

Production Technologies of Humid Tropical Underutilized Fruits in India

Prakash Chandra Tripathi

Email: prakaashtripathii2000@yahoo.co.in

Underutilized fruit crops refer to those fruits which may be high in value but that are not widely grown. An exact definition of underutilized fruit crops is perhaps difficult. In general, these fruits are consumable in relatively less quantity may be due to less palatable or less availability than other fruits. These fruits may have lesser demand in the market or grown in a limited extent. Other terms for these fruits are lesser-known, less appealing, less-exploited fruits, underutilized, stray fruits, wild fruits etc. However, any sharp line of distinction between the major and minor fruits is difficult. A fruits which is major fruit in one region or country may be minor in other region or country. If area and production are considered to be the criteria to call a fruit crop as major or minor, difference may be observed even in the same country as well. The climatic conditions are important for cultivation which influences the area and spread of crop. The production and the consumption may be considered as criteria for categorising crops as minor crop. The minor crops may categorise in several groups such as temperate, tropical and subtropical; native and introduced. As far as the native fruits are concerned, India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rainforests to alpine vegetation and from temperate forests to coastal wetlands. Several fruit plant species have originated in Indian subcontinent. India is centre of origin of jackfruit, bael, aonla, ber, khejri, jamun, tamarind, mahua, phalsa, lasoda, karonda, wood apple, pilu, bilimbi, Garcinia, and several other wild fruits. Several minor fruits such as Rambutan, mangosteen, longan, avocado, water apple, hog plum, macadamia nut, kiwifruit, longsat, durian,

passion fruit, dragon fruit, pulasan, carmbola, etc. were introduced during last few centuries and several are naturalized in Indian conditions (Tripathi *et al*, 2017; Table 1). Apart from these there more than 100 wild edible fruits native to India which are yet to be domesticated but these are gathered from forest by the rural and tribal people and sold in the rural market (Tripathi *et al.*, 2014a,b,2017,Tripathi , 2018,2019).

Table 1. Underutilized fruits suitable for humid topical conditions

Fruit	Scientific name	Family	Origin
Jackfruit	<i>Artocarpus heterophyllus</i>	Moraceae	Western Ghats (India)
Star Gooseberry	<i>Phyllanthus acidus</i>	Euphorbiaceae	India, South Asian countries
Bilimbi	<i>Averrhoa bilimbi</i>	Oxalidaceae	India, South Asian countries
Jamun	<i>Syzygium cumini</i>	Myrtaceae	India, South Asian countries
Pommelo	<i>Citrus grandis</i>	Rutaceae	India Malaysia, countries
Kokum	<i>Garcinia indica</i>	Clusiaceae	Western Ghats (India)
Rose Apple	<i>Syzygium jambos</i>	Myrtaceae	India, South Asian countries
Malabar tamarind	<i>Garcinia gumigatta</i>	Clusiaceae	Western Ghats (India)
Governor's plum	<i>Flacortia indica</i>	Flacourtiaceae	India, South Asian countries
Yellow mangosteen	<i>Garcinia xanthochymus</i>	Clusiaceae	India, South Eastern Asian countries
Barbados Cherry	<i>Malpighia glabra</i>	Malpighiaceae	Northern South America
Durian	<i>Durio zibethinus</i>	Malvaceae	South Eastern Asia countries
Soursop	<i>Annona muricata</i>	Annonaceae	West Indies and Northern South America
Passion Fruit	<i>Passiflora edulis</i>	Passifloraceae	Central American countries
Atemoya	<i>Annona atemoya</i>	Annonaceae	Central American countries
Dragon fruit	<i>Hylocereus.spp</i>	Cactaceae	Central American countries
Longan	<i>Dimocarpus longan</i>	Sapindaceae	Southern China
Longsat	<i>Lansium domesticum</i>	Meliaceae	South Eastern Asian countries
Surinam cherry	<i>Eugenia uniflora</i>	Myrtaceae	Central American countries
Malay Apple	<i>Syzygium malaccense</i>	Myrtaceae	South Eastern Asian countries
Mangosteen	<i>Garcinia mangostana</i>	Clusiaceae	South Eastern Asian countries
Rambutan	<i>Nephelium lappaceum</i>	Sapindaceae	South Eastern Asian countries
Avocado	<i>Persia americana</i>	Lauraceae	South Mexico to Northern South America
Macadamia nut	<i>Macadamia integrifolia</i>	Proteaceae	Australia
Wax apple	<i>Syzygium samarangense</i>	Myrtaceae	South Eastern Asian countries
Carambola	<i>Averrhoa Carambola</i>	Oxalidaceae	South Asian countries
Egg fruit	<i>Pouteria campechiana</i>	Sapotaecae	Central American countries
Bread fruit	<i>Artocarpus altilis</i>	Moraceae	Central American countries
Pulasan	<i>Nephelium mutabile</i>	Sapindaceae	Western Malaysia

Area and production

India has two subtypes of humid tropical climate, viz. tropical monsoon climate and tropical wet and dry climate. These area experiences persistent warm or high temperature which normally do not fall below 18°C. The tropical monsoon climate covers a strip of south-western lowlands abutting the Malabar coast, the Western Ghats, southern Assam, Lakshadweep and the Andaman and Nicobar Islands. This climate is characterised by moderate to high year-round temperatures with seasonal but heavy rainfall typically above 2,000 mm per year. The relative humidity remains high throughout the year. The tropical wet and dry climate prevails over most of inland peninsular India except for a semi-arid rain shadow area towards east of the Western Ghats, Parts of West Bengal, North Eastern States, Odisha, Coastal Andhra Pradesh. This region experiences very high temperature during summer and annual rainfall averages between 750–1,500 mm. These regions contribute around 20 percent of total area of the country. The area under for humid tropical underutilized fruits is less than 2 per cent of the total area under fruits and production is less than 1 per cent of total fruits production of India. Most the minor fruits are cultivation in rainfed and less fertile lands thus the productivity is low except in jackfruit. Among them highest area is under jackfruit followed passion fruit. The cultivation of other fruits is confined to parts of Kerala, Tamil Nadu and Karnataka (MAFW, 2017; Tripathi *et al.*, 2017, Table 2).

Table 2. Area, production and productivity of minor fruits in India (2015-16)

Fruit	Area (000 ha)	Production (000' tonnes)	Major production areas
Jack fruit	151	1731	Tripura, Odisha, Assam, West Bengal ,Kerala Karnataka, Chhattisgarh, Jharkhand
Passion fruit	13	78	Nagaland, Mizoram, Manipur, Kerala, Karnataka, Tamilnadu
Jamun	NA	NA	Maharashtra, Gangetic plains of Uttar Pradesh, Tamil Nadu, Gujrat, Assam,
West Indian cherry	Trace	NA	Hot humid regions of South India
Star gooseberry	Trace	NA	Maharashtra, Karnataka
Durian	Trace	NA	Tamil Nadu, coastal Karnataka
Soursop	Trace	NA	Coastal Karnataka, Kerala and Tamil Nadu
Bilimbi	0.02	NA	Hot humid regions of South India
Mangosteen	0.02	NA	Kerala, Karnataka, Tamil Nadu
Rambutan	1.0	NA	Kerala, Karnataka, Tamil Nadu
Avocado	2.0	NA	Tamil Nadu, Karnataka, Kerala
Atemoya	0.001	NA	Maharashtra, Karnataka
Java apple	Trace	NA	Hot humid regions of South India
Dragon fruit	2.0	NA	Maharashtra, Karnataka, Gujarat

APEDA website 2020, Tripathi *et al.*(2017)

Minor Fruits as Source of Nutrition

The world depends for its basic diet of carbohydrates, fats, and proteins on a very limited number of crop species. Many minor crops have been potential for achieving significant increases in productivity and thus improvements in nutritional security at local and regional levels. A number of studies have shown the importance of locally available indigenous or traditional fruits, vegetables, grains, and roots and tubers to nutrition and health of rural and indigenous communities. An important element in the use of minor fruits in particular to address micronutrient/vitamin deficiency. The minor fruits have less carbohydrates but rich in fibres, nutrients, vitamins and nutraceutical properties. Proteins form the important components of muscles, skin, hair and other tissues and vital body fluids like blood. Protein deficiency leads to disorders like protein energy malnutrition, kwashiorkor, etc. (Reddy, 1991). Although most of the minor fruits are low in protein but some underutilized fruits and nuts are good source of protein. These are Macadamia nut, Chronji, Java almond, Shea butter tree, Brazil nut, Indian almond, marula nut, Mogongo nut, Melinjo etc. (Pareek *et al.*, 1998; Table 3a).

Carbohydrates are a class of energy yielding substances which include starch, glucose, Fructose, etc. Carbohydrate deficiency in body causes weakness, weight loss, and reduced physical activity. Most of the fruit contains the simple carbohydrates (sugars) fructose, glucose and sucrose, as well as citric acid which can also provide a small amount of energy. Carbohydrates derived from different underutilized fruits form chief source of energy in Indian diets especially in tribal areas. (Gopalan *et al.*, 2004). Among the underutilized fruits, viz. bread fruit, Jack fruit, durian, Longan, Rambutan, Mangosteen, passion fruit, sour sop, jamun contain higher amount of carbohydrates (Gopalan *et al.*, 2004; Pareek *et al.*, 1998; Table 3a).

Fat is an important foodstuff for many forms of life, and fats serve both structural and metabolic functions. There are two essential fatty acids (EFAs) in human nutrition: alpha-linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid). Fat is a major nutritional concern in poor societies, especially in lower income rural and tribal. Fat deficiency in body causes pyronoderma (toad skin), weakness, and weight loss (Gopalan *et al.*, 2004). A molecule of dietary fat typically consists of several fatty acids to a glycerol. Most of the nuts are rich in fats. Among the fruits avocado, seeds of kokum, Malabar Tamarind, Mahua nut fruits are rich in fats (Table 3a).

Vitamins are classified by biological and chemical activity. Most of the fruits and vegetables are good source of vitamins. Vitamin A is necessary for clear vision in dim light. Lack of vitamin A thus leads to night blindness. Ripe yellow fruits such as jackfruit, mahua, phalsa are rich sources of vitamin A. Some of the underutilized fruits such as *Astrocaryum aculeatum* (51667IU), *Eugenia stipitata* (12917 IU), melinjo leave (*Gnetumgnemon*) (10889 IU), peach palm (*Bactris gasipaes*) (7300 IU), Barbados gooseberry (*Pereskia aculeata*) (3215 IU), Eggfruit (*Pouteria campechiana*)

(2000IU), Cape gooseberry (*Physalis peruviana*) (1000-5000 IU) are rich source of Vitamin A. Vitamin B1 or thiamine is an important vitamin. Prolonged deficiency of thiamine in the diet is one of the main factors leading to the disease beri-beri. Chronji (*Buchanania lanzan*), Pine nut (*Pinus edulis*), Coastal copper (*Capparis spinosa*), Shia butter tree (*Butyrospermum parkii*) are rich source. Vitamin B₂ or Riboflavin as a part of coenzyme is essential for several oxidation processes inside the cell and is concerned with energy and protein metabolism. Bael (*Aegle marmelos*), elephant apple (*Ferronia limmonia*), Mahua (*Madhuca indica*) flower are rich source of Vitamin B2. Vitamin B3 or Niacin is a vitamin intimately connected with several metabolic reactions. Bael (*Aegle marmelos*), Mahua (*Madhuca indica*) flower, Ilama (*Annona diversifolia*), Egg fruit (*Pouteria campechiana*) are rich source of Vitamin B3. Vitamin C (ascorbic acid), an essential water soluble vitamin, plays a key role in the formation of collagen. Vitamin C deficiency is wide spread in the third world countries. The common symptoms are pain in joints, swelling of limbs, bleeding of gums, tooth decay, rheumatism. Ascorbic acid found abundantly in several underutilized fruits. Some the very rich source of vitamin c are Barbados cherry (*Malpighia glabra*, 1550-5600 mg), Camu-camu (*Myrciaria dubia*, 2994-4000 mg), jaboticaba (*Myrciaria cauliflora*, 700-2400 mg), cabeludinha (*Eugenia tementosa*, 931 mg). Vitamin E benefits include treating and preventing diseases of the heart and blood vessels, such as chest pains, high blood pressure, and blocked or hardened arteries. Fruits and nuts like almonds, olives, macadamia nut and other nuts are rich in vitamin E (Pareek *et al.*, 1998; Table 3a).

Minerals are essential for maintaining the moisture content of tissues and for development of bones. Calcium is required component of bones; essential for energy processing. Approximately 80% is found in inorganic portion of bones and teeth. Phosphorus is a component of every cell, as well as important metabolites, including DNA, RNA, ATP, and phospholipids. It is generally found in jackfruit, passion fruit, chironji (*Buchanania lanzan*), Soncoya (*Annona purpurea*), Brazil nut (*Bertholletia excelsa*) are good source of phosphorus. Durian (10 mg), longan (10 mg), Carambola (10 mg), Barbados cherry (18 mg) are good source of magnesium. Among the minor fruits durian (28 mg), mangosteen (0.21 mg), Carambola (0.12 mg), wood apple (10 mg), jackfruit (0.13 mg) are good source of zinc. The value of minor fruits in treatment medicine is well known. Kokam (*Garcinia indica*) and Malabar tamrind (*Garcinia gummigutta*) are main component for anti obesity formulations. Several other underutilized fruits are used by tribal and rural people of North eastern India for wide range of common ailments like jaundice, diabetes, diarrhoea, dysentery (Pareek *et al.*, 1998; USDA database, 2017; Tripathi *et al.*, 2020, Table 3b).

Table 3a. Nutritional Value of underutilized fruits (per 100g of edible portion)

Fruits	Protein (g)	Carbohydrates (g)	Fat (g)	Fibre (g)	Vitamin A (mg/iu)	Riboflavin (mg)	Thiamine (mg)	Niacin (mg)	Ascorbic acid (mg)
Karonda	1.1	2.9	2.9	-	-	-	-	-	350
Kokum(dry basis)	1.92	36.4	10.0	14.3	-	-	-	-	0.06
Jack fruit	1.75	20.7	0.3	1.25	438	0.04	0.06	0.4	9
Jamun	0.7	15.0	0.22	0.8	80	0.01	0.02	0.29	92.0
Avocado	1.7	5.1	26.4	1.8	0.17	0.13	0.06	1.10	16.0
Dragon Fruit	0.18	-	0.41	0.8	0.08	0.043	0.29	1.29	8.5
Durian	1.47	27.09	5.33	3.8	44	0.2	0.37	1.07	19.7
Longan	1.31	15.14	0.1	1.1	-	0.14	0.031	0.3	84
Mangosteen	0.41	17.91	0.58	1.8	-	0.054	0.054	0.286	2.9
Rambutan	0.65	20.87	0.21	0.9	-	0.022	0.013	1.35	4.9
Bilimbi	0.61	-	-	0.6	0.035	0.026	0.010	0.302	15.5
Carambola	1.04	6.73	0.33	2.8	61 I	0.016	0.014	-	34.4
Governor's plum	0.5	24.4	0.6	1.2	30	0.02	0.01	0.4	5.0
Hog plum	0.7	4.6	0.4	1.0	270	0.02	0.2	0.3	21
Malabar Tamarind	0.61	8.6	1.5	3.1	-	-	-	-	-
Passion fruit(purple)	0.9	13.6	0.1	-	717	-	0.1	1.5	30
passion fruit(yellow)	0.7	13.1	0.2	-	2410	-	0.1	2.2	20
Sour Sop	1.0	16.8	0.97	3.3	-	0.05	0.07	0.8	20.6
Wax Apple	0.6	5.7	0.3	-	-	0.03	0.02	0.8	22.3
Yellow mangosteen	5.01	11.4	1.65	2.73	33.3	-	-	-	11.6

Table 3b: Nutritional value (minerals) of humid tropical underutilized fruits (per 100g of edible portion)

Fruits	Calcium (mg)	Iron (mg)	Magnesium (mg)	Manganese (mg)	Phosphorus (mg)	Potassium (mg)	sodium (mg)	Sulphur (mg)	Zinc (mg)
Karonda	2.1	-	-	-	28	--	-	-	-
Kokum(dry basis)	-	-	-	-	-	-	-	-	-
Jack fruit	29	0.5	0.8	28					
Jamun	11.5	1.41	55	15.6	55	26			
Avocado	10	0.60	35	4.21	38	368	28.5		
Dragon Fruit	7.5	0.55	-	-	30.2	-	2.0		
Durian	6	0.43	30	0.032	39	436	2		0.28
Longan	1.0	0.13	10	0.052	21	266			0.05
Mangosteen	12	0.30	13	0.102	8.0	48	7.0		0.21
Rambutan	22	0.35	7.0	0.34	9.0		11.0		
Bilimbi	3.4	1.01	-	-	11.1	-			
Carambola	3	0.08	10	12	133	2			0.12
Governor's plum	33	0.7	-	17	171	-			
Hog plum	36	3.9	-	11	-	-			
Malabar Tamarind	-	-	--	-	169	2.1			
Passion fruit(Purple)	3.6	0.2	-	12.5	-	-			
Passion Fruit(Yellow)	3.9	0.4	-	24.5	-	-			
Sour Sop	14	0.6	21	-	278	14	0.1		
Wax Apple	29	1.0	5.0	8	123	-	0.06		
Yellow mangosteen	278	1.1	-	0.05	10	-			

Underutilized Fruits for Livelihood

A number of species of underutilized fruits are being used by the people in Asia and Africa as suitable food, food supplements and sources of spices and condiments, edible oils etc. These provide life support and ameliorate the rigours of unfavourable conditions. In India, particular in central India, parts flowers, fruits and seeds of mahua, tamarind are important source of food and income. Similarly, in South India Jackfruit (*Artocarpus heterophyllus*) is important source of food (Arora and Pandey, 1996). The tribes of Rajasthan depend on minor fruits for 3-4 moths in a year. In African countries, plum tree (*Dacryodes edulis*) provide food during off season (Okafar, 1991). The peach palm (*Bactris gasipaes*) is important in South and central America.

PRODUCTION TECHNOLOGIES

Varieties

The research works humid tropical underutilized fruits in India was initiated recently. Although some of the collections of these fruits were made at State Horticultural Farm, Burliyar and Kullar (Tamil nadu) long back. Some of the research station such as Fruit Research Station, Bengurla (Maharashtra) on Kokum, Horticultural Research Station, Thadiyankudisai (Tamil Nadu) on Avocado and Central Horticultural Experiment station (IIHR), Chettalli (Karnataka) initiated some research works. In 2006, a Network project on underutilized fruits was launched by ICAR with 4 centres. This project gave a boost to research works on underutilized fruits. Meanwhile several nursery persons or private firms imported several underutilized fruit plants from south Eastern Asian countries and planted in humid regions of Karnataka, Kerala, Tamil Nadu. Central Horticultural Experiment station (IIHR), Chettalli is maintaining large collection of more than 20 underutilized fruits including Rambutan, Avocado, mangosteen, wax apple, passion fruits, longan, dragon fruit, karonda, kokum, Malabar tamarind etc. Two varieties of rambutan and one variety of avocado, one variety of passion fruit have been released and several promising lines have been identified. Similarly, two varieties of Kokum and one variety of karonda have been developed by Regional Fruit Research Station Vengurle, (Maharashtra). Horticultural Research Station, Thadiyankudisai (Tamil Nadu) released one variety of avocado. Several private nurseries have imported commercial varieties of these fruits from other countries and supplying the growers. Despite of this, few varieties of humid tropical fruits are available in India ((Tripathi *et al.*, 2014a,b, 2017, Tripathi, 2018, 2019; Table 4).

Table 4. Varieties and promising lines

Fruits	Varieties/ promising lines
Rambutan	Arka Coorg Arun, Arka Coorg Peetabh, N -18 , N-34
Butter fruit (Avocado)	Hass, Purple, Green, Fuerte, Pollock,TKD-1, CHESA-1 , Arka Supreme
Passion fruit	Kaveri, CHES P-4, Coorg Yellow, Ooty Purple, Coorg Purple, Thrissur Purple, Cherapunji Purple
Pummelo	CHES-8, White flesh, Pink flesh, Devanhalli, Kanapara, Triumph, Royal
Karonda	Konkan Bold, CHES K-2-7, K-35, Pant Manohar, Pant Suvarna, Pant Sudarshan
Kokum	Konkan Amrut, Konkan Hatis, CHES GI-V-8, GI-VIII-5 ,7-9
Jack fruit	Pant Mahima, Pant Garima, PLR-1, PPI -1, PLR (J) 2, Sankar, Siddu, Konkan Prolific, Lalbag Madhura, Singapore
Jamun	Konkan Bahadoli, Rajendra Jamun 1, Goma Priyanka, Narendra Jamun 6, CISH J-42, CISH J-37, Dhoopdal, Thar Kranti
Malabar tamarind	CHES GG-1 , Promising lines from NBPGRSS, Thrissur,2-10
Malayan apple	CHES M-1
Dragon fruit	Red rind with white pulp, Red rein with Red pulp, Yellow rind with white pulp
Mangosteen	Local seedlings
Soar sop	Local seedlings

Climate

The humid tropical underutilized fruits generally require high humidity and moderate temperature. Most of them are sensitive to frost and do not grow well if temperature falls below 12°C. The sensitivity to temperature varies species to species. Mangosteen, durian and Rambutan are orthodox tropical fruits and much sensitive to low temperature and low humidity. Kokum and Malabar tamarind requires high humidity but were found well performing well in Bangalore conditions. Passion fruit and avocado, dragon fruit are found better adaptability and now found growing in most of the regions of the country except temperate zones. Apart from temperature, relative humidity and rainfall is almost important for these crops. It has been found that the tree grows well but were not able to produce flowering and fruiting. Being tropical plants these required rainfall round the year. The temperature for optimum growth, rainfall for these the fruits is given in Table 5.

Table 5. Climatic conditions suitable for underutilized fruits

Fruit	Climatic	Optimum temperature	Rainfall (cm)
Rambutan	Tropical humid with high rainfall	22–30°C	200-500
Butter fruit	Tropical to Sub temperate	10–35°C	150-200
Passion fruit	Tropical and sub-tropical climate	10–35°C	120-150
Pummelo	Subtropical	20–30°C	
Karonda	Tropical , arid, subtropical	10–35°C	50-200
Kokum	Tropical humid with higher rainfall	22–30°C	150-200
Jackfruit	Tropical humid to subtropical	22–35°C	100-250
Malabar tamarind	Tropical humid with higher rainfall	22–30°C	150-200
Mangosteen	Tropical humid with higher rainfall	22–30°C	200-500
Malayan apple	Tropical humid with higher rainfall	22–30°C	200-500
Soar soap	Tropical humid with higher rainfall	22–30°C	200-500
Dragon fruit	Tropical , arid, subtropical	12–35°C	200-500
Durian	Tropical humid with higher rainfall	22–30°C	200-500

Soil

Most of these fruits can be grown successfully in wide range of soils. Well drained sandy loam to clay loam soils with organic matter are most suitable for optimum growth and yield. Some of these fruits can be grown successfully in red laterilte soil if adequate organic and inorganic fertilizers are applied. The optimum soil pH for most of the fruits is 5.5 to 7.5. Although, these are originated and grown in tropical high rainfall regions but most of them are sensitive to water logging. These fruits need good soil moisture for growth and fruiting, but water stagnation in root zone is detrimental. Rambutan is sensitive to water logging. The orchard on slight sloppy land have been found performing better (Table 6).

Table 6. Soil requirement for underutilized fruits

Fruit	Soil	pH	Drainage
Rambutan	Well drained sandy loam to clay loam soils with organic matter	4.5 to 6.5	Sensitive to water logging
Butter fruit	can be grown on a wide range of soils	5 to 7	Extremely sensitive to water logging
Passion fruit	light to heavy sandy loams, of medium texture are most suitable.	6.5 to 7.5	Sensitive to water logging
Pummelo	Well drained sandy loam to clay loam soils with organic matter	6.0-6.5	Sensitive to water logging
Karonda	All soil except very heavy and sandy soil	5.5 to 8.5	Hardy can tolerate water logging

Fruit	Soil	pH	Drainage
Kokum	Well drained sandy loam to clay loam soils with organic matter	5.5-6.5	Sensitive to water logging
Jackfruit	Rich deep soil with medium texture	5.5 to 7.0	Sensitive to water logging
Malabar tamarind	Well drained sandy loam to clay loam soils with organic matter	5.5-6.5	-
Mangosteen	Well drained sandy loam to clay loam soils with organic matter	6.0-6.5	Sensitive to water logging
Malayan apple	Well drained sandy loam to clay loam soils with organic matter	6.0-6.5	Sensitive to water logging
Soar soap	Well drained sandy loam to clay loam soils with organic matter	6.0-6.5	Sensitive to water logging
Dragon fruit	Well drained sandy loam to clay loam soils with organic matter	5.5-6.5	Very sensitive to water logging

Propagation

The propagation of most of these plants are done through seeds. But these crops like rambutan, kokum, Malabar tamarind which produces male and female seedlings in equal proportion. In some crops, the seedling growth is very slow such as dragon fruit. There are some fruits like mangosteen true seeds are not from and nucellar embryony is found. Some trees like jamun have polyembryony. Since seedling tree are not true to type thus, slowly the use of seedlings trees is decreasing and number of propagation techniques have been standardized in these crops (Tripathi *et al.*, 2014a,b,2017, Tripathi, 2018,2019, Tripathi and Karunakaran, 2020, Table 7).

Table 7. Multiplication method of humid tropical underutilized fruits

Fruit	Propagation method	Rootstocks
Rambutan	Air layering, chip budding Approach grafting	Own seedlings
Avocado	Cleft grafting	Own seedlings
Passion fruit	Cutting, serpentine layering	-
Pummelo	Patch budding	Own seedlings, Rangapur lime
Karonda	Air layering	-
Kokum	Cleft grafting	Own seedlings
Jack fruit	Cleft grafting, forkart budding	Own seedlings
Malabar tamarind	Cleft grafting	Own seedlings
Mangosteen	Nucellar seedlings	-
Malayan apple	Cutting, air layering	-
Soar soap	Cleft grafting	Own seedlings
Dragon fruit	Stem cutting	-

Planting

The planting distance depends on the size of the tree. Most of seedling trees are planted at larger distance due to more vigorous growth while vegetatively propagated are usually less vigorous and planted at shorter distance. Further, the climatic conditions and soil fertility status also important for planting distance. It has been observed that the growth rate of typical tropical fruits, such as rambutan, durian, pulasan, fruit is Indian conditions is slower than the growth of these trees in tropical humid conditions. Thus, grafted planted of Rambutan, mangosteen and avocado, jack fruit are planted at 6 x 6 m distance instead of 8x8 m distance. The grafted plants of Kokum and Malabar tamarind are also planted at 6 m distance. The passion fruit, karonda, dragon fruits are planted at lower distance due to different training and pruning system (Table 8).

Table 8. Planting methods and time of humid tropical underutilized fruits

Fruit	Planting distance	Pit size	Planting time
Passion fruit	2 m x3 m	45 cm × 45 cm × 45cm	June -July
Soar sop	4 m x 4 m to 6 m x 6 m	60 cm × 60 cm × 60cm	June -July
Rambutan	6 m x 6 m	1 m × 1m ×1m	June -July
Jack fruit	6 m x 6 m	1 m × 1m ×1m	June -July
Avocado	6 m x 6 m	1 m × 1m ×1m	June -July
Karonda	3m x 3m,0.6 m x 6m (hedge row)	60 × 60 × 60cm	June -July
Mangosteen	6 m x 6 m	1 m × 1m ×1m	June -July
Kokum	6 m x 6 m	1 m × 1m ×1m	June -July
Malabar tamarind	6 m x 6 m	1 m × 1m ×1m	June -July
Dragon fruit	3 x 3 m (4 plants per pillar)	60 cm × 60 cm × 60cm	June -July

Nutrient

Balanced nutrition is considered to be the most important which determines productivity and quality. Most of the underutilized fruits responds well to exogenously applied manure and fertilizers . The research data on the fertilizer doses in these fruits are available in scanty, as very little research have been done on these crops. The recommended doses used in other countries with similar soil type are used in Indian conditions. Since response varies depending upon cultivar, climatic conditions and soil types. There is need to work out nutrient doses for these crops. Most of the tropical underutilized fruits need more organic matter and high doses of nutrients as their growth is faster. The manure and fertilizers are given more than one time to reduce the runoff losses. Some vine crops requires lower doses.The best time of fertilizer application is June-July, September -October and after harvesting of fruits (Table 9).

Table 9. Fertilizer dose for underutilized fruits

Fruit	Farmyard Manure (kg)	N (g)	P (g)	K (g)	Time of application
Rambutan (6 year and Above)	50 kg	2400g	300g	1500g	Four times (Before and after harvesting and in between one application)
Avocado (6 year and Above)	50 kg	1200g	800g	1000g	Two times Before and after harvesting
Passion fruit (3 years and above)	10 kg	110g	60g	110g	Three times
Karonda (3 years and above)	10 kg	100g	100g	100g	Two times Before and after harvesting
Jamun (10 year and above)	50 kg	1250	500	500	Two times Before and after harvesting
Jack fruit (10 year and Above)	50 kg	750	400	500	Two times Before and after harvesting
Kokum (10 year and above)	20 kg	500	250	250	Two times Before and after harvesting
Dragon Fruit (3 year)	20	500	750	300	Four times Before and after harvesting

Training and Pruning

Most of the tropical underutilized fruits are evergreen and requires lesser pruning as compared to temperate fruits. It is necessary to trained the plants to reduce the height of plants for better management. Most of these plants are trained in open centre system to utilize maximum light and air circulation. The procedure of training the branches and making frame work of the branches should be completed in initial 3- 4 years. Thereafter pruning is done to remove the dried and diseased branches. Further, water suckers, crowded and crisscross branches are removed to facilitate better growth and yield. Some the fruits like passion fruit, karonda and dragon fruit required special type of training and pruning for better yield (Table 10). Karonda plant has comparatively weaker stem in initial years. The plant has tendency to produce several branches just above ground surface. The branches which are emerging near the ground surface need to be removed for convenience in cultural operations. The branches should be trained in open centre system for better production. The karonda plant grows very vigorously in humid and tropical regions and heavy pruning is required every year. Karonda planted for hedges purposes need not be trained in this manner and 3-4 branches are allowed to near ground level to make a compact hedge. The hedges are trimmed after harvesting of fruits.

Dragon fruit plants produce fast growing weak branches vines and produce thicker dense of branches in initial stage. The plant need support generally pillars with ring at top are used. The lateral buds and branches should prune to grow towards stands. Once

vines reach up to the top of the stands, the branches are allowed to grow. The removal of tip of stem induces lateral branching. The well grown vine may produce 30 to 50 branches in 1 year and may be more than 100 branches in 4 year. These branches should be trimmed to better aeration, easy cultural operation and prevention of disease & pest.

Passion fruit is a woody vine, it needs support for good growth and fruiting. The vines are trained on a frame of wires and poles 1.5 to 2 meter above the soil surface. Among the different types of trellising, Kniffin system is the most economical. After certain growth of main stem, two leader branches are allowed on either side of the wire. The tips of the leaders are cut to produce laterals which are trained downwards hanging from the wire. Passion fruit vines bear fruits only on current season's growth. Once the laterals have produced the fruits, they are cut back to four to six buds so as to induce regular bearing. Pruning is generally done twice in a year, first in March and April and another in October-November depending upon the harvest of the crop.

Table 10. Training and pruning of humid tropical underutilized fruits

Fruit	Training system	Pruning
Rambutan	Open centre	Minor pruning for removal of dead, diseased branches
Avocado	Open centre	Minor pruning for removal of dead, diseased branches
Passion fruit	Kniffin system	Pruning of secondary branched twice a year
Pummelo	Open centre	Minor pruning for removal of dead, diseased branches
Karonda	Shrub or hedge system	Heavy pruning after fruit harvesting
Kokum	Open centre	Minor pruning for removal of dead, diseased branches
Jackfruit	Open centre	Minor pruning for removal of dead, diseased branches
Malabar tamarind	Open centre	Minor pruning for removal of dead, Diseased branches
Mangosteen	Open centre	Minor pruning for removal of dead, diseased branches Minor
Malayan apple	Open centre	Minor pruning for removal of dead, diseased branches
Soar soap	Open centre	Minor pruning for removal of dead, diseased branches
Dragon fruit	Pillar system	Pruning of secondary branched once a year after fruiting

Intercropping

During the initial period of establishment, the space between the plants can be utilized for planting of intercrops. These give additional income in the initial stage of planting without competing with the main crop. Cowpea, French bean or other

suitable crops of the regions are grown as intercrops. In the mature orchards, green manure crops may be grown and incorporated into the soil, which improves its fertility, moisture holding capacity and physical condition. Some these crops like avocado etc are now grown as mix crop in the coffee and mandarin orchards in Kodagu and Kodaiknall region of south India.

Water Management

The tropical humid fruits need high humidity throughout the year. Thus, irrigation is required if needed in dry seasons. In some fruits like rambutan, longan etc. a dry period of 21-30 days is required to induce flowering. The rambutan plant are treated that they start to bloom within 10-15 days after water manipulation. Apart from this, newly planted plants should be given irrigation. Young plants should be irrigated at 10-15 days interval in the winter and 6-7 days in summer season. The basin or flood method of irrigation is normally practised. However, adoption of drip irrigation has been found to be effective in the economic use of water and enhanced growth. The studies conducted at CHES, Chettali found that passion fruit requires irrigation of 12-15 litre /vine/day in summer and 6-8 litre /vine/day) in winter. Drip irrigation was found very beneficial. It responds significantly to fertigation. In a study on response of passion fruit to K fertigation showed highest commercial production. Mulching with dry leaves or residues in the basin helps in moisture conservation.

Flowering and Fruit Setting

The flowering in underutilized fruits starts after 6-10 years of planting in seedling trees. The vegetatively propagated trees generally started fruiting in 4-5 years. Some crops like passion fruit, dragon fruit starts flowering in 1-2 years. The flowering time generally varies from December to May in different fruits (Table 11). Some fruits like rambutan, avocado, passion fruits, carambola flowers two times in a year under some climatic conditions. Some fruits like rambutan have male, female and hermaphrodite plants. The kokum and Malabar tamarind both male and female plants are separate. The avocado varieties are either A type or B type varieties. Other fruits also require cross pollination for fruiting. The pollinisers and pollinators play major role in proper fruit set. Some of the fruit crops such kokum and Malabar tamarind are wind pollinated while some fruit crops are insect pollinated. Bats play major role in pollination of durian. Honey bee, small bees, flies, bumble bees etc. are major pollinators. Honey bee colonies in orchards during flower season helps in increasing fruit set.

Table 11. Flowering time of humid tropical underutilized fruits

Crop	Initiation of Fruiting (years)	Flowering time
Rambutan	4-5	March-May
Avocado	3-4	August-September and February-March
Passion fruit	1	February-March and September-October
Pummelo	4-5	May-June
Karonda	3	December-January
Kokum	6-7	December-January
Malabar tamarind seedling)	8-10	January-February
Malayan apple	3-4	December-January
Soar soap	3-4	March to July
Dragon fruit	1	June- July
Mangosteen (seedling)	8-10	March - April
Jack fruit	4-5	December- March

Harvesting

It may take up to 2 to 8 months for the fruits to mature fruits after fruit set in different fruits. Dragon fruit and passion fruit matures within 2 months while pummelo, avocados may take 6- 8 months to mature. Majority of underutilized fruits matures during the months of May to September. The fruits turn red or yellow or purple at maturity. Harvesting is done by shears or sharp knives with stalk or bunches. Thereafter, the fruits are individually cut off and packed for sale. It is recommended that the fruits should not be allowed to fall directly to the ground as this cause injury and cannot be kept for a long time. The fresh fruit are easily bruised and have a limited shelf life. An average tree may produce 10–70 kg per tree. However, yield may vary from year to year (Table12).

Table 12. Harvesting and yield potential of underutilized fruits

Crop	Time of Harvesting	Ripe fruit colour	Yield /tree
Rambutan	July – October	Red, Yellow	500-1000 fruits (20-30kg)
Avocado	April-May and Aug-Sept	Yellowish Green Dark Maroon	150-300 fruits (30-50 kg)
Passion fruit	May- June and Oct-Nov	Purple, Yellow	10-15Kg
Pummelo	Dec-Jan	Yellow	100-150 fruits (75 to 100 kg)

Crop	Time of Harvesting	Ripe fruit colour	Yield /tree
Karonda	April-May	Dark purple	1000-1200 fruits 10-15 kg
Kokum	May-June	Dull Red	30-40 kg
Malabar tamarind	July -August	Dull Yellow	30-40 kg
Malayan apple	March-April	Bight Red	1000-1500 fruits 40-50 kg
Soar soap	June -September	Light Green	30-40 fruits/tree 25-30 kg
Dragon fruit	July - September	Dark Pinkish Red	20-30 fruit 10-15 kg
Mangosteen	June- July	Dark purple	20-30kg
Jack fruit	March -July	Greenish Yellow/ dull yellow	100-200 kg

Utilization and Value-addition

Most of the tropical fruits have shorter shelf life. The fruits must be sold immediately as they start shrivelling and decay begin. Keeping the harvested fruits within a plastic film of sufficient thickness to avoid water loss at a temperature of 10-12°C prolong the shelf life. The fruits stored at a lower temperature acquire a firmer texture and more translucent appearance. Most of the fruit exhibits chilling injury symptoms, if storage temperature is less than 7°C. Most of the fruits are used as fresh fruit but passion fruit, Malabar tamarind, kokum are exclusively used for processing purpose as they are sour or astringent. The main processed products are juice, squash, jam, canned fruits, dried flakes, powders etc.

Table 13. Utilization of underutilized fruits

Crop	Edible apart	Pulp Colour	Uses
Rambutan	Aril	Transparent White	Fresh fruit, squash, jam, canning
Avocado	Mesocarp(pulp)	Cream	Fresh fruit, bread spread, Milk shake
Passion fruit	Seed coating	Yellow	Fresh, squash, juice , concentrates
Pummelo	Pulp	White, Pink	Fresh juice
Karonda	Mesocarp	White, pinkish white	Fresh, candy preparation, Pickle

Crop	Edible apart	Pulp Colour	Uses
Kokum	Pericarp, Endocarp, Kernel	Rind- Red Pulp -white	Juice, flakes, powder, seed butter
Malabar tamarind	Pericarp, Endocarp, Kernels	Rind- Yellow Pulp -white	Flakes, vinegar, powder, seed butter
Malayan apple	Pericarp, Endocarp	white	Fresh fruit, jam
Soar soap	Mesocarp	white	Fresh fruits
Dragon fruit	Mesocarp	Red, white	Fresh fruit, jam, juice
Mangosteen	Mesocarp	White	Fresh fruit

Diseases and Pests Management

Several diseases of humid tropical underutilized fruits have been reported from growing areas. The level of severity of outbreak of these diseases varies as per the agro climatic conditions. The common diseases are Anthracnose, stem end rot, Phytophthora root rot, powdery mildew, fruit rot, anthracnose, stem cankers, pink disease, sooty mould and vein necrosis. There are several pests of affects humid tropical underutilized fruits. Since these crops have limited area the incidence of disease and insects is low. Diseses and insect pests are given in Table 14.

Table 14. Diseases and insect pests of underutilized fruits

Fruit	Diseases	Insects
Rambutan	Fruit rot, Leaf scorching	Leaf eating caterpillar, Stem borer, Mealy bug
Avocado	Anthracnose, stem end rot Phytophthora root rot	Fruit fly, Mealy bug, Scale
Passion fruit	Phytophthora root rot, Brown rot and Root rot	Fruit fly, Thrips, Mites
Karonda	Anthracnose	Fruit fly, Leaf eating caterpillar
Dragon fruit	Stem Rot	-
Jack fruit	Fruit Rot	Brown weevil, Stem borer
Kokum	Root rot	Leaf eating caterpillar
Malabar tamarind	-	Leaf eating caterpillar
Sour sop	-	Mealy bug, Fruit fly

The underutilized fruits are getting popularity due to their health benefits. There is tremendous potential of these crops in the crop diversification in tropical humid regions. Some of them have lot of potential for pharmaceutical and processing industries. Some research works have been done on identification of superior lines of these crops but very limited research works has been done in India on the production

technologies of these crops. There is need to pay more attention on the production, protection and post technologies of these fruits.

REFERENCES

- Anonymous .2017. Horticulture Statistics at a Glance. Horticulture. Division, Ministry of Agric. & Farmers welfare, Govt of India, p.514.
- APAARI. 2012. Jackfruit Improvement in the Asia-Pacific Region – A Status Report. Asia-Pacific Association of Agricultural Research Institutions, Bangkok, Thailand. 182 p
- Gopalan, C, Ramashastri, B V, Balasubramanian S C, Rao N B S, Deosthale, Y G and Pant K C. 2004. Nutritive Value of Indian Foods, ICMR Hyderabad: National Institute of Nutrition.
- Jayanthimala B R, Karunakaran G and Tripathi P C .2015. Have dessert Rambutan free from pests. *Indian Horticulture*. 60(2):34-35.
- Kader A A, Veazie P P and Lester G E. 2005. Nutritional Quality of Fruits, Nuts, and Vegetables and Their Importance in Human Health, Department of Pomology, University of California, Davis, CA.
- Karunakaran,G., Tripathi,P.C., Sakthivel, T., Ravishankar ,H, Sankar,V. and Senthil Kumar, R. 2016. Rambutan is a potential future fruit. *Indian Horticulture*, 61(2):3-5.
- Pareek O P , Sharma S and Arora R K.1998. Underutilised edible fruits and nuts-An inventory of genetic resources of their regions of diversity. IBPGR office of South Asia. New Delhi, India, 235p.
- Sankar V, Tripathi P C, Karunakaran G and Senthil Kumar R. 2014. Pummelo, Technical Bulletin8/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka. pp.10.
- Senthil Kumar R, Tripathi P C, Sankar V and Karunakaran G. 2014. Kokum – A potential fruits of Western Ghats. Technical Bulletin 6-/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, p.10.
- Shamina Azeez, Karunakaran G, Shivashankara K S , Keshava Rao V K, Tiwari R B , Sathisha G C, Roy T K, Tripathi P C, Bharathi L K and Narayana C K. 2019. Nutritional characteristics of underutilized crops with future potential, IIHR Tech Bull. No. 03/2019. pp.31.
- Tripathi P C. 2019. Advances in production technologies of major underutilized fruit crops . Workshop on Exploring prospects of under utilized fruits crops and their processing and value addition. College of Hortic. (UHS) Kolar, Karnataka, Sept 13, p. 29-42.
- Tripathi P C. 2018. Minor fruit crops of humid tropics. In Books of abstract of International Symposium on Orchids, strawberry, minor fruits and flowers, RARS, Ambalvayal (KAU), Kerala , Jan 13-15, pp. 12-13.
- Tripathi P C, Karunakaran G, Sankar V and Senthilkumar R. 2017. Diversity and utilization of future fruit crops of humid region. Souvenir and Abstracts. National Conference on Horticultural Crops of Humid Tropics - Diversification for Sustainability” at Madikeri May 20-21, pp. 20-26.
- Tripathi P C and Karunakaran G. 2020. Standardization of time and method of propagation in avocado. *Current Hortic*. 8(1):28-32.

- Tripathi P C, Shetti D L and Rupa T R. 2019. Nutrient content of some underutilized fruits. *Progressive Horticulture*. 50(2):115-22.
- Tripathi P C, Karunakaran G, Sankar V and Senthil Kumar R. 2014. Karonda - A Potential fresh fruit of future. Technical Bulletin 7/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, pp. 14.
- Tripathi P C, Karunakaran G, Sankar V and Senthil Kumar R. 2014. Dragon fruit – Nutritive and Ruminative fruit. Technical Bulletin 11/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, pp.10.
- Tripathi P C, Sankar V and Senthil Kumar R. 2014. Sour Sop – An emerging fruit of future. Technical Bulletin, 5/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka. pp. 14.
- Tripathi P C, Karunakaran G., Sakthivel T, Sankar V and Senthil Kumar R. 2014. Passion fruit cultivation in India. Technical Bulletin 3/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, pp.18.
- Tripathi P C, Karunakaran G, Sakthivel T, Sankar V and Senthil Kumar R. 2014. Rambutan cultivation in India. Technical Bulletin 1/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, pp.18.
- Tripathi P C Karunakaran G, Sakthivel T, Sankar V and Senthil Kumar R. 2014. Avocado cultivation in India. Technical Bulletin2/2014, ICAR-IIHR, Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, pp.18.
- Tripathi P C, Kanupriya C, Karunakaran G, Shamina A, Singh P and Radhika V. 2020. Variability studies in avocado (*Persia americana* Mill.) using physico-chemical properties. *Fruits* 75 (3): 115-122.
-