Affected shoots wilt and get dried. Bored fruits rot and drop.

Table 23. Insect-pests of jackfruit and their control measures

Common name	Scientific name	Nature of damage	Non-chemical methods	Chemical control
Shoot and fruit borer	<i>Diaphania caesalis</i>	Developing fruit, buds, young shoots; shoot borer mainly in nursery stock	Remove affected shoots and branches and bagging of fruit	Spray malathion (0.05%), methomyl (0.5%)
Stem borer	<i>Batocera rufomaculata</i>	Bores in wood	Cut the infested branches and kill the grubs; kill the beetles when seen; spike out the grubs if bore holes are located	Inject insecticide emulsions or fumigants into larval tunnels and seal the holes after injection with mud or clay
Fruit fly	<i>Dacus umbrosus</i> , <i>Bactrocera dorsalis</i> , <i>Chactodacus ferruginens</i>	Maggots feed on ripe and rotten fruits	Harvest mature fruits before ripening on the fruits; keep methyl eugenol traps to adults	Chemicals should not be sprayed as the pest infests only the ripening fruits
Trunk borer	<i>Aprionia germari</i>	Trunks, branches; affected parts show signs of wilt and subsequently dry up and severe infestation may cause fruits to drop	Cut the infested branches and kill the grubs; kill the beetles when seen; spike out the grubs if bore holes are located	Inject insecticide emulsions or fumigants into larval tunnels and seal the holes after injection with mud or clay

Contd...

Table 23 (Contd...)

Common name	Scientific name	Nature of damage	Non-chemical methods	Chemical control
Brown weevil	<i>Ochyrodera atrocarpi</i>	Bores into buds, shoots and fruits and causes fruit drop	Affected shoots, flower buds and fruits should be removed and destroyed	NA*
Aphid	<i>Greenidia artocarpi</i> , <i>Toxoptera aurantii</i>	Feeds on tender shoots and leaves, cause growth of sooty mould	Remove the affected parts	<i>Mahua</i> oil (2%), dimethoate (0.03%), acephate (1.5g/l)
Mealy bug	<i>Planococcus lilacinus</i>	Feeds on sap and cause leaf defoliation	Cut and destroy severely affected plant parts	Dimethoate (0.05%)
Short-horned grasshopper	<i>Melicodes tenebrosa</i>	Feeds on leaves	Collect and kill the stages of grasshoppers, if located	Neem seed kernel extracts (3%), Carbaryl (0.2%)
Root grub	<i>Anomala species</i> , <i>Leucopholis irrorata</i>	Feeds on leaves	Keep light trap to collect the adults of root grubs	Spray a contact insecticide like, quinalphos (0.05%), Carbaryl (0.2%)
Termite	<i>Nasutitermes luzonicus</i>	Feeds on the bark of trunk and branches	Remove the mud furrows of termites from the tree; keep the base of plant free of debris	Chlorpyrifos (0.05%) spray on the infested parts

Contd...

Table 23 (Contd...)

Common name	Scientific name	Nature of damage	Non-chemical methods	Chemical control
Spittle bug	<i>Cosmoscarta relata</i>	Reddish spittle bug infests the young shoot and covers with frothy secretion of the nymphs	NA*	Dimethoate (0.05%), quinalphos (0.05%)
Spittle bug	<i>Clovia lineaticollis</i>	Smaller greyish spittle bug found in Kerala, attack causes curling of leaves	NA*	Dimethoate (0.05%), quinalphos (0.05%)

NA\* = Information not available

Management strategies are: (i) destroy affected shoots along with caterpillars; (ii) collect and destroy fallen fruits, (iii) cover young developing fruits with perforated alkathene bags to prevent egg laying, (iv) spray of profenophos (1 ml/l) or *neem* oil (10 ml/l), Trix (5 ml/l) was effective. Alternatively, dimethoate (2.5 ml/l) can also be used as second option.

#### **4.12.2 Bud weevil/leaf eating weevil (*Ochyromera artocarp* M., *Onychocnemis careyae* Mshll, *Teluropus ballardi* Mshll)**

The bud weevil (*Ochyromera artocarp*) is a specific pest of jackfruit. The small whitish grubs bore into tender flower buds and fruits, and induce premature drop. These greyish brown adult weevils are found nibbling the leaves. Two more weevils, namely, *Onychocnemis careyae* and *Teluropus ballardi* have been reported feeding on leaves in South India. Control measures include removing and destroying the affected fallen shoots, buds and fruits and spray of carbaryl (3 g/l).

#### **4.12.3 Aphids (*Greenidia artocarp* Westw. and *Toxoptera aurantii* Bd.F.)**

Both species of aphids feed in colonies on the underside of tender leaves and shoots which get destroyed and devitalized. Aphids can be controlled through: (a) spray *mahua* oil at 2% and do not harvest fruits up to 2 weeks after spraying or (b) spray FPE, Nimbecidine @ 3 ml/l of water/spray application of Bio-magic-F @ 3 kg/ha and *neem* oil (1%) or spray Dimethoate (0.03%) or acephate (1.5g/l).

#### **4.12.4 Giant mealy bug (*Drosicha mangiferae* Gr.)**

Flat, oval, waxy white bugs observed in clusters on tender shoots and inflorescence cause damage by sucking vital sap. For managing this pest, the control measures reported are : (a) plough orchard during summer to expose eggs to natural enemies and

sun heat, (b) remove weeds like *Clerodendron infortunatum* which are alternate hosts of the giant mealy bugs, (c) apply 25 cm wide alkathene bands on tree trunk to prevent migration of crawlers from soil to trees, one week before their emergence, (d) spray crude garlic oil (1%) on tree trunk below band to kill the crawlers congregated, and (e) conserve natural enemies like *Coccinellids* and spiders by avoiding application of broad spectrum insecticides during peak activity period.

#### 4.12.5 Trunk borer

A number of wood borers that attack trunks and branches are reported from Florida. These are *Elaphidion mucronatum*, *Nyssordrysin haldemani* and *Leptostylopsdis terraecolor*. In Asia, they include *Apriona germani* (Soepadmo, 1992). These bore into the trunks and branches. Affected parts show signs of wilt and subsequently dry up and severe infestation may cause fruits to drop. The borer can be controlled by : (a) collect the grub using iron hook, and (b) fumigate with Dichlorvos and plug the hole with mud.

The bark eating caterpillars (*Inderbela tetraonis* Mo. and *Batocera rufomaculata* DeG.) are also found to attack jackfruit (Azad, 2000). Jack scales is the name given to a number of different species: the lesser snow scale (*Pinnaspis strachan*)i, coconut scale (*Aspidiotus destructor*), mango shield scale (*Protopulvinaria mangiferae*), and pyriform scale (*Protopulvinaria pyriformis*). These can be found on leaves, stems and fruits. Other insect-pests affecting jackfruit include sucking insects such as mealy bugs, fruit flies and thrips (Soepadmo, 1992). Reddy (1998) reported *Crossononema malabaricum* and *Neolobocrilonema palamiensis* from soil around the roots of jackfruit in India.

### 4.13 Diseases of jackfruit and their management

Several diseases adversely affect jackfruit trees in the region (Table 24) and the important ones are given below:



Table 24. Important diseases of jackfruit and their control measures

Common name of disease	Causal pathogen	Nature of damage	Control measures	
			Biocontrol	Chemical control
Leaf spot	<i>Laseodiplodia theobromae</i> , <i>Cercospora</i> species, <i>Colletotrichum gloeosporioides</i> , <i>Gleosporium</i> sp., <i>Phomopsis</i> sp., <i>Septoria</i> sp., <i>Phyllosticta artocarpina</i> , <i>Alternaria</i> sp.	Dark brown to brick red spots on both surfaces of leaf which later turn into greyish white in the center and dark brown margin; premature defoliation	No published information is available, application of bioagents like <i>Pseudomonas fluorescens</i> and <i>Trichoderma</i> sp. will definitely work	Carbendazim (0.1%), methyl thiophanate (0.1%) or chlorothalonil (0.2%)
Die-back	<i>Laseodiplodia</i> species,	Affects growing shoots, spreads downwards and eventually kills the tree	Prune the infected twigs	Carbendazim (0.1%), Topsin M (0.1%), or chlorothalonil (0.2%); also trunk injection with antibiotics
Fruit rot	<i>Rhizopus artocarp</i> , <i>Phyllosticta</i> sp., <i>Phytophthora</i> sp., <i>Rhizoctonia solani</i> , <i>Phylosporora rhodina</i>	Affects the flowering shoots or the stalk of the tender fruits; affected fruits develop soft rot	Collect affected fruits and destroy	Application of propiconazole (0.05%) or bordeaux mixture

Contd...

Table 24 (Contd...)

Common name of disease	Causal pathogen	Nature of damage	Control measures	
			Biocontrol	Chemical control
Fruit soft rot	<i>Rhizoctonia artocarp</i>	Rotting of inflorescence, young fruits and ripening fruits	Collect affected fruits and destroy	Bordeaux mixture spray Spray Dithane M-45 (Mancozeb 75% WP at 0.2%) and Carbendazim (0.05%) three times
Pink disease	<i>Botryobasidium salmonicolor</i> , <i>Laseodiplodia theobromaer</i> , <i>Rhizopus stolonifer</i> , <i>Cortitium salmonicolor</i>	Young woody branches of the affected trees lose their leaves and show die-back	Affected branches should be pruned	Bordeaux paste or copper oxychloride (0.2%)
Canker	<i>Corticium salmonicolor</i>	Affects the twigs and stem	Affected branches should be pruned	Bordeaux paste or copper oxychloride (0.2%)
Root rot	<i>Phitium, splendens</i> , <i>Phytophthora</i> sp., <i>Fusarium</i> sp., <i>Rhizoctonia</i> sp., <i>Gonoderma</i> sp., <i>Macrophomina phaseolina</i> , <i>Rosellinia arcuata</i> , <i>Rosellinia bunodes</i>	Affects roots and the stem base of seedlings	Improve cultural practices; avoid waterlogging	NA*

Source : Azad (2000), IPGRI (2000)

NA\* = Information not available

#### **4.13.1 Pink disease (*Cortitium salmonicolor*)**

It is widespread in tropical and subtropical areas. Young branches of trees lose their leaves and show die-back. Thin pink inclusions are seen on the lower shaded side of the leaves. The disease appears as a pinkish powdery coating on the stem. Pink colour represents profuse spore production of fungus. For the management of pink diseases, prune infected branches and paste cut ends with bordeaux paste or copper fungicides (copper oxychloride at 0.2%) (Pathak, 1980).

#### **4.13.2 Leaf spot (*Phyllosticta artocarpina*, *Colletotrichum gloeosporioides*)**

It is the most common disease of jackfruit. Dark brown spots which subsequently turn into greyish brown to brick red are commonly observed on leaves. Such leaves defoliate prematurely. Tender shoots and petioles of the leaves are also infected by the fungus. For the control of leaf spot, sprays of fungicides like carbendazim (0.1%) or mancozeb(0.3%) methyl thiophonate (0.1%) or chlorothalonil (0.2%) are recommended (Rawal and Saxena, 1997).

#### **4.13.3 Die-back (*Laseodiplodia theobromae/Colletotrichum gloeosporioides*)**

It is a highly destructive disease of jackfruit. Drying of young twigs from tip downwards and browning and rolling of leaves are common symptoms of the disease. Such branches are found to be infested by shoot borers. The infected twigs show internal discolouration when split open. In the early stages, epidermal and sub-epidermal cells of twigs are often slightly shrivelled. Pruning of infected twigs followed by spraying of carbendazim (0.1%) or Topsin M (0.1%) or chlorothalonil (0.2%) is recommended (Rawal and Saxena, 1997).

#### **4.13.4 Blossom rot or fruit rot**

Blossom rot, or fruit rot is caused by *Rhizopus artocarpi* and

may cause 15-32% crop loss. *Rhizopus* fruit rot attacks the male spikes and young fruits resulting in premature shedding of tender fruits. In Bangladesh, fruit rot is reported to be the major disease. Ghosh (1994) reported that 18.9% female spikes are dropped due to infection of *Rhizopus*, but it can be treated with the application of folicur or tilt. Fruit rot can be controlled by: (i) prune the tree to encourage good ventilation and to reduce relative humidity in the canopy; (ii) remove and destroy diseased fruits from trees and the ground; (iii) sanitation and preventing waterlogged condition; (iv) control weeds around young trees; (v) keep ripe fruit away from contact with the soil or decaying organic material; (vi) avoid wounding the fruit; (vii) wash fruit after harvest in clean water and dry thoroughly before packing or transporting; (viii) avoid storing fruit after harvest in hot, poorly ventilated containers and; (ix) spray of bordeaux mixture (0.5%) or copper-oxy chloride (0.2%).

Though there are reports of dry rot (*Phellinus* sp.), gray blight (*Pestalotia* sp.), charcoal rot (*Ustilina zonata*), anthracnose (*Colletotrichum gloeosporioides*), rust (*Uredo artocarpi*) and root disease (*Fomes durissimus*) (Azad, 2000) but these are not of serious nature and detailed information is not available.

#### **4.14 Fruit yield**

Jackfruit trees generally live for 100-120 years or even longer. However, fruit productivity declines with age, but the price of its timber increases as the tree gets older. Grafted trees bear fruits within 4-5 years after planting, while trees grown from seeds will start bearing fruits only after 6-8 years from planting. To achieve the maximum productivity, the trees should be 12 years or even older. The fruit yield varies depending on the variety, but most varieties yield 100-200 fruits/tree depending upon proper cultural management practices (SCUC, 2006). Fruit bearing is delayed and fruit quality is affected if the trees are grown at a higher elevation (Medagoda and Tennkoon, 2001). The time from

flowering to fruit maturity takes about 4-5 months depending on the variety and growing conditions. The small-sized fruits mature faster than the big fruits.

#### **4.15 Harvesting**

Tender jackfruit is harvested for use as vegetable during early spring and summer until the seeds harden. The fruit matures towards the end of summer in June. Period of fruit development is February to June. The optimum stage of maturity (harvest) of jackfruit has been reported to be 90-110 days after the appearance of the spike. Harvesting is done by cutting off the fruit stalks carrying the fruits.

Seedling trees start bearing from seventh to eighth year onwards while the grafted ones from third year, when a few fruits may develop. Singapore variety starts yielding from third year of planting. The tree attains its peak bearing stage in about 15-16 years of planting. At this stage, normally a tree bears up to 250 fruits annually with annual fluctuation in yield. The weight of fruits also varies depending on the type. On an average, about 40-50 tons of fruits per hectare could be obtained.

In order to produce the best marketable fruits, the fruits must be allowed to develop on the tree to full maturity, until they are ready for marketing. If harvesting is done a few days earlier than its maturity date, the fruit will not ripen to its best quality. Fruits require 3-8 months to develop from flower emergence to full maturity, depending on the individual tree, growing conditions, season of the year, temperature, rainfall, etc. This indicates that the time from flowering alone is not a good indicator of maturity (Elevitch and Manner, 2006). By just looking at the fruit, an experienced farmer can quickly identify the maturity date of the fruit. There are five primary indicators that can be used to identify fully mature fruits to be harvested for use as ripe fruits: (i) the

skin colour turns from light green to yellowish or brownish, (ii) the points of the spine grow further apart and flatten slightly (not very sharp any more), (iii) the skin yields slightly to pressure, (iv) the last leaf on the stalk turns yellow, and (v) the fruit produces a dull, hollow sound when tapped with hand. Usually two or more of these indicators are used to evaluate the maturity of the fruit. After harvesting a mature fruit, it ripens in 3-7 days and begins to emit a strong, characteristic jackfruit odour. For most people, the odour is too strong to bear indoors, so that the fruit is usually kept outdoors or in an open shed until they are ready to be eaten. For harvesting at other stages of maturity such as those intended for use as vegetable, one can use similar criterion such as when the spines start to grow further apart, but not yet fully flattened and the skin colour should be still green. Since individual trees will have fruits of different maturity levels, it is necessary to harvest the fruits at least weekly.

Harvesting ripe fruits between mid-morning and late afternoon can reduce latex flow. When cutting into a jackfruit, very sticky latex is exuded from the rind and fibrous parts of the fruit. Coating the knife and hands with edible oil will prevent the latex from sticking. If some latex becomes inadvertently stuck to the skin or hair, it can be removed by rubbing with edible oil (Acedo, 1992).

The fruits are harvested at different stages of maturity depending on the intended use and market demand. When fruits are used as a vegetable or for preparing pickles, very immature fruits, where fruitlets (bulbs) or seeds are not yet fully formed, are harvested. They are rather dark green with stiff, hard and closely spaced spines. The testa (exocarp) of the seeds is not yet formed; hence there is no need of removing the testa while preparing them for use as vegetables. The seeds at this stage are still very tender and tasty. In the third stage, fully developed fruitlets and seeds are used for making various preparations like curries. A dull, hollow

sound when the fruit is tapped is considered to be the most reliable indicator that the fruit is already mature. Harvesting at this stage permits the fruit to be used for making chips, various curries, etc. If ripe fruits are preferred, they can be also picked at the mature stage when they emit the jackfruit's characteristic aroma. In big cities, jackfruit is sold as a whole or cut into pieces (1/2<sup>nd</sup>, 1/4<sup>th</sup> 1/8<sup>th</sup> or even into smaller pieces) or sometimes the individual fruitlets are taken, packed and then sold in plastic bags.

It is always best to harvest and handle fruits with care to prevent mechanical injuries that hasten fruit deterioration. The middlemen, who buy in bulk, have to harvest a large number of fruits, and usually they have sacks filled with rice straw to drop the fruits from the tree without damage. While harvesting, the person on the ground will keep on moving the sacks around the tree, while the person on the tree will drop the fruits on the sacks. Alternatively, a person on the ground will be ready with a second sack full of straw so that in case the aim is not good, he will throw the sack on the spot where the fruit is falling. This technique has been proven to be very effective in harvesting jackfruits safely and without damaging them. For harvesting fruits located on high branches or at the top of the tree, it is advisable to lower the fruit on a rope or collect in a sack or basket which is then lowered slowly to the ground.

After harvest, the fruit should be laid for some time with its stalk down to allow the latex to flow and coagulate. The use of dried banana leaves, newsprint or other cushioning materials placed in between the layers of fruits can minimize mechanical damage during transport. It is also important to prevent the spread of latex on the surface of the fruits so that they still look fresh in order to command a better price when sold in the market. Harvesting ripe fruits between mid-morning and late afternoon can help reduce latex flow (Acedo, 1992; Elevitch and Mariner, 2006).

Fruits are sorted out and graded based generally on their size and physical appearance. Ripe fruits turn brown and deteriorate rapidly after harvest. If stored at temperatures of 11- 13°C at a relative humidity of 85-95%, the shelf life can be prolonged by 3-6 months (Morton, 1965, 1987). In Kerala, grading and harvesting is being done simultaneously on the tree itself, because the cost of harvesting is very high. If the fruit is meant for consumption as vegetable or pickles, young immature fruits are harvested. In this case, the person on the tree harvesting the fruits has an assistant staying on the ground that will make sure that uniform size fruits having the right age and maturity are harvested, so that there is no wastage. Based on the maturity, the following grading criteria can be applied:

- Stage I : Very immature fruits are generally used for making pickles and cooked as vegetables. No fruitlets (arils or bulbs) or seeds are formed. The preparations taste like chicken if proper spices are added.
- Stage II : Fruitlets and seeds are just starting to develop; good for cooking into vegetable.
- Stage III : Fruitlets and seeds are fully developed, but they are still very immature. Testa of the seed is not yet formed, hence there is no need of special cleaning of the seeds.
- Stage IV : Seeds and fruitlets are fully developed. This stage is ideal for making chips and for use in different food preparations like curries.
- Stage V : Fully mature fruits are utilized for making chips and used for preparing different vegetable dishes.
- Stage VI : Ripe fruits are used in various food preparations as well as eaten fresh as dessert.

Optimum harvesting for long distance transport is done when the fruit changes its color from green to yellowish green and



when a portion of the stalk attached to the fruit is already large enough to be used for handling (Kader, 2009). Once the fruit is harvested, it is not possible to differentiate between Varikka Arid Koozha, Chakka types, so they should be kept separately during harvesting.

The other grading system for jackfruit is based on the size of the fruit. Uniform fruits are selected for special markets while extra large and small fruits are sold locally. In the case of ripe fruits, orange coloured fruitlets are preferred as they command the highest price. If the fruitlets are big and very juicy, they command special prices. So the fruits are graded according to quality. While ripening, some varieties turn black giving the impression that the fruit is infected with fungus, so light coloured skin is preferred by the customers.

## 5. Diversified Uses and Value Added Products

The jackfruit is a multi-purpose species providing food, timber, fuel, fodder, medicinal and industrial products. The primary economic product of jackfruit is the fruit, used both when immature and mature. The fruit pulp is sweet and tasty and used as dessert or preserved in syrup. The seeds contained in the ripe fruits are also cooked. The fruits and seeds are also processed in a variety of ways for food and other products. In culinary use, the pulp of the fruit is made into various local delicious dishes including chutney and paste besides various types of curries. Additionally, jackfruit is used in traditional medicine (leaves, bark, inflorescence, seeds and latex). The wood of the tree is also used for various purposes.

It is a nutritious fruit, rich in vitamins A, B and C, potassium, calcium, iron, proteins and carbohydrates. Due to high levels of carbohydrates, jackfruit supplements other staple foods in times of scarcity in some regions (Tables 25 and 26). The tender fruits of the tree are used as vegetables and the ripe ones as table fruits. The traditional varieties bear fruits once a year, however the trees bearing fruits for more than once a year have been reported in India and Bangladesh. Usually, the flowering starts from mid-November and extend till mid-February, depending on the location and variety. The tender fruits come to market from March onwards and continue till August. The fruits begin to ripen in the month of June. However, the late varieties may ripen in October. Baliga *et al.* (2011) reviewed the dietary, medicinal and miscellaneous uses of jackfruit tree.

**Table 25. Composition of jackfruit (100 g edible portion), fresh weight basis**

Nutrients	Young fruit	Ripe fruit	Seed
Water (g)	76.2-85.2	72.0-94.0	51.0-64.5
Protein (g)	2.0-2.6	1.2-1.9	6.6-7.04
Fat (g)	0.1-0.6	0.1-0.4	0.40-0.43
Carbohydrate (g)	9.4-11.5	16.0-25.4	25.8-38.4
Fibre (g)	2.6-3.6	1.0-1.5	1.0-1.5
Total sugars (g)	NA*	20.6	NA*
Total minerals (g)	0.9	0.8-0.9	0.9-1.2
Calcium (mg)	30.0-73.2	20.0-37.0	50.0
Magnesium (mg)	NA*	27.0	54.0
Phosphorus (mg)	20.0-57.2	38.0-41.0	38.0-97.0
Potassium (mg)	287.0-323.0	191.0-407.0	246.0
Sodium (mg)	3.0-35.0	2.0-41.0	63.2
Iron (mg)	0.4-1.9	0.5-1.1	1.5
Vitamin A (IU)	30.0	175.0-540.0	10.0-17.0
Thiamine (mg)	0.05-0.15	0.03-0.09	0.25
Riboflavin (mg)	0.05-0.2	0.05-0.4	0.11-0.3
Vitamin C (mg)	12.0-14.0	7.0-10.0	11.0
Energy (Kj)	50-210	88-410	133-139

Sources : Arkroyd et al. (1966); Soepadmo (1992); Gunasena et al. (1996); Azad (2000).  
 NA\* = Information not available

**Table 26. Nutritive value jackfruit (per 100 g)**

Nutrients	Nutrient value	RDA (%)
Energy (kcal)	95.0	5.0
Carbohydrates (g)	23.5	18.0
Protein (g)	1.72	3.0
Total fat (g)	0.64	3.0

Contd...

Table 26 (Contd...)

<b>Nutrients</b>	<b>Nutrient value</b>	<b>RDA (%)</b>
Cholesterol (mg)	0	0
Dietary fiber (g)	1.5	4.0
<b>Vitamins</b>		
Folate (µg)	24.0	6.0
Niacin (mg)	0.920	6.0
Pyridoxine (mg)	0.329	25.0
Riboflavin (mg)	0.055	4.0
Thiamin (mg)	0.105	9.0
Vitamin A (IU)	110.0	3.5
Vitamin C (mg)	13.7	23.0
Vitamin E (mg)	0.34	2.0
<b>Electrolytes</b>		
Sodium (mg)	3.0	0
Potassium (mg)	303.0	6.5
<b>Minerals</b>		
Calcium (mg)	34.0	3.4
Iron (mg)	0.60	7.5
Magnesium (mg)	37.0	9.0
Manganese (mg)	0.197	8.5
Phosphorus (mg)	36.0	5.0
Phosphorus (mg)	21.0	3.0
Selenium (mg)	0.6	1.0
Zinc (mg)	0.42	4.0
<b>Phytonutrients</b>		
Carotene-β (µg)	61.0	*
Crypto-xanthin-β (µg)	5.0	*
Lutein-zeaxanthin (µg)	157.0	*

Source : USDA National Nutrient Database

\*No Recommended RDA for phytonutrients

The diversified uses of jackfruit are summarised as follows :

### 5.1 Dietary uses

- ◆ The unripe fruits are used in vegetable curries and pickles (Prakash *et al.* 2009).
- ◆ The ripe fruits are used to make icecream, drinks, jam, halwa and jelly. Pulp is desiccated and used as dried fruit during off season. Fruit can also be used to prepare alcoholic liquor (Elevitch and Manner, 2006).
- ◆ The bulbs/flakes of ripe fruits are cooked with jaggery, coconut milk or cow's milk and seasoned with raisins, almonds and cashew nuts to make a sweet dish known as *payasam* on special occasions.
- ◆ The ripe bulbs are used to make jackfruit nectar or reduced to concentrate or powder (Morton, 1987).
- ◆ The seeds are nutritious and important source of diet. They are boiled or roasted and eaten like chestnuts, or cooked as some local dishes (Samaddar, 1985). The seeds are also marketed in canned as in boiled form like the beans, in brine and in tomato sauce (Morton, 1987).
- ◆ Seed flour, which is high in protein and carbohydrate and has good water and oil absorption abilities, is used as an alternative for wheat flour to reduce calorie intake (Anonymous, 1985; Mukprasirt and Sajjaanantakul, 2004 a, b; Prakash *et al.* 2009; Tulyathan *et al.* 2002).
- ◆ Tender jackfruit leaves and young male flower clusters may also be cooked and served as vegetables (Morton, 1987).
- ◆ The leaves are used as a casing material for baking dishes. The leaves are also secured together in the form of a round plate and used as a single use biodegradable plate (Morton, 1987).

## 5.2 Medicinal uses

### 5.2.1 Putative use

- ◆ Jackfruit tree is of great importance in the various folk and traditional systems of medicine in Asia. Reports suggest that almost all parts of the jackfruit tree are of use in the preparations of various Ayurvedic and Yunani medicines (Gupta and Tandon, 1996; Saxena and Bawa, 2009). According to Ayurveda, jackfruit can reduce *Kapha* and *Pitha*. Regular consumption of jackfruit will improve facial skin glow. Being a rich source of potassium, it is an ideal food for patients with hypertension.
- ◆ Ripe jackfruit is considered to be nutritious, cool, delicious, satisfying and to prevent excessive formation of bile, develop flesh, phlegm, strengthen the body and increases virility (Anonymous, 2006).
- ◆ Extract from the seeds or bark is supposed to be helpful in digestion. Fresh extract from seeds is also useful in the treatment of diarrhea and dysentery (Anonymous, 2006).
- ◆ The root extract is used as a remedy against skin diseases, asthma, fever and diarrhoea.
- ◆ An ash produced by burning the bark helps in healing abscesses and in ear problems (Gupta and Tandon, 2004).
- ◆ The decoction of seeds or bark helps in digestion while ripe fruits may be used as a natural laxative (Hossain and Nath, 2002).
- ◆ Bark of a mature tree is useful in the treatment of dysentery and releasing the placenta after calving in cows (Morton, 1987).

- ◆ Wood possesses sedative properties, while the pith is believed to induce abortion (Morton, 1987).
- ◆ The leaf decoction and latex are effective in the treatment of asthma, prevent ringworm infestation, and heal cracking of the feet (Gupta and Tandon, 2004).
- ◆ The infusion of mature leaves and bark is effective in the treatment of diabetes, gall stones and to relieve asthma.
- ◆ Leaves are believed to possess antisyphilitic and vermifuge activity and induce lactation in women and domesticated animals (Khan *et al.* 2003).
- ◆ Leaves are thought to possess wound healing effects, reduce pain, decrease abscesses and relieve ear problems (Morton, 1987 and Gupta and Tandon, 2004).
- ◆ In the Chinese system of medicine, jackfruit is found to be of use in overcoming the influence of alcohol. The antioxidant and DNA damage protecting properties of jackfruit wine confirmed health benefits when consumed and could become a valuable source of antioxidant rich nutraceuticals. Additionally, the wine could be a commercially valuable by-product for the jackfruit growers (Jagtap *et al.* 2010). The jackfruit is a rich source of phenolics and flavonoids having good antioxidant properties (Jagtap *et al.* 2010; Soong and Barlow, 2004).
- ◆ Starch extract from the seed relieves biliousness, while the roasted seeds are considered to be aphrodisiac (Morton, 1987).
- ◆ Latex mixed with vinegar is believed to promote healing of abscesses, snakebite and glandular swellings. Even the warmed leaves have healing properties if placed onto wounds. Placing of heated leaves on wounds and the

ash obtained by burning with corn and coconut shells is used alone or with coconut oil to heal ulcers (Elevitch and Manner, 2006).

## 5.2.2 Pharmacology

Although a lot of pharmacological investigations have been carried out based on the constituents present in it, but a lot more can still be explored and utilized in a therapeutic manner. A summary of the findings of some of these studies is presented below:

### 5.2.2.1 Anti-inflammatory effect

- ◆ Cycloheterohyllin, Artonins B and artocarpanone inhibited the superoxide anion formation in IMLP-stimulated rat neutrophils (Wei *et al.* 2005).
- ◆ Dihydroisocycloartomunin inhibited release of beta-glucuronidase and histamine from rat peritoneal mast cells stimulated with P-methoxy-N-methylphenethylamine (Wei *et al.* 2005).
- ◆ Artocarpanone inhibited the release of lysozyme from rat neutrophils stimulated with formyl-Met-Leu-Phe. Artocarpanone inhibited LPS-stimulated production of NO and expression of iNOS in RAW 264.7 cells (Wei *et al.* 2005).
- ◆ Artocarpesin, norartocarpetin and oxyresveratrol isolated from the fruits caused a dose dependent decrease in the production of LPS-induced production of nitric oxide *in vitro* (Fang *et al.* 2008). Artocarpesin was effective in inhibiting the production of prostaglandin E2 (PGE2), reactive oxygen species and to decrease the levels of cyclooxygenase 2 (COX-2) and inducible nitric oxide synthase (iNOS) protein expression in the LPS-stimulated RAW 264.7 cells (Fang *et al.* 2008).



- ◆ Protease fraction and artocarpain also possess anti-inflammatory effects in carrageenan induced rat paw oedema and Cotton pellet-induced granuloma model (Chanda *et al.* 2009).

#### **5.2.2.2 Antifungal effect**

- ◆ The extract of the jackfruit leaf is shown to be ineffective (Khan *et al.*, 2003). However, the chitin-binding lectin present in the seeds (denoted as jackin) is reported to inhibit growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* (Trindade *et al.* 2006).

#### **5.2.2.3 Antineoplastic activity**

- ◆ Norartocarpin, cudraflavone C, artocarpin, brosimone I, cudraflavone B, kuwanon C and 6-prenylapigenin more active than the clinically used vinblastine, carmustine and 5-fluorouracil in the cytotoxic effects in 816 melanoma cells (Arung *et al.* 2010a).
- ◆ Artocarpin also possesses cytotoxic effects on cultured human T47D breast cancer cells *in vitro* (Arung *et al.* 2010b).

#### **5.2.2.4 Antioxidant effect**

- ◆ Ethanol extract of the defatted jackfruit seed and the pulp shown to be effective in ABTS and FRAP assays (Soong and Barlow, 2004).
- ◆ Ethanol extract of the dried mature fruits scavenged DPPI-1 radicals *in vitro* (Soubir, 2007).
- ◆ The methanolic, ethanolic, acetone and aqueous extracts of ripe pulp shown to possess free radical scavenging effects in DPPH, RAP, DMPD assays (Jagtap *et al.* 2010).

- ◆ Cycloheterophyllin and artonins A and artonins B also inhibited the copper-catalyzed oxidation of human low-density lipoprotein, iron-induced lipid peroxidation in rat brain homogenate, scavenged the DPPH radicals, the peroxy radicals and hydroxyl radicals (Ko *et al.* 1998).

#### **5.2.2.5 Antiviral activity**

- ◆ The heartwood of *Artocarpus lakoocha*, which contains a large amount of oxyresveratrol, could be considered as a source of starting material for the development of a new natural product as anti-HSV and anti-HIV agents (Likhitwitayawuid *et al.* 2005).

#### **5.2.2.6 Immunomodulatory effect**

- ◆ Jacalin, the major protein from the jackfruit (*Artocarpus heterophyllus*) seeds, is a tetrameric two-chain lectin. It is highly specific for the O-glycoside of the disaccharide Thomsen-Friedenreich antigen (Gal $\beta$ 1-3GalNAc), even in its sialylated form. This property has made jacalin suitable for studying various O-linked glycoproteins, particularly human IgA1. Jacalin's uniqueness in being strongly mitogenic for human CD4<sup>+</sup> T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus (HIV)-1. The abundance of source material for the production of jacalin, its ease of purification, yield and stability has made it an attractive cost effective lectin. It has found applications in diverse areas such as the isolation of human plasma glycoproteins (IgA1, C1inhibitor, hemopexin, 2-HSG), the investigation of IgA-nephropathy, the analysis of O-linked glycoproteins and the detection of tumours.

### **5.2.2.7 Antidiabetic effect**

- ◆ Investigations were carried out to evaluate the effects of hot water extract of *A. heterophyllum* leaves on the glucose tolerance of normal human subjects and maturity-onset diabetic patients. The extracts of *A. heterophyllum* significantly improved glucose tolerance in the normal subjects and the diabetic patients when investigated at oral doses equivalent to 20 g/kg of starting material.

### **5.2.2.8 Antibacterial effect**

- ◆ The methanolic extracts of stem root, barks, heart wood, leaves, fruits and seeds as well as their various fractions evaluated for antibacterial effects. The butanol fractions of the root bark and fruits were most effective (Khan *et al.* 2003).
- ◆ The aqueous extract as well the aqueous and ethyl acetate fraction of jackfruit leaves studied for the antibacterial effects by the agar diffusion and broth dilution methods. The activity varied from organism (Loizzo *et al.* 2010).
- ◆ The ethanolic and methanolic extracts of the jackfruit seed powder were observed to be effective on multidrug resistant methicillin resistant *Staphylococcus aureus* (Karthy *et al.* 2009).

### **5.2.2.9 Anthelmintic effect**

- ◆ The shoots revealed nematicidal activity against various nematodes, *viz.*, *Rotylenchulus reniformis*, *Tylenchorhynchus brassicae*, *Tylenchus filiformis* and *Meloidogyne incognita*.

### **5.2.2.10 Anticariogenic effects**

- ◆ Methanolic extract of the leaves and the phytochemicals artocarpin and artocarpesin, possess inhibitory effects on the primary carcinogenic bacteria *in vitro* (Sato *et al.*, 1996).

### **5.2.2.11 Inhibition of melanin biosynthesis**

- ◆ Jackfruit wood extract and the phytochemical artocarpanone was effective and inhibited both mushroom tyrosinase activity and melanin production in 816 melanoma cells (Arung *et al.* 2006a). Artoheterophyllin A, artoheterophyllin B, artoheterophyllin C, and artoheterophyllin D isolated from the twigs also possess tyrosinase inhibitory activity (Zheng *et al.* 2009).
- ◆ Artocarpin, cudraflavone C, 6-prenylapigenin, kuwanon C, norartocarpin and albanin A also inhibited the biosynthesis of melanin in 1316 melanoma cells without inhibiting tyrosinase (Arung *et al.* 2006b). 3-prenyl luteolin also inhibits the tyrosinase activity (Arung *et al.* 2010b).

### **5.2.2.12 Allergy to jackfruit**

- ◆ Jackfruit allergy has been reported just once. It is unknown whether this food allergy is caused by direct sensitization or cross-sensitization to pollen allergens. Jackfruit allergy can be added to the list of birch pollen-related food allergies. Increased consumption of this fruit will result in a rise in allergic reactions.

### **5.2.2.13 Effect on sexual performance**

- ◆ According to medicinal plants text of Sri Lanka, roasted seeds of *Artocapus heterophyllus* Lam. (Family: Moraceae) has aphrodisiac activity. However, some

reproductively active young men in rural areas of Sri Lanka claim that consumption of these seeds few hours prior to coitus disrupts sexual function. Because of these two conflicting claims, it was thought useful to scientifically investigate the effects of *A. heterophyllus* seeds on male sexual function and fertility. This was done using a seed suspension in 1% methylcellulose (SS) in rats. In a sexual behaviour study using receptive female rats, an oral administration of 500 mg/kg dose of SS markedly inhibited libido, sexual arousal, sexual vigour and sexual performance within 2 hours. Further, the treatment induced a mild erectile dysfunction. These antimasculine effects on sexual function were not evident 6 h post treatment indicating rapid onset and offset of action. Further, this action on the sexual behaviour was not due to general toxicity, liver toxicity, stress or reduction in blood testosterone level but due to marked sedative activity. In a mating study, SS failed to alter ejaculating competence and fertility. These results suggest that *A. heterophyllus* seeds do not have aphrodisiac action, at least in rats. Thus, subchronic treatment of high dose of jackfruit seed decreases sexual activity in rats without affecting vital functions. The observed effects were transient and reverted on withdrawal of the seeds from the diet (Ratnasooriya and Jayakody, 2002).

#### **5.2.2.14 Hypoglycemic effects**

- ◆ Aqueous decoction of jackfruit leaf possesses hypoglycemic effects in rats, mice and human health volunteers (Fernando *et al.* 1990, 1991). The aqueous leaf extract also inhibited  $\alpha$ -amylase activity *in vitro* (Kotowaroo *et al.* 2006).

### 5.2.2.15 Wound healing

- ◆ The ethanol extract of dried leaves and its various fractions (petroleum ether, butanol, butanone and methanol) revealed wound healing effects in rats. The methanol fraction was observed to possess the best effect (Patil *et al.* 2005).

## 5.3 Other uses

- ◆ The jackfruit wood with good grains is useful as a durable timber. It is termite proof and resistant to fungal and bacterial decay (Prakash *et al.* 2009).
- ◆ Mature wood is used to make furniture, turnery, masts, oars, implements, brush backs and Indian traditional musical instruments like *veena*, *mridangam* and *kanjira* (Prakash *et al.* 2009). Its timber is a medium hardwood and is valued for furniture making since it is rarely attacked by white ants and fairly resistant to fungal and bacterial decay. The roots of older trees are good materials for carving and picture framing. The timber is exported from Sri Lanka and India to Europe.
- ◆ Sawdust or chips of heartwood is useful as a dyeing agent and is useful in colouring silk and the cotton robes used by the Buddhist priests (Morton, 1987).
- ◆ The splinters of the wood are inserted in bamboos used to collect coconut toddy, as this jack wood imparts yellow colour to palm sugar (Morton, 1987).
- ◆ The latex collected from the trees is used to mend cracks on earthen pots and china ware (Prakash *et al.* 2009).
- ◆ The canopy of the full grown trees provides good shade and is used to grow important cash crops like coffee, pepper, betel nut, vanilla, cocoa and cardamom and also gives support for black pepper (*Piper nigrum*) vines (Hossain and Haq, 2006).

- ◆ Jackfruit may also be used as an intercrop with coconut, durian and mango (Elevitch and Manner, 2006).
- ◆ The leaves as well as the non pulp parts of the jackfruit are of use as feed for livestock (Elevitch and Manner, 2006).
- ◆ The leaves are also excellent adsorbents and are reported to remove methylene blue, an industrial dye from the aqueous solutions (Uddin *et al.* 2009).
- ◆ The trees are also used in landscaping in gardens and are effective at withstanding hurricane-force winds (Elevitch and Manner, 2006).
- ◆ The latex which flows from all parts of the plant when injured is also used as adhesive. The resins within the latex is also of some value for varnishes.
- ◆ The rind, rich in pectin, can be used for making jelly. Calcium pectate is found in flakes (4.6%), seeds (1.6%), sterile flowers (3.2%), skin (3.2%) and core (2.1%). They are considered as a good source of pectin.
- ◆ The skin of the fruit and its leaves are excellent feed for cattle and other livestock.

#### **5.4 Health benefits of jackfruit**

- ◆ The fruit is made of soft, easily digestible flesh (bulbs) with simple sugars like fructose and sucrose that when eaten replenishes energy and revitalizes the body instantly.
- ◆ Jackfruit is rich in dietary fibre, which makes it a good bulk laxative. The fibre content helps to protect the colon mucous membrane by decreasing exposure time as well as binding to cancer causing chemicals in the colon.
- ◆ Fresh fruit has small amounts of vitamin-A and flavonoid pigments such as carotene- $\beta$ , xanthin, lutein and cryproxanthin- $\beta$ .

Together, these compounds play vital role in antioxidant and vision functions. Vitamin A is also required for maintaining integrity of mucus membranes and skin. Consumption of natural fruits rich in vitamin-A and carotenes has been found to protect from lung and oral cavity cancers.

- ◆ Jackfruit is also good source of antioxidant vitamin-C; provides about 13.7 mg or 23% of RDA. Consumption of foods rich in vitamin C helps body develop resistance against infectious agents and scavenge harmful free radicals.
- ◆ It is one of the rare fruits that is rich in B-complex group of vitamins. It contains very good amounts of vitamin B-6 (pyridoxine), niacin, riboflavin, and folic acid.
- ◆ Fresh fruit is a good source of potassium, magnesium, manganese, and iron. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure.

## 5.5 Value added products

In view of its important properties, ripe jackfruit bulbs (flakes) are consumed worldwide as a dessert fruit or processed in various forms like canned segments (with syrup and honey), jackfruit flavours, drum-dried powder (Pua *et al.* 2005), osmo-air dried segments, enzyme liquefied juice, candy, jam, spread, jelly, ready to serve beverage (RTS), squash, syrup, nectar, slab or bar and chips/papad are also prepared by frying the ripe and semi ripe flakes in margarine (Chauhan *et al.* 1999; Rekha *et al.* 2002; Susanta and Joshi, 1995; Ukkuru and Pandey, 2011). The pulp is also used to flavour icecream and beverages, made into jackfruit honey, reduced to concentrate or powder, and used for preparing drinks. Pickles and dehydrated leather are its preserved delicacies. The seeds can be eaten boiled, roasted or dried and salted as table nuts, or they can be ground to make flour and blended with wheat flour for baking. A yellow dye also can be



extracted from the wood particles and used to dye cotton. The fruit has a delicious taste, captivating flavour, attractive colour and excellent quality, which make it suitable for processing and value addition (Krishnaveni *et al.* 2000). However, Nunjundaswamy and Mahadeviah (1993) reported that difficulty in the collection of fruits, separation of bulb from the rind, uncertainty and variability in the yield and quality are the major problems involved in the utilization of jackfruit. Hence, there is a need to process the fruit at commercial level.

The potentiality of processed products such as pickles/ chutney, canned jackfruit, fruit leather, jam, candy, toffee, biscuit, beverage, powder, dried jack flakes and pulp is reviewed below:

### 5.5.1 Preserved jackfruit bulbs

Fresh jackfruit bulbs (Figs. 11-14) are a consumer preferred commodity and relished well by all sections of population. Ready-to-eat fresh jackfruit bulbs along with seeds were preserved under



**Fig. 11.** Preserved jackfruit products from Karnataka, India



**Fig. 12.** Preserved jackfruit



**Fig 13.** Fresh honey jackfruit packed in 500 g PVC container (Malaysia)



**Fig. 14.** Preserved jackfruit in sugar syrup

vacuum (760 mm lbs pressure) by treating with 1.5% KMS and 0.5% sodium benzoate (Ukkuru and Pandey, 2005). Preserved bulbs depicted negligible changes in the chemical constituents and were organoleptically stable for a period of 15 days under refrigeration. Singh and Mathur (1954) investigated the freezing of jackfruit bulbs. The edible bulbs from ripe fruits (excluding the seeds) were sliced and packed (i) with dry sugar, and (ii) in 50% sugar syrup with 0.5% citric acid (on the basis of syrup), into jam cans. The product was frozen at  $-29^{\circ}\text{C}$  and subsequently stored at  $-18^{\circ}\text{C}$ .

### 5.5.2 Ready-to-serve jackfruit beverages

The ready-to-serve beverages (Figs. 15-16) can be prepared from fruits very easily with a composition of 10% of juice, 10% of TSS and 0.3% acidity (Chopra and Chauhan, 2001). Singh *et al.* (2001) has formulated ready-to-serve beverages from jackfruit pulp with 10% pulp content, 12% TSS and 0.3% acidity.



**Fig. 15.** Jackfruit beverages: Jackfruit products made by CARD KVK Pathnamthitta, Kerala (India) (Courtesy: Shree Padre)



**Fig. 16.** Jackfruit blend yoghurt (beverage) (India)

### 5.5.3 Jackfruit squash

As early as 1956, Bhatia *et al.* standardized a refreshing beverage with pleasant taste and aroma from the bulbs of ripe jackfruit, which was found to have a shelf life of 60 weeks when stored at room temperature (24-30°C). Sadasivam and Neelkantan (1976) found that jackfruit squash (Fig. 17) could be stored for one year at room temperature without any change in quality except for a slight reduction in vitamin C content. Singh *et al.* (2001) standardized a method for producing squash from jackfruit. Bhatia *et al.* (1956) also suggested fortification of jackfruit squash with vitamin C and found that ascorbic acid was 50-70% when stored at room temperature, 6-13% at 37°C and 88-97% when stored at 25°C. The ascorbic acid fortified samples exhibited increased browning especially at high temperatures during storage.

### 5.5.4 Jackfruit nectar

Fruit nectar is a concentrated form of fruit pulp having honey-like consistency. Singh *et al.* (2000) opined that nectar is a ready to serve beverage like juice. Nectar is the pulp of the fruit blended



*Fig. 17. Jackfruit squash (Courtesy: Shree Padre)*

with sugars and citric acid to obtain a product of 15-20°Brix with mild acid taste. CFTRI (1977) standardized nectar from jackfruit pulp. Jackfruit nectar was standardized successfully from the two popular varieties of jackfruit available in Kerala individually and by blending with other fruit pulp (Ukkuru and Pandey, 2005). Organoleptic evaluation of the nectars formulated indicated that overall acceptability of plain and blended nectars ranged between 77-79% indicating good acceptance of the products. Blending with other fruit pulps resulted in improvement in flavour and taste in the nectars. All the sensory attributes of the nectars formulated from Varikka variety stood superior as compared to Koozha nectars.

Khader (1999) reported that the juice extracted from the various fruits contains mainly sugar and small quantities of vitamins and minerals. Attempts were made by John and Narasimham (1993) to standardize the preparation of clarified juice from jackfruit, in which jackfruit pulp was subjected to enzyme treatment at 0.3%

level. Clarified juice recovery was 60% with a pH of 0.15-0.20%. Ukkuru and Pandey (2005) standardized clarified juice from Varikka variety of jackfruit treated with 1% enzyme at 40°C and incubated for 2 h. Clarified juice obtained was found to have pH 5.6, acidity 2.5% and TSS 15.03°Brix with 31% higher juice yield and excellent clarity when compared to untreated pulp.

### 5.5.5 Jackfruit preserve

Preserve is a candied product in which the fruit is impregnated with cane sugar and glucose and subsequently drained and dried (Fig. 18). Ukkuru and Pandey (2005) standardized jackfruit preserve from fully ripe Varikka jackfruit bulbs, which were found to be nutritionally rich organoleptically sound, shelf stable with excellent consumer appeal. With increased awareness among the consumer for minimally processed foods, jackfruit preserve could be an ideal choice. Jackfruit bulbs preserved in brine in karnataka, India are depicted in Fig. 19.



**Fig. 18.** Jackfruit bulbs preserved at 2°C



**Fig. 19.** Jackfruit bulbs preserved in brine (Karnataka, India)

### 5.5.6 Jackfruit wine

Joshi and Bharathkumar (2004) reported that wine is the oldest known fermented food in the ancient scriptures. Joshi *et al.* (1991) stated that there is a considerable scope for fruit based fermented beverages in India, especially wine and vinegar. Two fermented products, which can be prepared from jackfruit pulp are wine and vinegar. Jackfruit in general contains high amount of easily fermentable sugars, which makes it suitable medium for the growth of wine yeasts. Krishnaveni *et al.* (2000) standardized wines from two varieties (Local and Vellipala) of jackfruit. Organoleptic qualities of the wines formulated were found to be acceptable and comparable with grape wine. Jackfruit wines prepared in Sri Lanka and India are depicted in Fig. 20.



**Fig. 20a.** Jackfruit wine, Sri Lanka



**Fig. 20b.** Jackfruit wine, GKVK, Bangalore, India



**Fig. 20c.** Jackfruit wine, Kerala, India

### 5.5.7 Jackfruit vinegar

Vinegar is another fermented product which can be formulated from jackfruit. Datta and Biswas (1972) had described the process for making vinegar from fruit juice. They further mentioned that jackfruit vinegar recovered from the ripe fruits yielded 7% alcohol and 6% acetic acid upon fermentation. Khader (1999) standardized a method for preparation of vinegar from jackfruit, which was found to have a shelf life of one year.

### 5.5.8 Canned jackfruit products

Shanmugam *et al.* (1992) pointed out that canning is widely practiced to extend the period of availability of fruits. Jackfruit bulbs both raw and ripe could be successfully canned for subsequent use in vegetable curries and also for table purpose (Berry and Kalra, 1987). Lal *et al.* (1960) standardized a method for canning raw jackfruit bulbs in brine solution containing 0.5-0.75% citric acid.

Bhatia *et al.* (1956) reported that canned jackfruit when stored at room temperature (24-30°C) was found to retain normal colour and characteristic taste and aroma. However, the product when stored at 37°C for 19 weeks depicted deteriorative changes. Siddappa and



**Fig. 21a, b.** Canned jackfruit of Kerala, India  
(Courtesy : Shree Padre)



Bhatia (1956) reported that canned jackfruits were found to retain  $\beta$ -carotene content even after 6 months of storage.

### 5.5.9 Dehydrated jackfruit bulbs

Bhatia *et al.* (1956) recommended steeping of jackfruit bulbs in 0.1% potassium metabisulphite solution for 30 min in order to improve the quality of the dried products. Good quality dehydrated products were obtained (drying ratio 3:1) when sulphured at the rate of 16 lbs sulphur /ton fruit/1000 cft space (Shanmugam, 1992).

### 5.5.10 Dehydrated jackfruit flakes

Dehydrated jackfruit flakes with a shelf life of one year were standardized by KAU (1999). A farmer family in Sirsi village in India regularly uses unripe dehydrated flakes and flour to prepare pancake for breakfast. Dehydrated jackfruit flakes are used as vegetable by Vista Company in Sri Lanka. The jackfruit powder produced by Hardikars Food Processing, Pune (India) can be used as a raw material for several products (Fig. 22). The flour prepared from dehydrated jackfruit flakes was found to be



**Fig. 22a.** Unripe jackfruit dehydrated flakes & flour to prepare pancake for breakfast



**Fig. 22b.** Dehydrated unripe jackfruit for use as vegetable  
(Courtesy : Shree Padre)



**Fig 22c.** Jackfruit powder for use as raw material for different products

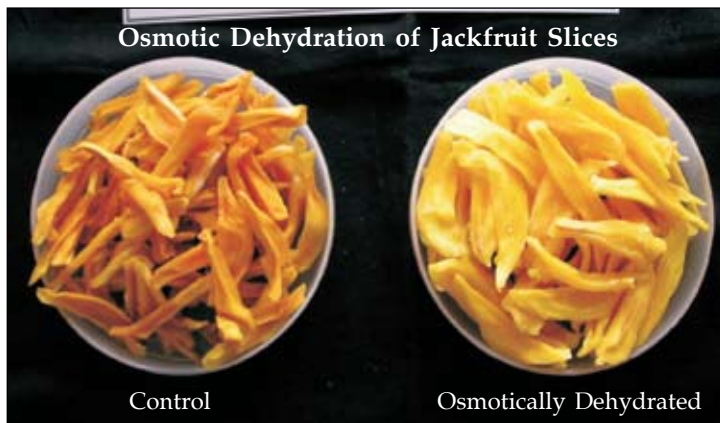
suitable for preparing *chapattis*, *pazhampori* and *bhaji* by replacing 25% wheat flour, maida or Bengal gram flour, respectively with jackfruit flour.

### 5.5.11 Candied jackfruit

Candying of fruits is widely practiced to extend their utilization. Giron *et al.* (1975) prepared candied jackfruit by osmotic dehydration. Jackfruit bulbs were sliced and immersed in sugar syrup of 70°Brix. It was then dried at 60°C. Bindu (1995) conducted a study to standardize osmotic dehydration in two varieties of jackfruit. The results indicated that organoleptically acceptable and shelf stable products could be prepared by applying a pre-treatment of 30 min immersion in 70°Brix at 50°C, containing 20% glycerol for soft flesh variety of jackfruit. The same treatment without any preservatives could be applied for the firm flesh variety of jackfruit. Recently, at IIHR, Bangalore (India), a process has been developed for making osmotically dehydrated jackfruit slices. (Fig. 23a, b) Osmo-air dried fruits are the dehydrated fruit products based on the novel approach towards dehydration. Suitable fruits are selected at optimum stage of ripeness (hard ripe stage) made into slices



**Fig. 23a.** Osmotic dehydration of jackfruit



**Fig. 23b.** Osmotic dehydration of jackfruit slices  
(Courtesy : Dr. Tiwari, IIHR, Bangalore, India)

and dipped in sugar syrup containing citric acid, preservatives and with and without maltodextrin. After immersion time, slices are drained and dried in cabinet dryer till the moisture content reaches to around 15%. Dried slices are packed in plastic punnets and can be stored at room temperature for one year. The quality of osmotically dehydrated product is near to the fresh fruit in terms of colour, flavour and texture. It can be consumed as a snack. Such

product can be used in ready-to-eat type of foods, icecreams, fruit salad, *kheer*, cakes, bakery products, etc. About 11-12 kg ripe fruits are required to make one kg of osmo-air dried slices and shelf life of product is 1 year under ambient conditions.

### 5.5.12. Jackfruit bar and icecream

Ready-to-eat fruit bars are well-relished products and are being commercially prepared and marketed in our country (Fig. 24a, b, c). Jackfruit icecream and jackfruit mixed mango icecream are also becoming popular in India (Fig. 24d, e). Fruits like mango, papaya, pineapple, guava, jamun, jackfruit and banana individually or in combination could be used for preparing fruit bars (Krishnaveni *et al.* 1999). Krishnaveni *et al.* (1999) standardized the preparation of jackfruit bar from two varieties of jackfruit. They also investigated the suitability of different packing material for the storage of the products. The results indicated that jackfruit bars stored in modified polypropylene packets (MPP) recorded higher percent of nutrient retention and minimum microbial



**Fig. 24a.** Jackfruit toffee made by GRAMA Bharananganam (India)  
(Courtesy : Shree Padre)



**Fig. 24b.** Jackfruit icecream bar blended with papaya and mango pulp for better taste



**Fig. 24c.** Jackfruit candy bar by Langka



**Fig. 24d.** Jackfruit mixed mango icecream (India)



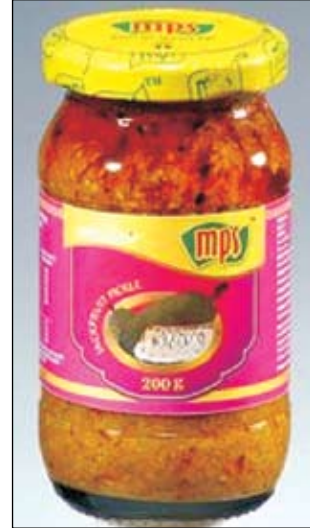
**Fig. 24e.** Jackfruit icecream (India)

count. Ukkuru and Pandey (2005) standardized plain and blended jackfruit leather from two varieties of jackfruit which proved

to have distinct taste and flavour. Blending papaya pulp with jackfruit pulp imparted better appearance, colour and textural qualities, while blending with mango pulp resulted in better flavour, taste and overall acceptability. Products exhibited good keeping quality and consumer acceptance.

### 5.5.13. Jackfruit pickles

The Central Food Technology Research Institute (CFTRI) had undertaken studies in 1977 on preservation of jackfruit and reported that tender jackfruit can be preserved in the form of pickles (Fig. 25). The important pickle preservations include sweet oil pickle, spiced vinegar pickle and plain vinegar pickles.



**Fig. 25.** Jackfruit pickle (India)

### 5.5.14 Jackfruit chips

Jackfruit chips are prepared using raw bulbs (Fig. 26 a, b). The oil used for frying



**Fig. 26a.** Jackfruit chips (India)



**Fig. 26b.** Packaging of jackfruit chips, India (Courtesy : Shree Padre)

influence the shelf life of jackfruit chips. Shelf stability of jackfruit chips could be increased by adding antioxidants like butylated hydroxytoluene and sorbic acid. Gokul brand of vacuum fried chips from Kundapur (India) are very popular. The housewives in Sirsi area Karnataka (India) prepare three different types of chips of jackfruit.

### 5.5.15 Jackfruit papad

Jackfruit bulbs which are neither fully mature nor completely raw, could be used for preparing jackfruit papads (Bhatia *et al.* 1956). He found that jackfruit papads wrapped in a paper had a shelf life of 4-6 months at room temperature (24-30°C). Ukkuru and Pandey (2005) standardized jackfruit papads of different taste and flavour from raw jackfruit which were very crispy and tasty when fried. Mayura brand of jackfruit papad produced by Kadamba Marketing Cooperative, Sirsi, Karnataka and Ponsa Appolu papad in Karnataka are very popular in India (Fig. 27a, b).



**Fig. 27a.** Mayura brand of jackfruit papad (Courtesy : Shree Padre)



**Fig. 27b.** Ponsa Appolu brand of jackfruit papad

### 5.5.16 Jackfruit based sweets

Various sweet delicacies such as jackfruit halwa (varatty), pudding, jackfruit toffee, jackfruit burfy, elayappam, adda, muffin and payasam, etc. could also be prepared from jackfruit bulbs (KAU, 1999). These sweet dishes are depicted (Fig. 28a, b, c, d, e). Ukkuru and Pandey (2005) standardized jackfruit halwa (varatty) - a traditional product of Kerala and toffee by using pulp of Varikka and Koozha varieties. The product remained stable for a period of 12 months and was found to be highly acceptable to the consumers.



**Fig. 28a.** Jackfruit pudding



**Fig. 28b.** Deep-fried jackfruit sweet, Karnataka (India)



**Fig. 28c.** Jackfruit burfy (Courtesy : Shree Padre)





**Fig. 28d.** Moist muffin with the sweet smell of jackfruit



**Fig. 28e.** Jackfruit payasam, Kerala

### 5.5.17 Jackfruit jelly

Jackfruit rind contains fair amount of sugar and pectin could be used for pectin extraction. Siddappa and Bhatia (1956) standardized a method for preparing jelly and suggested an extract-sugar ratio of 1:1 with 0.6 and 0.8 acid preparing a good quality jelly (Fig. 29 a, b).

### 5.5.18 Jackfruit seed flour

Gandhi *et al.* (1974) reported that jackfruit seeds may be



**Fig. 29a.** Jackfruit jelly



**Fig. 29b.** Jackfruit jelly for marketing Karnataka (India)

converted into flour after inactivating the antinutritional factors by drying. The flour prepared from jackfruit seeds can be used for making *chapattis* by blending with wheat flour (25:73). Ocloo1 *et al.* (2010) reported that the jackfruit flour produced may be used as thickening and binding agent in food systems.

Rajarajeshwari *et al.* (1999) studied the properties of seed protein and its utilization in product development. They found that jackfruit seed flour is a good source of protein and exhibits low water and fat absorption capacity. Hence, the flour could be incorporated in the preparation of deep fried products.

Studies conducted by KAU (1999) found that jackfruit seed flour can be used for preparing cereal/pulse based fried preparations like *vada*, *pazhampori*, *baji* and *puri* by replacing 50% of flour of cereals/pulses. The products were found highly acceptable in sensory evaluation test. Ukkuru and Pandey (2005) standardized the procedure for obtaining good quality flour which could be utilized for the preparation of bakery and confectionary products. Seed flour biscuit was crispy with good taste and flavour and remained shelf stable for two months whereas confectionary products were short lived, but adjudged to be excellent in consumer preference studies.

### **5.5.19 Roasted nuts**

The roasted jackfruits seeds are reported to resemble chestnuts in nutritive value and flavour and also much liked by people (Berry and Kalra, 1987). However, the shelf life of fried seeds is low, as these cannot be stored for more than a few days at room temperature of 24-30°C (Bhatia *et al.* 1956).

According to the agriculture experts of Kerala, market glut and waste accumulation is a major setback in jackfruit processing. Difficulty in the collection of fruits, separation of bulbs from the rind, uncertainty and variability in the yield and quality are

some of the problems involved in the utilization of jackfruit. Jackfruit peels, cores and seeds left as waste during processing are reported to be a rich source of pectin, fibre and starch which find application in several industries including food processing and pharmaceuticals.

### 5.5.20 Jackfruit recipes

Raw jackfruit and seed flour of jackfruit are used in making a large number of recipes, namely, biryani, curry, tarte tatin, idli, dumplings, unni appam, dosa, etc. (Fig. 30a, b, c, d, e, f, g)



**Fig. 30a.** Raw jackfruit biryani  
(Karnataka, India)



**Fig. 30b.** Raw jackfruit curry  
(Karnataka, India)



**Fig. 30c.** Jackfruit tarte tatin made  
at Hotel Casino, a 5 star Hotel of  
Kerala, India



**Fig. 30d.** Jackfruit idly (Karnataka,  
India)



**Fig. 30e.** Jackfruit dumplings  
(Kerala, India)



**Fig. 30f.** Jackfruit unni appam



**Fig. 30g.** Jackfruit flour dosa (Kerala, India)

Ready-to-cook tender jackfruit is also very popular in urban areas of Sri Lanka and is easily available (Fig. 31a). The Saras Company in Kerala, India has also developed a new product from tender jackfruit which is being marketed as a ready-to-cook product (Fig. 31b).



**Fig. 31a.** Ready to cook tender jackfruit in Sri Lanka



**Fig. 31b.** Ready to cook tender jackfruit, Kerala, India  
(Courtesy : Shree Padre)

## 6. Economics and Marketing of Jackfruit

Jackfruit is usually grown as an intercrop with other crops but it is seldom grown as a monocrop. Despite being a heavy producer with versatile uses of its fruits, seeds, rags, leaves and timber, the jackfruit is still considered as a minor crop in most countries. Therefore, data on actual areas of jackfruit cultivation, total volume and cost of production, yield per ha and marketing are scarce. Similarly, information on volume of local consumption, export and wastage during the peak season and volume of raw materials used for value-added products, processing, etc. are also scanty.

In India, The quantity of jackfruit being wasted is not exactly known but the wastage is estimated around 75%. Kerala wastes around 35 crore jackfruits annually. There is no information on state-wise area and production figures for jackfruit except a few reports. Under such circumstances, it is not possible to quantify the wastage. Still, assuming one jackfruit costs Rs. 3 and the national wastage is 50%, India is loosing Rs. 214.4 crore worth of food every year.

The jackfruit is a very large, oval fruit with a thick rind that has hexagonal sharp protrusions or spines. It is the largest tree-borne fruit in the world weighing up to 40 kg (Singh, 1986). Even a relatively small tree can have huge fruits hanging on its trunk and main branches. The fruits can attain a huge size up to 90 cm long and 50 cm in diameter. The average yield ranges from 20-100 fruits per tree, with mean fruit weight ranging from 10-30 kg (Veeraragavathatham *et al.* 2004). In India, a good yield is 150 large fruits per tree annually, though some trees bear as many as

250-500 small to medium-sized fruits. Jackfruits turn brown and deteriorate very quickly after ripening. Cold storage trials indicate that ripe fruits can be kept for 3-6 weeks at 11.11°C-12.78°C at a relative humidity of 85-95%. The pulp constitutes 25-40% of the fruit's weight, which is rich in carbohydrate, proteins and vitamin A. The juicy pulp of the ripe fruit is eaten fresh as a dessert or preserved in syrup. The seeds are eaten cooked, roasted or fried. Unripe fruits are consumed as a vegetable which is similar to breadfruit (Jaiswal and Amin, 1992).

In South India, the jackfruit is classified into two general types: Type 1 jackfruit has firm flesh and is called Varika. This is more important commercially and possesses crispy carpels of high quality. On the other hand, Type 2 jackfruit has soft flesh and is called Koozha. It has small fruits whose flesh is fibrous, soft, mushy, but it has very sweet carpels. The fruit of the Koozha variety is consumed mainly in the raw stage for preparing pickles or cooking different vegetable dishes. The fruits of the Koozha variety if allowed to ripen, do not taste as good as the Varika variety because the flesh is soft or soggy. In contrast, the Varika variety is used both in the raw (unripe) and ripe stages. If used in the unripe stage, it is usually made into curries and deep-fried chips. The Varika types are preferred for canning in the processing industries.

In general, farmers cultivate jackfruit in their home gardens but the number of trees planted vary depending on the size of the home garden. In India, organized direct marketing had always been difficult. Jackfruit is not cultivated as a standalone crop. It is planted in homesteads, as windbreakers or shade trees in a scattered way. The peak crop season is the monsoon. Harvesting and transporting fruits from different trees where roads do not exist is difficult. Also, the fruits on a tree do not mature simultaneously. Selective harvesting makes it more complex. For an individual farmer, carting a few jackfruits to a distant city is not practical. Mahrouf (2004)

reported that the availability of marketing facilities is a major factor contributing to the level of production of jackfruit.

## **6.1 Economics of production**

Jackfruit is not considered a major fruit by most national research programmes and because of this, actual production areas, total production and production cost data are difficult to obtain. As a result, there is a lack of information on the economics of jackfruit, a situation which is rather surprising considering that the fruit is valued as a staple in times of scarcity in some countries particularly in South and Southeast Asia.

From the information available, in certain areas in Kerala, India, there is great demand for jackfruit because the middlemen collect the fruits and send them to other states. The middlemen usually can get on an average Rs. 100 per fruit. In contrast, in some areas in Kerala, nobody will buy the jackfruit.

In Sri Lanka, the cost of crop establishment during the first-year was estimated as Rs. 56,427 per hectare. The present value of cost and returns on per hectare basis were estimated as Rs. 2,21,137 and Rs. 2,70,802 respectively (Medagoda, 2010). The cost: benefit ratio is about 1:1.22.

In certain areas in Kerala, jackfruit has recently become the most profitable crop. Farmers do not use chemical fertilizers and pesticides in jackfruit production. Even systematic irrigation for jackfruit is unknown in this part of India. Family labour is mainly used for planting, pruning and harvesting. As soon as the tree starts flowering, the middlemen buy the fruits of the entire tree for a certain period. Harvesting, transporting and marketing are also done by the people who were hired by the middlemen. The middlemen pay the price at once or during the harvesting time. In fact, whatever the farmer gets is a net profit. The middlemen will harvest the crop on a weekly basis.



Assuming that the farmer will get about 250 fruits from a tree, he can earn Rs. 2,500 per tree. Assuming that there are 100 trees in one hectare land, the farmer will get Rs. 2,50,000 (US \$ 5,000/ha). Since there are no additional expenses once the tree starts fruiting, this can be considered as net profit for the farmer. For establishing one ha jackfruit plantation with initial expenses to be used up to three years, it will come to US \$ 1,000 per year. However, during the first 3-4 years, one can lease the plot for cultivating pineapple where the leaser will maintain the jackfruit trees.

The farmers in some jackfruit growing countries are getting a good return from jackfruit than from mango or other major fruits. Certainly, farmers get more income from early or late produce than from peak season harvests. According to Hossain and Haq (2006), most of the farm owners in large jackfruit producing countries sell their trees on contract basis and the amount of the produce is fixed regardless of the number and size of fruits. It varies between US \$ 8-20 per tree. Based on 100 plants per ha, a mature jackfruit plantation can fetch US \$ 1,500 per ha. In many villages in India, there are weekly or bi-weekly markets which facilitate local trading of jackfruit. By means of bargaining, the price is fixed depending upon the supply, demand, quality of jackfruit, etc. Usually the farmers, traders, vendors, etc. are present in those markets and the term "Farmers' Market" is used locally. Once the price is agreed, an immediate cash payment is made by the buyer. This is the right venue where farmers bring their various jackfruit products and sell them directly to other farmers or vendors. It is generally believed that the farmers get better price for their products in these markets. There are also agents who collect fruits from various farmers in these markets and charge a minimal fee for his services including transport costs.

In Central Kerala, India, the price for jackfruit soared in 2010 in line with the national and global inflation. However, it

is not known whether such pre-season price can be maintained throughout the peak season. Under the situation of pre-season crop maturity, the middlemen will pay about US \$ 20-25 per tree and assuming that there are 100 bearing trees in one ha, the farmer can expect to get US \$ 2,000-2,500 per ha. It is already a very good return for the farmer as he is not spending much for the crop in terms of fertilizer or other crop management inputs. However, this price is very low if the calculation is based on actual return per tree. A tree may produce 100-150 fruits and if the price for an individual fruit is about US \$ 2.00-5.00 depending upon the size, so with a minimum of 100 fruits, the farmer can get US \$ 200-500 per tree with a total of US \$ 20,000-50,000 per ha.

In Kerala, most of the jackfruit produced may be considered as organic since the farmers are not using any pesticides and inorganic fertilizers. Therefore, there may be a niche market available in those countries where the population prefers organic food. However, presently no attempt is being made to exploit this opportunity and promote export of organic jackfruit.

Among the various produce of fruits, jackfruit production was 4, 29,147 million tons from 4 North Eastern States of India (Table 27). The APEDA has projected the export target of 2,360 mt for jackfruit from the surplus quantity (estimated as 1,18,000 mt) from Assam and Tripura through processed food and pickles.

**Table 27. Jackfruit production in North Eastern States of India**

States	Production (mt)
Arunachal Pradesh	NA*
Assam	1,70,000
Manipur	3,137
Meghalaya	NA*

Contd...

Table 27 (Contd...)

States	Production (mt)
Mizoram	1,065
Nagaland	NA*
Sikkim	NA*
Tripura	2,54,945
<b>Total</b>	<b>4,29,147</b>

Source : CMI Social Research Center 2005-06

NA\* = Data not available

## 6.2 Marketing

### 6.2.1 Domestic market

A stable marketing chain is not in existence for jackfruit. At the village level, collectors from outside as well as those from the village itself purchase the fruits and sell them in external markets, mainly at village fairs and road-side sheds. Transactions at the farm level occur mainly on ready cash payment basis and rarely on credit. Middlemen decide the market prices resulting in the exploitation of the producers. A very low percentage of total production is consumed as food (30-35%) and 70% is lost during pre- and post-harvest stages.

Local industry in Bangladesh uses jackfruit for pickles at a rate of 500- 1,100 kg/month. In a market study in Bangladesh, it was shown that the marketing margin of retailers (Tk 571/100 fruits, US \$ 1= Tk 55) was higher than that of wholesalers (Tk 164/100 fruits) (Ahmed and Islam, 1996).

In India, in addition to fresh fruit, processed products like chips and papads are sold locally for US \$ 0.30-0.60 in a plastic bag of 100-300 g.

In Nepal, fruits are sold for the price of NRs 50-70/fruit (US \$ 1=NRs 70) and the farmers earn a net income of NRs 6,000-8,000/tree (US \$ 120-160) for ripe fruits (Chaudhary and Khatari, 1997). In Mysore, Bangalore and Mumbai, each fruit costs Rs. 100. But in Ratnagiri or Kerala, it costs next to nothing. In Kerala, farmers used to hang a board on their jackfruit tree saying, "Anybody can pluck jackfruit from this tree" (Shree Padre, 2011).

In Bangladesh, the usual suppliers again are the middlemen and they collect orders from exporters, collect crops from farmers/local markets and deliver these to the exporters on the day of shipment. No standard post-harvest handling practices are followed. As a result, post-harvest loss is enormous in particular because the packaging materials are of very poor quality, generally consisting of bamboo baskets or second hand cartons.

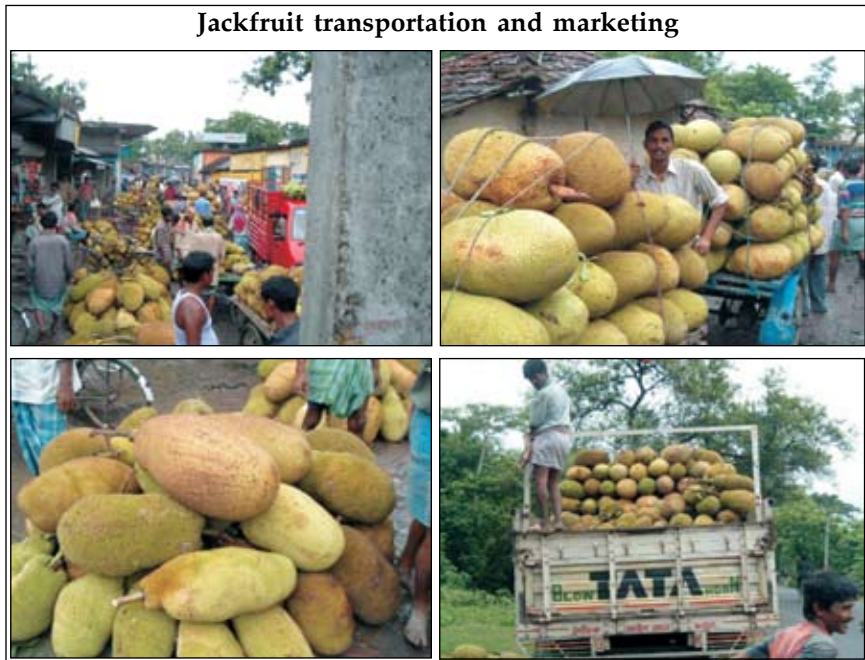
Availability of processed products in the local market is low due to lack of interest shown by the producers. However, primary processing at the household level using traditional methods was reported only for local consumption but these traditional products are still scarce in the market. Only a few commercial scale processing plants are available within the country. Thomson Bakery near Mannar in Kerala sells 300 kg of jackfruit *halwa* during the jackfruit season. Asian Home Products Pvt. Ltd, Thiruvananthapuram, produces 400 kg of salted chips daily by outsourcing to smaller units. Its proprietor, NR Pillai, says the chips sell quickly. Adilakshmi Home Industries in Moodabidri, Karnataka produces 7,000 jackfruit papads daily. Kadamba Marketing Co-operative, Sirsi has for the first time introduced branded jackfruit papads. They sold 60,000 papads last year. To make papads during the monsoon season, they installed a food grade drier which boosted the production. There is a lot of demand for chips alone. Customers arrive in their cars and buy

jackfruits, as mentioned by Annappa Pai, Director, Ace Foods, a reputed food products exporter in Mangalore.

Jackfruit timber is highly valued. It is mostly produced in home gardens, although there are recent attempts to introduce it in agro-forestry systems. It fetches a high price due to the high demand for construction material and for furniture making. The tree is sold as timber through various channels, involving either local saw mills or those in the cities. Some logs are sent directly to the furniture producers. The saw mills sell as fuel all the wastes from the timber.

The following avenues are important for the sale of jackfruit: (i) selling to neighbours and relatives of small farmers, (ii) selling along roadsides, (iii) selling to local shops who in turn sell them as pieces, or as packets of 10 arils (fruitlets) or whole fruits, (iv) selling to local agricultural product markets, (v) selling to specialized fruit markets, (vi) selling to super markets in the towns and cities, (vii) selling to urban markets, (viii) selling to women's groups for making jackfruit chips or other value-added products, (ix) selling to processing plants, (x) selling to middlemen who send the fruits in return to other states or cities where there is more demand, and (xi) selling to export markets.

Jackfruit marketing involves three groups of channels, namely, producers, traders (middlemen) including wholesalers and retailers (Haq, 2006). At present, there is no standard marketing information system and quality standard. The future of jackfruit production will depend upon the development of suitable cultivars for the consumers (if the consumers prefer very sweet variety, then all efforts should be made to supply such quality fruit in the market), proper production strategies, post-harvest management strategies, processing and utilization systems and also transportation and marketing (Fig. 32) and possibly export market development.



*Fig. 32. Jackfruit transportation and marketing*

### 6.2.2 Overseas market

Haq and Hughes (2002) estimated that the production of jackfruit will expand mostly due to an expanding market for processed products. It is also estimated that the demand for fresh fruits will expand in countries such as Japan, Malaysia, and the United Kingdom in addition to Singapore and Hong Kong and some Middle Eastern countries. Bangladesh exported 54,340 kg of jackfruit to the United Kingdom at a price of £1.23/kg. In the United Kingdom, a fresh fruit is sold at £2.45 per kg and a medium size fruit may cost £16-20 (Haq, 2006).

In Bangladesh, there is no government support for exporters from the Export Promotion Bureau, but the Malaysian Government has recently signed a contract with Bangladesh to supply jackfruit

which will be processed in Malaysia for re-export. Colombia, India, Malaysia, Uganda, Jamaica, Thailand, Sri Lanka, Bangladesh and Kenya export jackfruit to the United Kingdom market. Among these, Colombia, India, Malaysia and Uganda supply throughout the year. Thailand exports throughout the year except for July-September and Sri Lanka exports during all calendar months except December and January. The jackfruit has regional and international markets because it is available as a fresh fruit as well as a processed product.

In India, the only unit that has reached a level of scale is Gokul Fruits Pvt. Ltd. in Udupi district of Karnataka. It makes jackfruit chips using the vacuum dry technology. Parayil Exports of Kottayam district is one of the few companies exporting frozen jackfruit to USA and other countries. A small quantity of fresh jackfruit is exported to the Gulf, UK and other countries from Kerala, to cater to the Malayalee and Tamil population there. Rural Enterprises Network (REN) in Sri Lanka is another pioneer in dried jackfruit. Unripe flakes are dried through driers in 10 Centers. The product is sold locally and exported to Europe. To popularise its product, REN conducts cookery shows.

Jackfruit is gaining popularity even in the United States and in the United Arab Emirates (UAE) due to emerging ethnic and mainstream marketing opportunities. Value-added products like chips and dried fruits are also exported. Immature and mature fruits ready-to-cook are also exported as frozen or preserved in cans. Ripe fruits are available fresh, packed in cans or preserved in bottles with sugar syrup or mixed in fruit cocktails along with other fruits.

A Vietnamese company has shown interest in importing tons of jackfruit flakes (without shell, fibre and seed) from Karnataka (India). The pilot project has given impetus to commercial exploitation of jackfruit by creating a Jackfruit Growers'

Association and organizing jackfruit fairs to showcase various varieties of jackfruit as well as its products to the people ([www.thehindu.com /2009/06/29/stories/2009062954620500.htm](http://www.thehindu.com/2009/06/29/stories/2009062954620500.htm)).

### **6.3 Marketing channels**

The channels may vary between large, medium and small farmers. Large farmers sell their harvest to wholesalers, while medium farmers sell their fruits to local markets or sell surplus fruits to neighbours or to village vendors and local retailers. (Valvi *et al.* 2011)

When the fruits are intended for export, the exporters or their commission agents visit production areas, examine the fruits and buy only those that meet the exporter's specifications. Fruits of the same maturity level are loaded and banana leaves are placed in between them to protect them from damage by direct sunlight. All around the truck, coconut leaves are placed to protect the fruits from sunburn. When fully loaded, coconut leaves are used to cover all around the truck and saw dust and ice sheets are placed to keep the fruits cool so that they will still be fresh at their point of destination. The big trucks are used to transfer the fruits to big cities where major markets are located. Once the truck reaches the destination, fruits are transferred to small trucks and ferried to their final destination. The expert loads the fruits one by one to the people standing in the small trucks.

Rural farmers have limitations to grade, prepare and market produce as demanded by the retail sectors and other markets. So, the like minded farmer associations and self help groups have to attempt on cluster marketing with support of farmer friendly administration like NABARD, agriculture departments, agri banking sector, horti corporations, KVK, etc. Further common standard trading practice can be evolved as already followed in cooperative trading and open market Centers, etc.



Jackfruit of the Tubugere area (Karnataka, India) had vast demand for consumption in view of high quality fruit but it was exploited by middleman realizing less than one third of the profit by jackfruit growers. Being a bulky fruit, it is difficult for the individual farmer to transport and sell the produce. In order to address organized arrangement for the production of seedlings, Jackfruit Growers Association was formed which enabled to sell the produce and get good price for the produce as compared to local market. The successes have created interest in many jackfruit farmers in other parts of the state and they are making such local associations for establishing an effective market channel.

In India, more than half of the fruits go waste without even harvesting. Once it ripens, the soft fleshed types such as Koozha and Chakka have practically no takers at all. Though India is producing a huge amount of jackfruit, no sincere efforts are being made to commercialize its production. Only around a dozen branded jackfruit products are available in India. Even these products never cross the boundaries of the producing state. Kerala has three brands of jackfruit Varatty - Saj, Saras and Double Horse. Amar brand of tinned tender jackfruit from Maharashtra is the only product of that kind. So is vacuum dried fruit chips produced by Gokul Fruits of Karnataka. The only modified atmosphere packed jackfruit chips come out of Aditya Agro Foods of Lucknow. Mayoora brand jackfruit papad from Kadamba Marketing Cooperative of Sirsi and Chirag brand of papads from Shivapura, Karnataka are two branded papads in the country. Jackfruit jam from Grandmas, pickle from some north-eastern states, fruit papad, burfi, etc. from Yojak Associates of Ratnagiri are some other products worth mentioning. Parayil Food Products of Kottayam is exporting a dozen of jackfruit products like tender jackfruit thoran (stir fry), Varatty, etc. (Shree Padre, 2011).

In recent decades, Sri Lanka has gone far ahead in the value addition of jackfruit. Rural Enterprises Network, a voluntary

organization is producing about ten tons of unripe jackfruit flakes. This apart from being sold locally is being exported to European countries. Preserving in brine is also followed commercially on large scale. Polos (tender jackfruit) in brine, jackfruit seeds in brine are some of the commercial products. Sri Lanka has at least a dozen companies that among other products produce value added products of jackfruit for export. Ready-to-eat Polos curry in tin/ bottle is a very popular product that is exported to several countries like Australia, California and USA (Shree Padre, 2011).

#### **6.4 Products of commercial value**

- 1. Planting materials :** This has a good market. There are three types of planting materials: i) seedlings, ii) grafted saplings and iii) tissue culture propagated plantlets. Right now, there is a big shortage of good planting materials. Therefore, many private nurseries and government farms are promoting the production of good quality planting materials for sale. Small farmers, in general, use only seeds for planting which they collect from good fruits. The tap root system is better with seedlings and ultimately good quality timber will be produced. However, the seedlings may not produce the same quality fruits as the mother plant. Moreover, seedlings will start producing fruits only after 6-8 years, while grafted plants will start producing fruits after 3-4 years. With grafted seedlings, the quality of fruits is guaranteed. Currently, a grafted plant costs US \$ 0.50-2.00. Region specific varieties are being multiplied by the nurserymen.
- 2. Tissue cultured plants :** These are yet to become popular. In Arusha, Tanzania, very recently Abd El-Zaher (2009) reported an effective micropropagation method for jackfruit that can help to generate quality seedlings in a relatively short time interval. Azam *et al.* (2009) reported successful production of plantlets from tissue culture from a selected fruiting variety in Bangladesh that bears fruits continuously throughout the

year. Therefore, the prospects are good for developing plantlets by micropropagation (Amin and Jaiswal, 1993). Producing the plantlets *in vitro* using tissue culture is yet to enter the market and the technology needs to be perfected.

- 3. Tender and immature fruits :** Tender and immature green fruits of Idiyan Chakka with young seeds are more popular in Sri Lanka and Nepal than ripe fruits. They are sold either as whole fruits or in sliced form. Since different sizes are available, the consumers can choose the right size of fruit. These products are also canned in some countries such as Thailand, Malaysia and the Philippines and are mainly intended for export. Here, the procurement of raw materials for canning is done by the wholesalers. Price fluctuations are noticeable due to cultivar differences, season of the year, localities, market demand, proximity to the processing plant, transport costs, size of fruits, actual demand, etc. It is not uncommon that the wholesalers make 25-50% profit on trading as they exploit the farmers since there is no Government pricing policy for jackfruit in most countries.
- 4. Mature unripe fruit :** For making chips and for preparing various vegetable dishes. Tender raw jackfruit and seeds are popular products of the jackfruit tree. These are marketed mainly by the producers. In some countries, like Sri Lanka and Nepal, these products are more popular than the ripe fruits and are sold either as whole fruits or in sliced form. Price is determined on the basis of size, weight and condition of fruits and varies from US \$ 0.2-0.5 per kg in these countries and fluctuates depending on season and localities. The mechanism of procurement for unripe fruits is similar to ripe fruits for processed products. Price fluctuations are found to be very high depending on cultivars, season, localities and market demand. It was reported that in Nepal, 200 kg/day of jackfruit

is sold in Illam as a vegetable, 650 kg/day in Dharan, and 800 kg/day in Biratnagar. The vegetable was marketed at the price of NRs 45 (US \$ 0.9) per kg in Biratnagar, NRs 35 (US \$ 0.7) per kg in Dharan, and NRs 55 (US \$ 1.1) per kg in Illum (AEC, 2003). The wholesalers make profits of 20-25% on wholesale trading.

5. **Mature ripe fruits** : Bulbs can be packed in bags and kept at 12°C for 3 weeks. In a large jackfruit producing country, most of the owners sell their trees on a contract basis and the amount is fixed based on the number and size of fruits which varies between US \$ 8-20/tree (Hossain and Haq, 2006). On this basis, a mature jackfruit plantation can fetch on average US \$ 1500 per hectare (based on 100 plants per hectare). The market chains for ripe fruits operate in two ways in many countries: either the producers bring their produce themselves to the market, or collectors assemble the produce from the farmers' fields. Sometimes, wholesalers also perform a secondary role as collector. The supply and marketing of jackfruit largely depends on the fruiting season (Table 28) and the time of maturity which varies with the agroclimatic conditions and ecosystems.

**Table 28. Availability of jackfruit in different countries**

Countries	Main season(s) of availability
Australia	June-April
Bangladesh	June-August
Brazil	January-March; August-October
Colombia	January-December
India	April-July

Contd...

Table 27 (Contd...)

Countries	Main season(s) of availability
Indonesia	August-January
Jamaica	January-July
Kenya	June-October
Malaysia	April-August; September-December
Philippines	March-August
Sri Lanka	February-November
Thailand	January-May; October-December
Uganda	January-December
USA (Florida)	May-August; September-October
Zanzibar	June-December

Source : Soepadmo, 1992; Crane et al. 2003 ; Haq, 2006

## 6.5 Processed products

The less used products of jackfruit develop country-wide demand only when good marketing has been established. Products like chips and papads in India are produced at the village level and marketed by producers either as individuals or as cooperatives, such as self-help women's groups in India. Pickles, leather, candy, dry pulp and juice are also produced at the village level for local marketing. These products may have brand names of their own or be marketed through cooperatives under the cooperative brand name. The products do not in general follow strict quality assessment or packaging systems for market channels. However, most countries now require certificates from Food Standards Departments, and the Cooperatives in India and Sri Lanka have started to market jackfruit products with certification.

Although there is recent interest in underutilized fruit products,

the small scales of operation, irregular availability of raw material, limited markets, and continued use of traditional processing make this unorganized sector of minor economic importance. Therefore, marketing chains of growers-processors-wholesalers-retailers do not always exist. Sometimes, processors have problems in marketing because of the limited outreach for products and concentration by processors in a small area. Nevertheless, the underutilized fruit products hold promise for expansion with appropriate promotional efforts which could include trade-fares, exhibitions, and door to door sales. In addition, value added products from the fruit, such as jacin, will encourage industries to use the crop as a raw material. The common processed products reported are jam, jelly, candy, powder, juice, pickles, leather, milk shake, icecream, chips and papads. The pulp can be sold in soft cartons locally and big containers for urban use. Canned ripe fruits, immature fruits, fruit salads or mixed fruit salads are also reported. For pre-processing of pulp, the crush de-seeded jackfruit bulbs using a blender; add 40-45 g sugar to every 100 g smashed pulp; dry in a hot air at 80-85°C until moisture content reaches 20-22%; transfer plastic containers, freeze the pulp and store for further processing (SCUC, 2006).

Where large quantities of jackfruit are available, it is worthwhile to utilize the inedible portion. For instance, the rind has been found to yield a fair amount of jelly with citric acid. A pectin extract can be made from the peel, undeveloped perianths and core, or just from the inner rind and this waste also yields some syrup used for curing tobacco.

The drying of the fruit bulbs to make fruit leathers is a convenient method of marketing the fruit as confectionery and yields a product that is stable for more than two months at room temperature. There might be a good market for jackfruit leather depending on price, packaging, marketing and distribution

(Che-Man and Sunny, 1997). Fruit leather was developed from the unfertilized floral parts of jackfruit. The fruit leather was most stable when packaged laminated aluminium foil (LAF) for longer storage. Sensory evaluations showed that samples were acceptable to the panelists (Che-Man and Sin, 1997). Jackfruit thandra (bar) was prepared using two varieties of jackfruit and packed in butter paper, polypropylene pouches and metallic polyester low density polyethylene laminated pouches and stored at room temperature (Manimegalai *et al.* 2001). It was estimated that properly processed jackfruit juice packed in plain tin-plate cans could keep well for more than 17 months at temperature above 30°C (Seow and Shanmugam, 1992).

Ready-to-serve (RTS) beverage was prepared from two varieties of jackfruit with 10% pulp that are packed in coloured (green) and colourless bottles and stored at room temperature. The sensory quality attributes were found to be highly acceptable even after storing for 6 months at room temperature (Krishnaveni *et al.* 2001). Mature jackfruit can be dried and stored. The fruit is sliced into small pieces and put in hot water (blanch) for 5 min. After draining the water well, the fruit should be dried well in the sun, but before drying, some salt should be added. This will keep the product for several months. During the off season, one can make jackfruit curry out of the flesh.

The jackfruit timber is classified as a medium hardwood (specific gravity 0.6- 0.7) and is highly valued as building material, furniture and cabinet making, manufacture of turnery, masts, oars, and even for making musical instruments. It is highly durable, resistant to termites and decay, seasons easily, resembles mahogany in appearance, and takes a beautiful polish. As the wood ages, it turns from yellow or orange to red or brown. Although not as strong as teak (*Tectona grandis*), the jackfruit wood is considered as a superior building material.

There is also a report that the timber is considered superior to teak and it deserves greater attention by foresters (Jaiswal and Amin, 1992). Jackfruit timber is highly priced but it varies depending upon the age and size of the tree. The timber from a straight trunk of older jackfruit trees fetches very high price. In Bangladesh, the price of jackfruit timber is US \$ 18-26 per cubic foot or US \$ 640-929 per cubic metre (SCUC, 2006).

The dried leaves are sold for fuel. A full sack is sold for Tk 30-50 (US \$ 0.6-1.0) in Bangladesh, depending on the season and the production area. The green leaf is also sold for fodder by the small van load (rickshaw) for the price of Tk 120-150 (US \$ 2.4-3.0), again depending on the season and the area.

## **6.6 Socioeconomic importance**

Jackfruit does not spread readily and is not considered invasive species. In most areas of the world where jackfruit is grown, its presence is indicative of human cultivation. Jackfruit was introduced to most Pacific Islands, mainly in home gardens, where it finds a place among other favourite multipurpose plants. It is easy to grow and more adaptable than some of the other common *Artocarpus* species like the breadfruit (*A. altilis*). All parts of the tree have been reported to have medicinal properties. Morton (1987) reported that the Chinese consider jackfruit pulp and seeds as tonic, cooling and nutritious, and to be useful in overcoming the influence of alcohol on the system. The seed starch is given to a person to relieve biliousness and the roasted seeds are regarded as aphrodisiac. The ash of jackfruit leaves if mixed with corn and coconut shell ash is used alone or mixed with coconut oil to heal ulcers. The dried latex yields artostenone, a compound that is convertible to artosterone, which has a potent androgenic property (having male hormone activity). If mixed with vinegar, the latex promotes healing of abscesses, snakebite



arid glandular swellings. The root is a remedy for skin diseases and asthma. An extract of the root is taken and used as cure for fever and diarrhoea. The bark is made into poultices. Heated leaves are placed on wounds. The wood has a sedative property; its pith is reported to induce abortion. Aside from flavouring for beverages, the fruit can be fermented and distilled to produce alcoholic liquor.

The benefit of cultivation of the jackfruit depends upon whether it is grown in the homestead as a backyard crop or as a plantation crop. Establishment of a jackfruit plantation requires a large investment such as the nursery establishment, proper management of the crop, etc. However, during the first 3-4 years, other crops such as pineapple or vegetables can be grown which will cover the cost of maintaining the jackfruit plants. Since jackfruit is very bulky and perishable, processing can reduce transport costs, prevent spoilage, increase shelf life. Processed products usually command higher prices especially during the off-peak season. If the farmers can form cooperatives and arrange cold storage facilities, they can increase their profits by storing the produce during the peak season and then sell the fruits during the off-peak season.

## 7. Future Prospects and Strategy for Jackfruit Production and Utilization

In view of the increased population growth coupled with limitations on resources, the steady supply of food and adequate nutrition in many developing countries assumes greater significance. Thus, the quality and quantity of food have become an important issue at the global level in view of widespread malnutrition. Carbohydrates, proteins and fat are in general supplied from cereals, pulses and oilseeds, respectively but there are notable vitamin and mineral deficiencies in many regions. In this context, high levels of vitamins and minerals have been recorded in a number of underutilized fruits. Table 29 compares jackfruit with other more widely grown tropical fruits such as ber or jujube, another underutilized fruit. The comparison highlights the jackfruit as being nutritionally rich and is a good candidate to meet the nutritional significance.

Recent commercial interest in several tropical underutilized fruits has resulted in an increased cultivated area in Asia and other regions of the developing world. The export of fruits from Asia alone has been increasing by a little over 10% annually (Singh, 1993).

**Table 29. Comparison of tropical fruits for their nutritive value**

Fruits	Energy (kcal)	Protein (g)	Ca (mg)	Fe (mg)	Vit. A (IU)	Thiamine (mg)	Vit. C (mg)
Orange	53	0.8	22	0.5	295**	0.05	40
Banana	116	1.0	7	0.5	100	0.05	10
Mango	63	0.5	10	0.5	600	0.03	30

Contd...

Table 29 (Contd...)

Fruits	Energy (kcal)	Protein (g)	Ca (mg)	Fe (mg)	Vit. A (IU)	Thiamine (mg)	Vit. C (mg)
Pineapple	57	0.4	20	0.5	100	0.08	30
Papaya	39	0.6	20	0.5	1000	0.03	50
Ber	21	1.75	25.6*	0.5-1	66.66*	0.02*	166
Ripe jackfruit	98	2.0	37	1.1	540	0.09	10
Tender jackfruit	50	2.0	53	0.4	30	0.12	12
Jackfruit seeds	139	7.04	50	1.5	17	0.25	11

Adopted from Haq (2006); \* Pareek (2001)

\*\*<http://www.healthalternatives2000.com/fruit-nutrition-chart.html>

Jackfruit is grown mainly on homestead farms and produces multiple products for food, feed, and industry as well as contributing towards soil management for sustainable environments. Jackfruit in Asia is still considered as a minor fruit crop. Unpredictable yield, strong odour of ripe fruit and its large size, long gestation period, limited choice of suitable varieties, crop losses due to disease like bacterial wilt in Malaysia, etc. are some of the negative attributes of jackfruit. Above all, commercial scale cultivation is still quite low in most of the countries and improved cultivation practices are not being followed by most of the farmers. Planting materials raised from seedlings show wide range of variation in their performance. Vegetative propagation is not yet widely practised in most of the developing countries of Asia in view of lack of perfected techniques. Due to limited development of downstream products, jackfruit has remained mainly as a minor fresh fruit in domestic markets. Although the importance of jackfruit for these purposes has been well recognized, very little research work has been done on this important fruit species.

In recent decades, a number of scientific and economic interests have emerged to promote and commercialize jackfruit products. The primary reason for this is that the crop is already well-suited to the household and farming systems of small farmers vulnerable to food shortages and nutritional deficiencies. Diversification within these systems, through enhanced use of jackfruit could lead to increased production of new products which can be sold to raise income as well as to satisfy the subsistence needs.

To address these issues, suitable approaches need to be adopted by policy makers, researchers, extension workers, food processors and traders to improve the crop. Suggestions have been made in particular for research requirements and for technology transfer to remove the constraints being faced by the farmers and the industry.

- ◆ Documentation of area, production and productivity needs to be undertaken and effective method of documentation has to be worked out.

## **7.1 Genetic resources of jackfruit**

For the efficient utilization and conservation of jackfruit germplasm, the researchers are showing keen interest in studying genetic diversity of this species. Underutilized crops have been overlooked for improvement by scientists possibly due to lack of knowledge of the crop. In jackfruit, collecting, characterization, documentation and evaluation from the region of origin and centers of diversity have been sporadic and are far from complete. There is an urgent need to undertake targeted collecting from the Indian sub-continent and other jackfruit growing countries of Southeast Asia to assemble the diverse germplasm and use in the varietal improvement. In terms of genetic resources, collecting of wild species will not be justified unless they are evaluated and used

for crop improvement. However, pointers can be derived from data recorded on local knowledge and ethnic uses. The following points need consideration:

- ◆ Future collecting and genetic diversity studies should focus on specific desirable characters and the germplasm need to be conserved both in *in situ* and *ex situ* conditions.
- ◆ There is a need to develop strategic plans based on the results of research and cooperation between neighbouring countries or regions, for genetic conservation of the jackfruit gene pool, needs to be strengthened.
- ◆ Germplasm collecting, characterization (including use of DNA markers as a tool), evaluation, and documentation the genetic diversity needs to be given a greater thrust. Through farmer participatory studies, quality planting materials need to be identified, in particular to meet the marketing needs.
- ◆ A comprehensive understanding of genetic diversity and molecular characterization of jackfruit cultivars is needed for formulating appropriate sampling and management strategies. A detailed analysis of a large number of genetic markers will provide with useful gene conservation strategies and help in popularizing this species as a commercial crop.
- ◆ Jackfruit is thought to be originated in the Western Ghats region of India, and there is a possibility of occurrence of wild forms which need to be collected. The original progenitor of the cultigen is not precisely known and it is not confirmed whether truly wild material still exists which needs to be explored.

## 7.2 Varietal improvement

The basic understanding of the existing clones is an essential prerequisite for the further improvement in jackfruit. Some trees produce sweet aromatic fruits; others are nearly dry and

sour. Better selection and vegetative propagation of clones is practicable and efforts should also be made to extend the fruiting season. Although little work has been done on rootstock and scion compatibility, the evidence so far is that there is a wide variability in scion performance with different rootstocks. At present, selection in jackfruit has not been rigorous. Farmer's selection criteria include high yield, fruit quality, sweetness, early fruiting types and off-season types. However, there are no true cultivars developed as such, but local types have been identified which have been given specific names. Little is known about the breeding of jackfruit. This may be due to it being a long-lived tree and a minor fruit. Any attempt to produce improved jackfruit cultivars needs to be targeted both for commercial production and for their value in home gardens and for small growers, thus adding substantially to the latter's income generation and food requirement. The following important aspects need consideration for varietal improvement:

- ◆ In breeding for improvement of qualitative traits, studies on genetic correlations between traits need to be undertaken in order to decide the parents for the hybridization programme.
- ◆ An assessment of the patterns of existing genetic diversity needs to be made. Such a study will help planning for national genetic conservation activities, either in natural ecosystems or on-farm sites, or in well-known, well-described and focused *ex situ* collections.
- ◆ Suitable cultivars/varieties need to be developed to meet the specific needs for fruit and timber production as well as for multipurpose use.
- ◆ Information on the mode of inheritance of important characters need to be generated and identification of gene(s) for

seedlessness, dwarfness, resistance against fruit fly, fruit-rot and soil salinity need to be initiated on priority.

- ◆ The close relatives need to be identified and species relationships needs to be studied so as to throw light on the taxonomy of the genus, *Artocarpus*, which can be made use in the breeding programmes.

### **7.3 Package of practices for enhanced production**

For homestead gardens and small orchards, land preparation requires technical skills (Coronel, 1983) but for commercial or large scale plantations, land preparation requires much more attention to attain the desired tilth. Most cultivated material is of seedling origin which often represents relatively inferior genetic material. There is a need to promote vegetatively propagated material thus improving uniformity and also early bearing. Extension efforts to improve nursery techniques and provision of better planting materials are urgently needed. Region-specific production techniques for jackfruit are not well established as limited research work has been done in this area. Systematic experimentation is needed to develop optimum agronomic packages for jackfruit in different agro-ecological areas. The potential of the crop in different cropping systems has not yet been adequately investigated. The crop can be more widely grown once the combination of crops in agroforestry systems has been established. Thus, the future research has to focus on the following areas:

- ◆ There is a great need for developing of optimum and standard vegetative methods of propagation for the use by small farmers who can develop small businesses through the establishment of nurseries.
- ◆ Greater thrust needs to be given for developing reproducible *in vitro* methods of propagation to multiply promising planting materials.

- ◆ Systematic studies on the wild species need to be conducted to assess grafting compatibility to identify vigorous and genetically stable rootstocks.
- ◆ The production technologies including organic production techniques need to be standardized for better crop management and input use efficiency.
- ◆ Suitable strategies need to be developed for integrated pest and disease management (IPDM) using botanicals and biological control agents (BCA).
- ◆ Efforts need to be made to established appropriate mechanism for transfer of information and technology to the farmers
- ◆ There is a need to study the impact of climate change on the performance of jackfruit.

#### **7.4 Post-harvest handling, processing and product development**

Possibilities and opportunities exist for small food producers to process jackfruit for local income generation and employment. In rural areas in jackfruit producing countries, food processing is a major source of employment. It is not only important to the national micro-economy but also is one of the fastest growing sectors and is particularly relevant to marginalized and vulnerable women. Enhanced income allows this group of women the flexibility to spend on education, nutrition, and health. As a result, it increases their income capacity and raises their status in the society so that women command increased respect from families and communities. The present status of post-harvest handling and processing of jackfruit is very poor. There is high degree of wastage because seasonal production causes gluts in the market and low prices. A major constraint is the lack of accessible practical information, in particular on post-harvest



handling and processing. However, the policy environment is also important. Agro-processing sectors involved with major crops receive government support in the form of subsidies, foreign exchange allowances, price stabilization or guarantees, and access to specialists and consultants. Small-scale processors involved with underutilized fruits do not have such advantages. The following important points need consideration:

- ◆ Appropriate methods for post-harvest handling, processing and product development for local and regional markets should be developed.
- ◆ At the local level, technology needs to be transferred to promote products, packaging techniques and better long distance transportation.
- ◆ Current information on the possible efficacy of some of the remedies might be based upon some limited phytochemical screening and very limited amount of clinical testing greater efforts need to be made in this direction to explore and utilize in a therapeutic manner.
- ◆ For jackfruit seed powder, pasting behaviour of jackfruit seed flour at different level of incorporation and utilization in non-bakery industry need to be investigated.
- ◆ Outreach activities need to be strengthened for popularizing the utilization of jackfruit seed flour at household level.
- ◆ A cumbersome process is involved in cutting and scooping out the bulbs/flakes and making it ready besides big size fruit which small family finds difficult to consume in a day. Hence, there is a need to develop efficient mechanical methods for cutting and scooping out the bulbs/flakes.
- ◆ Greater efforts need to be made for processing, value addition and product development.

## 7.5 Economics and marketing

There are a number of factors, limiting the potential exploitation of jackfruit, the major reason being unorganized supply chain management. Unlike other potential crops, absence of strong marketing system is the major hindrance in its commercial exploitation. Although a number of indigenous methods are available for post-harvest handling including processing and value addition, these fruits have not been widely cultivated involving scientific management practices. In spite of sizable production, the growers by and large neglect it. Cutting and cleaning of the fruit is also cumbersome and this also results in neglect of the fruit. The following aspects need urgent attention:

- ◆ To improve income of growers and producers, government agencies and institutions should carry out policy research and stimulate the formation of cooperatives, women's self-help groups or other such associations so that they can reach regional and international markets.
- ◆ It is extremely important that systematic information is gathered and disseminated to all concerned, including those involved in rural development, growers, product producers and small entrepreneurs.
- ◆ There is a great need to establish appropriate market linkages so that the jackfruit farmers/growers can channelize the sale of their produce in an efficient and cost-effective manner.

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