PHENOLOGY AND FRUIT CHARACTERIZATION OF *ARTOCARPUS HIRSUTUS* LAM IN TWO ALTITUDINAL ZONES OF THRISSUR DISTRICT

by

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Saveen

SAVEEN THAKUR

Dedicated to my parents

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Introduction

1. INTRODUCTION

Western Ghats have been endowed with a rich diversity of flora and fauna in its wet evergreen forests. These forests generally occur throughout the tropical parts of Southern India and Andamans. The vegetation comprises of overwood species like *Artocarpus hirsutus* Lam commonly known as wild jack tree (Khanna, 2009). The tree being one of the endemic timber species of Southern Western Ghats is especially popular along the Malabar Coast (Mathew *et al.*, 2006). The name *Artocarpus* has been derived from the Greek words *artos* (bread) and *carpos* (fruit). The genus *Artocarpus* belongs to the family Moraceae which is part of the tribe Urticales. The family includes plethora of economically important species. Family Moraceae covers over 50 genera and over 800 species, mainly tropical and sub-tropical. However, a few are temperate. Peculiar feature of this family is the exudation of latex by all its members (Haq, 2006).

Genus *Artocarpus* possessing stipules which leave scars when they fall off, and straight stamens and ovules near the top of the ovary are included in the sub-family Artocarpoidae. All the members of the genus *Artocarpus* produce syncarp, the achenes being surrounded by fleshy pulp and the common receptacle becoming fleshy (Haq, 2006).

The yellowish green inflorescence appears from December to March and the fruit ripens during May–June. The fruit is yellow and ovoid, covered with spines, and contains numerous white seeds. The tree seeds every year but these seeds lose their viability quickly (Troup and Bor, 2009). The mature ripened fruits are pleasantly sweet and edible. A variety of medicinal uses have also been reported (Mathew *et al.*, 2006).

Till now, very less emphasis has been given on phenology of this species. Phenology refers to the study of timing of recurring plant life cycle stages, and their relationships with weather and climatic patterns. Silvicultural operations, plantation development and forest restoration, are all influenced by phenological events (FORRU, 2006). Phenological events of this species can be helpful for plantation development as it gives information about the life cycle of the species. Moreover, fruit availability can be ensured by studying seasonal changes with respect to the different altitudinal zones. In the present scenario, the importance of phenology lies in its effectiveness as a tool to monitor impacts of climate change on plants and animals, hence, acting as the simplest and cost-effective means of observing the effects of changes in temperature. With sufficient phenological observations, we can document patterns of phenology for important plant species, and further this information can be used to build models to help humans understand and adapt to changing landscapes and climates.

Study on the seasonal changes with respect to reproductive behaviour of the species can provide information on various aspects related to natural as well as artificial regeneration. Information on the time and period of fruit production at different altitudinal zones can further prove helpful in collection of seeds specifically for mass multiplication in the nursery.

Artocarpus hirsutus forms one of the major woody components of homegardens in Southern India especially in Kerala. The timber obtained from this species comes next after teak in economic value. In addition to the uses of wood, the fruit and roasted seeds were eaten as a staple food until the latter half of the 20^{th} century. But with the technological advances and changing social status, these traditional uses have now been neglected (Mathew *et al.*, 2006). Hitherto, the fruit remains underutilized. Furthermore, no studies have been reported on physical and biochemical composition of this fruit.

Studies on fruit characterization can be helpful in selecting better quality fruits. Physical characteristics like size, shape, weight, volume etc. act as an important tool to properly design machines for harvesting, handling and storage processes. Information on physical characters of fruit forms the basis for studying growth and developmental changes occurring in fruits. The physical and chemical properties of fruits are important indicators of their external and internal quality and decisive factors for accomplishment of market demands (Cavalcante *et al.*, 2012).

Fruits are generally acceptable as good source of nutrients such as vitamins and minerals. Fruit composition database attains prime attention while addressing various health and nutrition issues. It is essential for planning food, nutrition and health related policy tools (Shajib *et al.*, 2013). Lack of data on chemical composition of fruits limits their use. Therefore, knowledge on the biochemical composition of such underutilized fruits enhances their utilization and consumption by the rural poor. With the hike in population, exploration of nutritional potential of these fruits will help in curbing food insecurity. A comparison of qualitative evaluation of fruit from two different altitudinal zones can be helpful in determining nutritional qualities of fruit which further can lead to standardization of the processing technique for fruit in later stages. Based on this comparison, selection of the best quality fruit can be done.

So, present study was carried out with following objectives:

1) To study the phenological variations and fruit characteristics of *Artocarpus hirsutus* with respect to two altitudinal zones

2) To evaluate physical, biochemical, nutritional and organoleptic qualities of the fruit.

Review of Literature

2. REVIEW OF LITERATURE

In this chapter, an attempt has been made to put together various findings related to phenology and biochemical attributes of *Artocarpus hirsutus* in comparison with other fruit trees.

2.1. Introduction

Genus *Artocarpus* is a member of the family Moraceae, a part of the tribe Urticales. Some species are economically important as timber trees, while jackfruit (*Artocarpus heterophyllus*), breadfruit (*Artocarpus altilis*) and champedak (*Artocarpus integer*) are grown mainly for their fruits (Purseglove, 1968). The genus consists of approximate 50 species of small to large evergreen trees and is native to South and South-east Asia (Rajendran, 1992 and Soepadmo, 1992). *Artocarpus* species are distributed from Sri Lanka and India to South China and through Malaysia to Solomon Islands (CSIR, 1985). According to Troup and Bor (2009) this genus includes eight Indian species, of which some are important timber trees or fruit trees. The trees are found mostly in tropical forest. They bear fleshy fruits that ripen early in the rainy season. Some of the species are *Artocarpus hirsutus*, *A. heterophyllus*, *A. chaplasha*, *A. altilis*, *A. lakoocha* etc.

Artocarpus is a unique genus, which on account of its peculiar characteristics and edible fruits has attracted attention from the very past. About 50 species of evergreen and deciduous forests, finds mention in this genus. Economically, the genus is of appreciable importance as a source of edible fruit, good quality timber and is widely used in folk medicines. Species are rich in phenolic compounds and Jacalin, a lectin (Jagtap and Bapat, 2010).

2.2. *Artocarpus hirsutus*: An overview

Artocarpus hirsutus is a tall evergreen tree, generally 70-80' in height and up to 15' in girth, with a straight clean bole and dense foliage. The tree is common in Western Ghats from North Kanara to Malabar, Coorg and Travancore. The tree requires heavy rainfall and thrives well in any soil, both at the foot of the Ghats and on the slopes (CSIR, 1985). Various uses have been reported from different parts of the tree. Most common is in boat making (Manilal, 2003). Wood obtained from the tree is having high calorific value and hence, it can be used for fuel wood purpose (Gopikumar, 2009). Furthermore, it is also used locally in medicines and is edible (CSIR, 1985). Its bark is used for treating ulcers, diarrhoea and pimples (Dibinlal *et al.*, 2010).

According to Ramesh and Pascal (1997) *Artocarpus hirsutus* or the wild jack tree is one of the endemic timber species of southern Western Ghats, extending geographically from Kalinadi river of Maharashtra in the north to Agasthyamala in Thiruvananthapuram district of Kerala in south. Apart from uses of its wood, the fruit and roasted seeds are eaten by villagers (Mathew *et al.*, 2006).

With regards to its propagation, seeds can be either sown directly in the raised beds or it can be propagated through stump planting (Rai, 1978). *Artocarpus hirsutus* represents Rauh's model with monopodial growth. Branches are orthotropic showing rhythmic pattern of growth. Features like straight bole, erect and short branches under moderate light conditions make the species suitable for obtaining straight timber (Chandrashekara and Sankar, 2004).

Numerous studies have been conducted on various aspects related to *Artocarpus hirsutus*. These include: characterization of the sugar specificity and binding site (Gurjar *et al.*, 1998), litter decay rates and release of nutrients (Jamaludheen and Kumar, 1999), and effect of leaf litter decomposition on the physico-chemical properties of soil (Isaac and Nair, 2002) etc. An analysis on diameter increment of *A. hirsutus* in mixed deciduous forests of Wynaad revealed that annual d.b.h. increment for the tree was 0.48 cm concluding that it would take atleast 137 years for this species to reach a d.b.h. of 60 cm in these forests (Rai and Sarma, 1993). Nagaraja *et al.* (2001) proved the potentiality of *A. hirsutus* for afforesting the wastelands of Western Ghats, Karnataka on the basis of its survival percentage and growth. Prakash *et al.* (2007) were the first to report *Macrophomina* leaf spot disease on older (lower) leaves of *Artocarpus hirsutus* in India and elsewhere.

Germination studies revealed 73 per cent germination percentage in *Artocarpus hirsutus* (Gopikumar and Mahato, 1993). Seedling mortality rate for the species ranged from as high as 100 per cent in small sacred groves to none in large sacred groves. Hence, implying that with the increase in the area of grove, there was a decrease in percent seedling mortality rate (Tambat *et al.*, 2005).

Ethno botanical survey of Bhadra Wildlife Sanctuary in Karnataka revealed the potential of *Artocarpus hirsutus* in preparing various herbal drugs. According to Conservation Assessment and Management Program (CAMP) survey, this species has been placed under vulnerable category (Parinitha *et al.*, 2004). Kottaimuthu (2008) noted that Valaiyans in South Eastern Ghats of Tamil Nadu use fruits of this tree as an appetizer and the powdered seeds mixed with honey are used for treating asthma. Similar uses were reported from the tribes of Nilgiri hills in Southern Western Ghats (Sasi and Rajendran, 2012).

2.3. Phenology

The term phenology was first introduced in 1853 by the Belgian botanist Charles Morren and it has been derived from the Greek words; *phaino*, meaning "to appear, to come into view" and *logos*, meaning "to study." Phenology is the science that measures the timing of life cycle events for plants, animals, and microbes, and detects how environment influences the timing of these events. In case of flowering plants, these life cycle events include leaf budburst, first flower, last flower, first ripe fruit, and leaf shedding (Haggerty and Mazer, 2008).

Leith (1974) described the term phenology as the study of the rhythm of repetitive biological events, causes of these events (biotic and abiotic) and also the relationship between phenophases for different species. To understand the dynamics of plant species, the study of phenology is important. It is necessary to study first how species operate within the context of their respective environments. According to Reich (1995) because of more restricted seasonal variation in temperature and limited photoperiodic and thermoperiodic adaptations, the phenology of tropical forests is distinct from that of the temperate vegetation.

2.3.1. Importance of phenology in forestry

Most widely known concept of forest restoration for biodiversity conservation, watershed protection and carbon sequestration requires in depth knowledge of plant phenology (FORRU, 2005). Phenological observations on tree species could be effectively utilized as an aid to seed collection (Mahadevan, 1991). Pushpakumara (2006) opined that study of reproductive phenology can provide important information to ensure adequate sampling for seed collection programmes for tree improvement and ex-situ conservation. For instance, seeds from an individual within a population may ripen asynchronously, so that seed collected at only one point in time may not adequately represent the genetic diversity of the population. Similarly, reproductive phenology of seven dioecious *Ficus* species generated scientifically-based recommendations, useful for development of forest restoration programs, such as optimum time and place for seed collection, recommendations on the propagation of dioecious fig species, optimum planting sites for each species etc. (Kuaraksa *et al.*, 2012).

Hitherto, phenological studies have been restricted to forest ecosystems with very few studies on multipurpose trees in agroforestry. Information on the phenological response of various multipurpose trees can be implemented for further understanding and strengthening of the traditional systems of agroforestry. Also, it can be useful in future selection of species for incorporation into agroforestry systems which can be sustainable in the long run (Das and Das, 2013). From the phenological studies conducted by Mulik and Bhosale (1989), they concluded that these studies were helpful in combating afforestation and in plant management, studying floral biology and estimation of reproduction and regeneration. Phenological observations of dry evergreen forest of North-east Thailand formed the basis of scheduling the logging operation. Logging operations were recommended after seed shedding by the trees (Dhamanitayankul, 1979).

Phenology can contribute to various scientific disciplines from biodiversity, agriculture and forestry to human health. Knowledge regarding timing of phenological events and their variability can provide valuable data for planning, organizing and timely execution of certain standard and special (preventive and protective) agricultural and forestry activities (Ruml and Vulic, 2005). They can also describe how populations, species, communities, and biomes respond to changes in the regional and global climate. Therefore, phenological studies measure the pace of nature's clock, and in doing so can detect the changing pulse of the planet (Haggerty and Mazer, 2008). According to Sparks and Menzel (2003), phenology is probably the simplest and most cost effective means of observing the effects of changes in temperature, and hence, it has become an important tool in global change research.

Importance of phenologically driven changes in soil resource acquisition by plants has not been dealt in detail till now. Acquisition of mobile (water, nitrogen, silicon, magnesium and calcium) and immobile resources (potassium, phosphorus and ammonium) increases with longer growing season. Transpiration is the major driver for the acquisition of mobile resources, while root life-span is the major driver of immobile resource acquisition (Nord and Lynch, 2009).

2.3.2. Leaf phenology

Leaf phenology comprises various events like initiation of leaf flush, completion of leaf flush, initiation of leaf fall and completion of leaf fall. Leaf flush period is the duration from first leaf flush to the last one. Leaf fall represents the duration from estimated first leaf fall to the last one (Singh and Kushwaha, 2005).

Ficus fulva shows continuous production of leaves throughout the year. The trees drop their leaves during drought and initiate flushing after renewal of the rain. Significant negative correlation was observed between leaf drop and rainfall (Harrison *et al.*, 2000). According to Zhang *et al.* (2006) leaf fall and flushing in *Ficus racemosa* occurs twice a year i.e. during mid-dry and mid-rainy season and the species renews its leaves continuously. Patterns of leaf phenology coincided with the reproductive phenology. Leaf phenology of this fig species could be an adaption to local climate. Leafing phenology in *Ficus obtusifolia* revealed that massive leaf fall was immediately followed by leaf flushing, with the peaks of foliar exchange occurring during both dry and rainy seasons (Ballestrini *et al.*, 2011).

While studying the phenology of multipurpose trees in homegardens of north-east India, Das and Das (2013) came across three categories of flushing patterns by the species i.e. single, double and continuous determinate flushing. Among the species studied, *Artocarpus heterophyllus* showed continuous leaf fall and continuous flushing.

Singh and Kushwaha (2006) were of the opinion that in *Shorea robusta*, annual leaf exchange seems to be a survival strategy during the drought period. The tree replaces all its old leaves of differing longevity with the new ones to reduce water loss due to transpiration and supports asynchronous flowering. Phenological observations on tree species in tropical moist forest of Uttara Kannada district revealed a strong seasonality for leaf flush, leaf drop and reproduction. Leaf flushing begins in the pre-monsoon dry period whereas abscission of leaves in post-monsoon winter period (Bhat, 1992). These results were further supported by Bajpai *et al.*

(2012) while studying the phenology of *Shorea robusta* and *Ficus hispida* in tropical moist deciduous forest and Singh and Singh (1992) in dry tropical forests.

Various authors have put forward their views on flushing patterns in different forest types. Nitta and Ohsawa (1997) investigated the shoot phenology including leaf emergence, leaf fall, and leaf life span of evergreen broad-leaved tree species in warm-temperate rain forest in central Japan. Periodic leaf flushing pattern was observed, and the species were classified as single and multiple flush species. Also, seasonal patterns of leaf fall were categorized as unimodal, bimodal, broad unimodal and multimodal type. They concluded that these phenological patterns varied in relation to leaf life span, leaf size and tree habit. Kikim and Yadava (2001) noted asynchronous behaviour in leaf fall among the individuals in subtropical forests of Manipur. Four distinct categories of leaf flushing pattern were observed: single, double, multiple and continuous determinate flushing.

Phenological processes can be correlated with various environmental factors like rainfall, temperature etc. Pereira *et al.* (2007) concluded that leaf fall was negatively correlated with monthly average temperature as maximum leaf fall occurred during cold months. On the other hand, leaf flushing was better correlated with monthly average temperature. According to Sundarapandian *et al.* (2005) leaf flushing is triggered by high temperature and increased day length while low temperature and reduced day length favours leaf fall. These results were in agreement with those reported by Shukla and Ramakrishnan (1982) and Bhat (1992) in tropical forests of India. Rainfall and leaf initiation showed strong negative correlation implying that leaf flush occurred before onset of monsoons. While leaf fall had a high one or two month lag correlation with moisture, indicating that leaf shedding occurred one or two months after rainy season (Bhat and Murali, 2001). This has also been noted by Suresh and Sukumar (2011).

In contrast to the above findings, Xiao *et al.* (2006) opined that leaf flushing in tropical evergreen forests is not determined by precipitation. Rather, these phenological processes may be driven by availability of solar radiation and/or avoidance of herbivory. Furthermore, timing of the leaf flushing during dry season acted as an advantage to escape the damage from herbivorous insects which emerged mainly during rains (Murali and Sukumar, 1993; and Tesfaye *et al.*, 2011). Apart from climatic variables, soil characteristics also influence the phenological patterns and growth in tropical forests (Cardoso *et al.*, 2012).

2.3.3. Flowering phenology

Newstrom *et al.* (1994) were the first to provide a basic framework for classification of tropical flowering phenology. Several indices like frequency, amplitude, duration, synchrony and regularity can be used for describing phenological patterns. In tropical forests, association of intensified flowering activity with hot, dry season is a commonly observed phenomenon. Reasons being that tree are leafless and flowers are more visible and accessible to pollinators. Furthermore, it is essential if fruits are to ripen and seeds are to be dispersed in time for the following rainy season, when conditions for germination are optimal (Elliott *et al.*, 1994).

Artocarpus altilis and *A. heterophyllus* shows various flowering peaks every year with breadfruit flowering in both rainy and dry seasons while jackfruit flowering during rainy season only (Falcao *et al.*, 2001). Khatibu *et al.* (1985) were of the opinion that *Artocarpus heterophyllus* is characterized by prolonged flowering and fruiting. When moisture is not depleted, flowering starts again after the onset of short rains and subsequent fruiting and development the following three months. Pushpakumara (2006) reported that *Artocarpus heterophyllus* showed highly synchronous flowering and male biased inflorescence sex ratio. Phenological studies revealed complete synchrony of the female flowering phase with the male phase for a given individual; which provides ample opportunities for geitonogamous self-pollination. On the other hand, this synchronous flowering among the individuals increased the possibilities of cross pollination.

Phenology of selected tree species in tropical forests of Western Ghats revealed that several peaks for flowering in different seasons evolved so as to avoid competition for pollinators (Sundarapandian *et al.*, 2005). According to Shukla and Ramakrishnan (1982), in case of *Artocarpus* spp. it has been seen that individuals that flower in one year may not flower at all in the next year.

The phenology of three native fig species (*Ficus luschnathiana, F. enormis* and *F. glabra*) revealed that the populations displayed continual syconia production, with *F. luschnathiana* showing intra-tree flowering asynchrony (Figueiredo and Sazima, 1997). Pereira *et al.* (2007) studied the phenological patterns of *Ficus citrifolia* in Southern Brazil. They came with the conclusion that, flowering onset was asynchronous among individuals. Also, flowering and vegetative phenology were highly correlated. Full leaf canopy individuals showed higher crop initiations suggesting that flowering onset is related to the branch maturation status.

Flower initiation differs with respect to forest types. In evergreen trees, flowering started during the winter season (Bhat, 1992, Sundarapandian *et al.*, 2005 and Nanda *et al.*, 2011). Whereas in deciduous forests, Desai and Patel (2010) reported that maximum flowering in deciduous forests occurred during April to May and lowest during October to January. Flowering initiated during the beginning of dry season when most of the trees were leafless or leaf flushing stage (Nanda *et al.*, 2011).

Clarke and Myerscough (1991) observed flowering phenology of *Avicennia marina* (Grey mangrove), on the south-east coast of Australia in New South Wales. They reported that flowering in all the populations of trees extends up to several months and there is a synchronicity in flowering among trees within populations. But there's a high variation in reproductive status of individual trees between the years. There can be a shift from reproductive to non-reproductive state synchronously among the individuals. And such patchy flowering pattern may sometimes promote outbreeding.

In terms of phenological flowering sequence, differences among *Quercus* species were found for inflorescences i. e. male and female flowers. Different floral development patterns were observed for both male and female inflorescence. Male inflorescence showed homogenous development. All individuals were protandrous. Phenological trends varied with species and year with the overall phenological trend following a sigmoid curve, increasing with phenological development (Gomez-Casero *et al.*, 2007).

A comparative study on the phenological patterns of Atlantic rain forest trees by Morellato *et al.* (2000) revealed the occurrence of a general flowering pattern, suggesting that the flowering pattern did not differ significantly among the trees of four sites analysed. The study also concluded that seasonal variation in day length has got influence over evergreen-wet forest tree phenology.

Based on flowering time, possible flowering cue(s) and the state of leaf phenology during flowering; Singh and Kushwaha (2006) categorized five flowering types among the trees of tropical deciduous forests in India. These were summer flowering, rainy flowering, autumn flowering, winter flowering and dry season flowering. This wide diversity of several flowering types has evolved as a strategy to ensure survival and reproduction under a monsoonic bioclimate. Tesfaye *et al.* (2011) studied the phenology of seven indigenous tree species in a dry Afromontane forest of Ethiopia for two years. Flowering patterns observed were annual, unimodal and seasonal. Among the species studied, no significant correlation in flowering time was observed, hence a kind of adaptation to avoid interspecific overlap and thus competition for pollinators.

To propose the factors triggering flower production (rainfall, temperature, cloud cover and photoperiod), flowering patterns for more than 100 species was studied by Stevenson *et al.* (2008) in Colombia. Majority of the species showed intraspecific synchronization. Photoperiodism most likely triggered flowering in these species but the proportion of species responding to photoperiodism was less than 23 percent as most of the species flowered during different periods each year. Favourable environmental conditions at the time of flowering differentiation leads to increased flower production, although it may not always lead to increased fruit set (McCarthy and Quinn, 1989). According to Law *et al.* (2000) flowering of myrtaceous trees was influenced by climatic variables like temperature and rainfall. Cool temperature experienced prior to floral budding was a strong predictor of flowering. Nunes *et al.* (2012) also observed the same correlation in tropical dry forests of Southeastern Brazil. In contrast, no significant correlation between reproductive phenological phases and monthly rainfall was observed by Medeiros *et al.* (2007) while studying the phenology of tropical coastal vegetation.

2.3.4. Fruiting phenology

Fruiting shows a strong seasonal pattern in a tropical forest and occurs throughout the year. Dry fruited species fruit principally in dry seasons while the fleshy fruited species fruit in either wet or dry seasons, although fleshy fruits are most abundant in wet seasons (Lieberman, 1982). Fruiting in rainy season for fleshy fruits like *Artocarpus lakoocha* and *A. chama* is necessary to maintain moisture in the fruits and for their proper development (Shukla and Ramakrishnan, 1982; Sundarapandian *et al.*, 2005).

Ficus racemosa bears fruits throughout the year. Fig production was independent of leafing. At population level, asynchronous fig production was observed to avoid selffertilization. Production peaks for fig were not evident, but fluctuations were clear (Zhang *et al.*, 2006). Similar results were reported from *Ficus citrifolia* by Pereira *et al.* (2007).

Bentos *et al.* (2008) reported a significant relationship between flowering and fruiting among the pioneer species of Central Amazon. Degree of continuity in flowering was matched closely to the degree of continuity in fruiting i.e. continuous flowering species exhibited continuous fruiting, seasonal flowering was associated with seasonal fruiting and likewise. Also, fruiting season occurred shortly after the flowering season with some overlap. Mishra *et al.* (2006) also noted that the peak fruiting period of both overstorey and understorey species in Similipal Biosphere Reserve, Orissa; were same i.e. from May to June. The fruiting phenology followed closely the flowering phenology.

Like flushing patterns, different fruiting patterns have been categorized. The fruiting phenology of 22 woody plant species belonging to 19 families was studied for one year at monthly intervals, in a tropical dry evergreen forest on the Coromandel Coast of India. Among the species studied, an annual, bimodal and seasonal fruiting pattern was observed. The peak period for fruit production was during dry season for evergreen and deciduous species whereas for brevi-deciduous species, fruiting initiated in the early wet season (Selwyn and Parthasarathy, 2007). Annual, sub-annual and continuous fruiting patterns were reported in dry Afromontane forests in Ethiopia. Most of the annual fruiting species exhibited non-seasonal fruiting or extended fruiting over several months of the year, ensuring the availability of fruit resource for frugivores throughout the year (Tesfaye *et al.*, 2011).

Duration of fruit maturation was longest in deciduous forest from monsoon to pre-monsoon period with a peak in November to January. While in evergreen forest, the fruit maturation was more in pre-monsoon period with a peak in the month of April (Nanda *et al.*, 2011).

Salinas-Peba and Parra-Tabla (2007) compared the phenological patterns of *Manilkara zapota* in sub-deciduous forests and homegradens. Trees in the homegardens showed greatest fruit production and probability of a flower converting into a mature fruit was higher in homegardens. Also, mature fruits were of better quality (i.e. greater fresh weight) in homegardens which may be attributed to greater nutrient and water availability in homegardens.

2.4. Morphological Characters

Artocarpus hirsutus is an evergreen tree, attaining a height of 45.73 m and a girth of 4.57 m or more, with a straight clean stem and dense foliage (Troup and Bor, 2009). In *A. hirsutus,* leaf length and leaf breadth ranges from 10 to 25 cm and 5 to 15 cm respectively (CSIR, 1985). *A. heterophyllus* is also a tall, evergreen tree that attains a height of 9 to 21 m (Morton, 1987) and a stem diameter of 30 to 80 cm (Elevitch and Manner, 2006). Another species *A. altilis* can reach a height of 21 m or more at maturity with stem diameter reaching up to 2 m (Ragone, 2006). Sarker and Zuberi (2011) studied morphological characteristics of jackfruit trees growing at two different sites in Bangladesh. Based on their observations, they concluded that leaf blade length ranged from 13.26 to 21.82 cm and leaf blade breadth from 4.64 to 13 cm respectively. On the other hand, according to Morton (1987), leaves of jackfruit are 22.5 cm long.

2.5. Physical Characters

Fruits have several unique characteristics that differentiate them from other engineering materials. These physical characters determine the quality of the fruit. Information regarding dimensional attributes such as length, diameter, weight etc. is used in describing fruit shape, designing of various machines and evaluation of consumer preference (Beyer *et al.*, 2002 and Naderiboldaji *et al.*, 2008).

2.5.1. Fruit Length

Fruit length in jackfruit ranges from 20 to 90 cm (Morton, 1987). Bhanu *et al.* (2006) evaluated different clones of jackfruit, harvested at monthly intervals, for changes in their physical attributes during fruit growth and development. Maximum value for fruit length was 38.56 cm. Among different germplasms of *Artocarpus heterophyllus*, fruit length varied from 44.42 to 70.42 cm (Sarker and Zuberi, 2011). Various studies have been conducted on physical characteristics of tropical fruits. In *Spondias mombin, Garcinia indica* and *Simarouba glauca,* almost similar fruit length has been reported (Bora *et al.*, 1991; Patil *et al.*, 2009; and Dash *et al.*, 2008). Fruit length in *Adansonia digitata* was found to be remarkably higher than in *Averrhoea carambola* (Nour *et al.*, 1980; and Narain *et al.*, 2001).

2.5.2. Fruit Width and Diameter

According to Morton (1987) *Artocarpus heterophyllus* fruit width ranges from 15 to 50 cm. Bhanu *et al.* (2006) reported a maximum value of 80.80 cm for jackfruit diameter. Fruit diameter as measured by Sarker and Zuberi (2011) among old and young trees of jackfruit was in the range of 29.94 to 76.7 cm. Fruits of *Artocarpus lakoocha* are 5 to 12 cm in diameter (Joshee *et al.*, 2002). Range of fruit width in *Adansonia digitata* as reported by Nour *et al.* (1980) also lies close to that of *Artocarpus lakoocha*. Fruit width of *Spondias mombin* as reported by Bora *et al.* (1991) and that of *Mespilus germanica* as reported by Haciseferogullari *et al.* (2005) were also found to be similar. Carambola fruit varies widely in its physical composition during maturation from green mature to fully ripe stage. During these two successive stages (green mature and fully ripe), diameter of the fruit increased from 4.69 cm to 5.24 cm respectively (Narain *et al.*, 2001). Fruit width and diameter in *Garcinia indica* were found to be ranging from 3.14 to 4.29 cm and 3.20 to 4.04 cm respectively (Patil *et al.*, 2009).

2.5.3. Fruit Weight

Fruits of *Artocarpus heterophyllus* weigh about 4.5 to 20 kg (Morton, 1987) and *Artocarpus lakoocha* weigh about 200 to 350 g (Joshee *et al.*, 2002). Jagadeesh *et al.* (2010) found that fruit weight of different jackfruit selections were falling in the range of 2.15 to 18.74 kg. In *Garcinia indica*, fruit weight varied from 14.15 to 34.54 g (Patil *et al.*, 2009) and from 52.36 g to 60.38 g in carambola fruit (Narain *et al.*, 2001). Fruit weight in *Adansonia digitata* (Nour *et al.*, 1980) and various *Punica granatum* cultivars (Akbarpour *et al.*, 2009) were also close to each other. Maiti (2010) conducted a study to assess the correlation between fruit weight and its components to provide an idea on effect of various characters on fruit weight of jackfruit. They observed a positive correlation between fruit weight of edible part, fruit and rind weight, and number of stones and flakes.

2.5.4. Fruit Volume

Volume of medlar (*Mespilus germanica*) fruit was found to be 13.68 cm^3 (Haciseferogullari *et al.*, 2005). In *Punica granatum* cultivars fruit volume varied from 99.41 to 547.88 cm^3 (Akbarpour *et al.*, 2009). Volume of mature fruits in different *Averrhoa* spp. ranged from 9.54 to 31.67 ml (Bhasker and Shantaram, 2013).

2.5.5. Weight of pulp, peel and seeds

Pulp, peel and seed weight as reported by Pathak and Chakraborthy (2006) in jackfruit was 2025 g, 2775 g and 588.25 respectively. Nour *et al.* (1980) reported that in baobab fruit, weight of pulp and seeds per fruit were 28 g and 63.7 g respectively. Edible portion and individual seed of carambola fruit weigh about 55.62 g and 0.70 g respectively (Narain *et al.*, 2001). Pulp weight and seed weight in tropical fruits have been reported to be 67.85 g and 4.38 g in sapota, 3.91g and 1.42 g in jamun, 103.16 g and 11.53 g in custard apple and 112.50 g and 1.32 g in carambola respectively (Pathak and Chakraborthy, 2006). In *Garcinia indica* selections, pulp weight ranges from 8.00 to 15.95 g and rind weight ranges from 6.05 to 18.79 g (Patil *et al.*, 2009).

2.5.6. Other fruit characters

In jackfruit, fruit stalk length and diameter among old and young trees as analyzed by Sarker and Zuberi (2011) were found to be varying from 6.08 to 17.66 cm and 11.26 to 19.5 cm respectively. Minimum and maximum values for bulb mass, seed mass and seed number in jackfruit selections of Karnataka were reported as 0.59 to 10.03 kg, 0.20 to 3.67 kg and 19 to 445 respectively (Jagadeesh *et al.*, 2010). On the other hand, maximum bulb weight as recorded by Bhanu *et al.* (2006) was 44.30 g. A single fruit of *Artocarpus lakoocha* contains 20 to 30 seeds (Joshee *et al.*, 2002) and that of Sikkim mandarin contains 15.01 seeds (Kishore *et al.*, 2010).

According to Sharma *et al.* (2006) there existed a significant association between fruit yield per tree and average fruit weight, which is further associated with fruit length, weight of bulbs (with seed) per fruit and weight of bulbs (without seed) per fruit. Study revealed that number of fruits per tree and number of bulbs per fruit, and average fruit weight, exhibit direct effect on fruit yield per tree.

2.6. Variability studies on morphological and physical characters

An effort was made by Sarker and Zuberi (2011) to find out the pattern of morphological characters in jackfruit growing at two different sites. Significant variation was observed for quantitative parameters like leaf length and leaf breadth. Similar variations were reported by Nyarko *et al.* (2012) between the leaf parameters (laminar length and laminar width) of *Vitellaria paradoxa* at three different locations. While studying the genetic diversity of jackfruit at different topographical levels, Muthulakshmi (2003) noted significant variation with respect to leaf length and leaf width.

Fruit parameters like length and diameter in *Artocarpus heterophyllus* showed significant variations between the studied sites (Muthulakshmi, 2003). These findings were further supported by Sarker and Zuberi (2011). Goswami *et al.* (2011) opined that variation in physical characteristics of jackfruit is influenced by location. Thakur *et al.* (2011) also concluded that variability existed for physical parameters (fruit size and weight) of wild pomegranate fruit collected from different districts. Cosmulescu *et al.* (2010) observed that the difference in physical characteristics of *Juglans regia* was caused probably by different agro-climatic conditions and genetic characteristics. According to Okello (2010), morphological characteristics of *Tamarindus indica* pods (pod length, pod breadth, pod mass etc.) showed variations in different agro-ecological zones. From the findings, he opined that these morphological differences expressed in genetic variations can be useful for promoting domestication and commercialization of *Tamarindus indica.*

Variation in fruit characteristics is an important aspect of germplasm evaluation of the species whose fruits have multipurpose uses. Studies on fruit characteristic variation in the species of *Terminalia bellirica* with respect to geographic source was done by Sood *et al.* (2009). Average fruit weight (fresh and dry), average pulp weight (fresh and dry), and average fruit length and diameter varied significantly possibly due to genetic and environmental factors. Similar findings were reported in walnut from different agro-climatic regions (Cosmulescu *et al.*, 2010). Yadav *et al.* (2006) opined that a large variability exists in *Hippophae salicifolia* populations particularly for fruit length, 100 fruit weight, number of fruits per unit length of fruiting branch and fruit yield. Further, they concluded that this variability among different characters can be utilized for selection of best genotypes for plantation and utilization in making different value added products.

2.7. Biochemical and Nutritional Composition

Major constituents of fruit include sugars, polysaccharides, and organic acids whereas minor constituents include pigments, aroma substances, vitamins and minerals of nutritional importance. Investigations on biochemical composition of fruits form the basis for establishing the nutritional value and overall acceptance by the consumers. Study on nutritional components of tropical fruits revealed that different fruit varieties may deliver healthful benefits by supplying natural antioxidants, dietary fibre, vitamins and carotenoids (Baldwin *et al.*, 2008).

2.7.1. Moisture

Moisture content in jackfruit ranges from 72 to 77.2 per cent (Morton, 1987; and Love and Paull, 2011). Similar values were reported by Mannan *et al.* (2005) while working on the chemical composition of off-season jackfruit germplasms. However, Goswami *et al.* (2011) reported higher values for moisture content in jackfruit collected from different growing areas. In *Artocarpus odoratissimus* it varies from 67.9 to 73.4 g/100g (Tang *et al.*, 2013).

2.7.2. Total Soluble Solids

Analysis on biochemical composition of *Artocarpus heterophyllus* revealed that the fruit possessed 17.63 ^{o}Brix TSS (Mannan *et al.*, 2005; and Pathak and Chakraborty, 2006). Even higher brix was noted in the same species by Jagadeesh *et al.* (2007) and Goswami *et al.* (2011). For various tropical fruits like bael, custard apple, carambola, jackfruit etc., TSS ranged from a lowest value of 6.25 to a highest value of 32.20 ^{o}Brix (Pathak and Chakraborty, 2006). Among different selections of *Garcinia indica* values for TSS ranged from 8.46 to 17.70 ^{o}Brix (Patil *et al.*, 2009). TSS as observed in fruits of *Berberis lyceum* was at par with that in jackfruit and kokum (Sood *et al.*, 2010).

2.7.3. Titrable acidity

For selected off-season jackfruit germplasms, titrable acidity ranged from 0.50 to 0.80 per cent (Mannan *et al.*, 2005). This was further supported by the findings of Goswami *et al.* (2011). Pathak and Chakraborthy (2006) opined that most of the tropical fruits studied were low in acidity. Higher titrable acidity (5.31 to 17.91 per cent) was reported among different kokum selections (Patil *et al.*, 2009). Nour *et al.* (1980) concluded that pulp of baobab tree, *Adansonia digitata* L. was acidic, and rich in ascorbic acid.

2.7.4. Sugars

Jackfruit has been reported to contain 10.26 per cent total sugars and 5.26 per cent reducing sugars (Pathak and Chakraborty, 2006). Even higher total sugars and reducing sugars among the clones of jackfruit was noted by Goswami *et al.* (2011). He emphasized that combined perception of colour, texture, TSS, sugars, acidity level and flavor determines the organoleptic quality. According to Nour *et al.* (1980) pulp of baobab tree, *Adansonia digitata,* contains total sugar and reducing sugar content of 23.2 per cent and 18.9 per cent respectively. Nazarudeen (2010) investigated the nutritive value of wild fruits of Kerala. Total sugars for these wild fruits varied from 5.98 to 16.2 per cent and reducing sugars from 4.91 to 1.79 per cent respectively.

2.7.5. Starch

Goswami *et al.* (2011) who mentioned that starch content in different varieties of jackfruit ranged from 6.11 to 8.34 per cent. Furthermore, this was supported by the findings of Jagadeesh *et al.* (2007) in different selections of jackfruit. Starch and total dietary fibre contents of *soft* and *firm* varieties of jackfruit increased with the maturity (Rahman *et al.*, 1999). Starch quantities in various chestnut cultivars ranged from 54.45 to 69.70 g/100g (Erturk *et al.*, 2006).

2.7.6. Carotene

An analysis on nutrient composition of some wild edible fruits of Andaman and Nicobar Islands was done by Singh *et al.* (2001). Among the fruits studied, *Artocarpus heterophyllus* and *A. lakoocha* were found to be exceptionally rich in carotenoid content. These findings corroborated with the results obtained in jackfruit by Jagadeesh *et al.* (2007) and Goswami *et al.* (2011). Compared to jackfruit, breadfruit possessed lesser amounts of beta carotene content (12.9 μg/100g) (Ragone and Cavaletto, 2006). Compared to the *Phyllanthus emblica* and *Spondias pinnata*, *Antidesma velutinosum* Blume contained higher levels of most nutrients as well as carotenoids (335 g/100g). From their findings, authors concluded that consumption of a variety of such fruits can potentially contribute to health improvement (Judprasong *et al.*, 2013).

2.7.7. Ascorbic acid

Mannan *et al.* (2005) were of the opinion that jackfruit contains 4.85 to 5.08 mg/100ml ascorbic acid. Pathak and Chakraborty (2006) also found it to be occurring in the nearby range. While Morton (1987); and Love and Paull (2011), concluded that it ranges from 8 to 10 mg/100g. Fruits of *Garcinia indica* have been reported to be rich in ascorbic acid with the values varying from 13.59 to 64.70 mg/100g (Patil *et al.*, 2009). Nutrient evaluation of *Annona muricata* also revealed that soursop pulp contains appreciable amounts of micronutrients and can be incorporated into diets (Onyechi *et al.*, 2012). Pulp of *Balanites aegytiaca* was found to be rich in Vitamin C content with the value 1.26 g/100g (Sadiq *et al.*, 2012). Judprasong *et al.* (2013) compared the nutritional potential of various indigenous fruits (*Phyllanthus emblica, Antidesma velutinosum* and *Spondias pinnata*). They observed that *Phyllanthus emblica* L. exhibited the highest levels of vitamin C (575 mg/100g).

2.7.8. Fibre

Ripe jackfruit contains 1 to 5 per cent fibre (Morton, 1987; and Love and Paull, 2011). Fibre content in *Artocarpus odoratissimus* occurs in the range of 0.8 to 1.3 g/100g which is relatively lower than that reported in jackfruit (Tang *et al.*, 2013). Adepoju (2009) analysed pulp of wild fruits like *Spondias mombin, Dialium guineense* and *Mordii whytii* for their nutrition potential in meeting needs of consumers. Crude fibre content in these fruits ranged from 0.6 to 11.8 mg/100g. Investigations on chemical composition of *Annona muricata* revealed that fruits possess high fibre content of 6.26 per cent (Onyechi *et al.*, 2012). A comparison was made between the biochemical composition of *Tamarindus indica* and *Ziziphus spina christi* seed and fruit. Highest crude fibre content (18.83 per cent) was observed in *Tamarindus indica* pulp. (Adekunle and Adenike, 2012).

Wild edible fruits play an important role in the dietary requirements of the tribal as well as local communities. Nazarudeen (2010) and Mahapatra *et al.* (2012) compared the nutritive values of wild fruits collected from forests with those of commonly cultivated fruits. It was concluded that some of the wild fruits are more nutritional than commonly cultivated fruits. An analysis of the nutritional content of Saba fruit (*Saba senegalensis*) revealed that the fruit recorded Vitamin C content of 16.41 mg/100g, brix level of 14.1 per cent, crude fibre 13.52 per cent and 74.23 per cent available carbohydrates. Results suggested that the nutritional composition of this fruit was even higher than commercially available fruits (Boamponsem *et al.*, 2013).

Studies have also been conducted on physico-chemical changes occurring in fruits during growth and maturation. Narain *et al.* (2001) noted that with the advancement of maturity, titrable acidity decreased to 0.36 per cent from 0.98 per cent and total sugars increased from 2.91 per cent to 5.60 per cent and reducing sugars from 2.80 per cent to 5.04 per cent in carambola fruit (*Averrhoa carambola*). Similarly, significant changes in titrable acidity and colour were obtained in *Artocarpus heterophyllus* during ripening. Total soluble solids and total sugars increased significantly. However, total organic acids decreased as the fruit reached later stage in ripening (Ong *et al.*, 2006). These observations were in agreement with those studied by Rosalizan *et al.* (2010) in *Morinda citrifolia* fruit.

2.8. Mineral Composition

2.8.1. Potassium

According to Webster and Varner (1954) potassium is essential as an activator for enzymes involved in the synthesis of certain peptide bonds. In *Artocarpus heterophyllus*, potassium occurs in the range of 292 to 407 mg/100g (Love and Paull, 2011). While studying the mineral contents of *Artocarpus lakoocha*, Shajib *et al.* (2013) observed potassium content as 350 mg/100g. While in another species of *Artocarpus* genus, i.e. *Artocarpus odoratissimus* flesh contained less potassium with the value ranging from 176 to 298 mg/100g (Tang *et al.*, 2013). Similar values were reported by Judprasong *et al.* (2013) in Thai indigenous fruits like *Antidesma velutinosum.* Investigations carried by Adepoju (2009) on proximate composition of fruits like *Spondias mombin*, *Dialium guineense* and *Mordii whytii* proved these wild fruits to be rich in potassium (260 to 410 mg/100g). Study conducted by Erturk *et al.* (2006) on mineral composition of fruits of chestnut also revealed fairly higher values for potassium (761 to 1271 mg/100g). According to Li *et al.* (2007); owing to its high potassium content, *Zizyphus jujuba* cv. *Yazao may* contribute to reducing the risk of heart disease, cancer and ageing process. Highest potassium content was reported in *Ficus racemosa* (1922 mg/100g) by Valvi and Rathod (2011) and in *Zizyphus mauritiana* (1865 to 2441 mg/100g) by Nyanga *et al.* (2013). According to Arukwe *et al.* (2012), *Persea americana* also showed potassium content falling in the nearby range (385.14 mg/100g).

2.8.2. Phosphorous

A series of phosphorous compounds are formed in the utilization of carbohydrates in the body. It is vital to the fundamental process of metabolism in the body (Saunders, 2007). Ripe fruits of jackfruit contain 38 mg/100g phosphorous (Love and Paull, 2011). In *Artocarpus lakoocha* phosphorous content was found to be 22.1 mg/100g (Shajib *et al.*, 2013). Narain *et al.* (2001) observed a large variation in mineral composition of carambola fruit during maturation from green mature to ripe stage. Phosphorous content decreased from 20.50 to 19.24 mg/100g. Arukwe *et al.* (2012) analysed mineral composition of *Persea americana.* They concluded that the fruit contained 51 mg/100g of phosphorous. Erturk *et al.* (2006) opined that phosphorous content in various domestic and foreign hybrid cultivars of chestnut varied greatly. Values were found to be varying from 107 mg/100g to 185 mg/100g. Different cultivars of *Zizyphus jujuba* as well as *Zizyphus mauritiana* showed almost similar values (Li *et al.*, 2007 and Nyanga *et al.*, 2013).

2.8.3. Calcium

In the tissue of many fruits, calcium is one of the mineral believed to be an important factor governing fruit storage quality (Lechaudel *et al.*, 2005). Love and Paull (2011) stated that *Artocarpus heterophyllus* contains 22 to 37 mg/100g of calcium. Shajib *et al.* (2013) observed that calcium content in *Artocarpus lakoocha* varied as 66.6 mg/100g. However, Tang *et al.* (2013) reported very low value for calcium in other species belonging to the same genus viz., *Artocarpus odoratissimus* with the range from 0.48 to 1.35 mg/100g. Narain *et al.* (2001) were of the opinion that; with the maturity, calcium content in carambola fruit varied as 2.87 to 4.83 mg/100g. Various cultivars of chestnut reported relatively higher values ranging from 43 to 230 mg/100g (Erturk *et al.*, 2006). Furthermore, in fruits of *Zizyphus jujuba*, *Persea americana* and *Zizyphus mauritiana* calcium content was found to be occurring almost near to this range (Li *et al.*, 2007, Arukwe *et al.*, 2012 and Nyanga *et al.*, 2013). However, fruits of *Antidesma velutinosum* also possessed high calcium content varying as 325 mg/100g (Judprasong *et al.*, 2013). Even higher values have been reported by Adekunle and Adenike (2012) in the pulp of *Tamarindus indica* and *Ziziphus spina christi* in the range of 450 mg/100g. After investigating the mineral content of various wild edible fruits, Valvi and Rathod (2011) came to the conclusion that fruits of *Ficus racemosa* were richest in calcium content as 928.4 mg/100g.

2.8.4. Iron

Iron is included in the synthesis of chloroplastic protein and it may impair the machinery for chlorophyll synthesis (Gauch, 1957 and; Alabi, 1987). Iron content in jackfruit varies from 0.5 to 1.7 mg/100g (Love and Paull, 2011). Iron contents of *Artocarpus lakoocha* and *Artocarpus odoratissimus* does not differ much. Values reported are 0.77 mg/100g and 0.29 to 0.53 mg/100g for *Artocarpus lakoocha* and *Artocarpus odoratissimus* respectively (Shajib *et al.*, 2013 and; Tang *et al.*, 2013). Narain *et al.* (2001) studied the range of iron content in *Averrhoa carambola* from green to ripe stage. Data were found to be in the range of 0.55 to 0.49 mg/100g. These values were in agreement with those reported in the fruits of *Persea Americana* by Arukwe *et al.* in 2012. However, a bit higher values (5.7 mg/100g and 7.90 mg/100g) were reported in chestnut cultivars by Erturk *et al.* (2006) and in Chinese jujube cultivars by Li *et al.* (2007) respectively. Even higher values varying from 35 to 39 mg/100g have been noted in wild edible fruits of *Meyna laxiflora* and *Ziziphus spina christi* (Valvi and Rathod, 2011; and Adekunle and Adenike, 2012). Nazarudeen (2010) opined that iron content of underutilized fruits from the wild was higher compared to other popular fruits like pineapple, pomegranate, sapota, apple etc.

2.9. Mineral Composition of seed

Apart from fruit pulp, seeds are also considered as cheap source of nutrients like carbohydrates, proteins, mineral elements etc. Utilization of seeds minimizes the waste production during processing stage.

According to Abedin *et al.* (2012), moisture content in jackfruit seeds ranged from 21.10 to 42.25 per cent, while Morton (1987) and Love and Paull (2011) found it to be occurring in the range of 51.6 to 57.77 per cent. On the other hand, seeds of *Artocarpus odoratissimus* contain 31.0 to 55.0 g/100g moisture (wet basis) (Tang *et al.*, 2013).

Study carried out by Ajayi (2008) proved *Artocarpus heterophyllus* seeds a good source of mineral elements. Potassium (2470 ppm) was found to be the prevalent mineral followed by sodium, magnesium and calcium. Seeds also contained reasonable quantity of iron i.e. 148.50 ppm. Substantial amount of potassium (1.30 to 1.42 per cent) and phosphorous (119 to 170 mg/100g) has been reported by Abedin *et al.* (2012) in jackfruit seeds. Even higher values for mineral composition have been reported varying from 3418.55 mg/kg for potassium, 2281.15

mg/kg for calcium, and 197.95 mg/kg for iron. Data revealed that fruit parts with high elemental composition can serve as a supplementary source of essential nutrients to man (Bello *et al.*, 2008). For the same species, Love and Paull (2011) observed that minerals like calcium, phosphorous and iron were found to be ranging from 0.05 to 0.55 mg/100g, 0.13 to 1.23 mg/100g and 0.002 to 1.2 mg/100g respectively.

Tang *et al.* (2013) made an effort to analyze the mineral composition in the seeds of *Artocarpus odoratissimus*. They observed that mineral content in the seeds was comparatively higher than that in the pulp. Composition of various minerals (mg per 100g) was reported as Potassium (352 to 443), Magnesium (103 to 132), Calcium (1.5 to 3.0) and Iron (0.8 to 1.2) etc.

Seeds of *Tamarindus indica* were reported to contain (mg/100g) Potassium–21.0, Calcium–10.0, Iron–75.9, and Phosphorus–25.5 respectively with the moisture content of 11.75 per cent. Overall, iron was highest mineral element in the seed, indicating that it can serve as a good source of iron. From their findings, authors came to the conclusion that removal of the seed coat increases the moisture and ash content, thus increasing mineral content of the seeds (Yusuf *et al.*, 2007). *Annona muricata* seeds contains significant amount of important minerals like potassium (357.14 mg/100g), calcium (149.1 mg/100g) and phosphorous (136 mg/100g). The results showed that seeds contain 7.7 per cent moisture content (Kimbonguila *et al.*, 2010).

Studies were carried on the seeds of *Lablab purpureus*, *Leucaena leucocephala* and *Mucuna utilis* to determine their potential for domestic consumption and industrial utilization. Seeds of *Leucaena leucocephala* contained highest amount of mineral nutrients including N, P, K, Ca, Mg, Mn, Fe, Cu and Zn followed by *Lablab purpureus* and *Mucuna utilis* (Alabi and Alausa, 2006). Kernels of *Adansonia digitata* and *Sclerocarya birrea* were reported to be rich in calcium, iron, magnesium and zinc (Magaia *et al.*, 2013).

Composition of minerals in the seeds of *Terminalia indica* varied between different ecological zones. This can be attributed to differences in climate, elevation and soil in different agro-ecological regions. Seeds contained higher percentage of minerals compared to pulp (Okello, 2010).

2.10. Variability studies on biochemical attributes

Jagadeesh *et al.* (2007) analyzed the chemical composition of *Artocarpus heterophyllus* clones from different districts to study the variability. A wide variation in TSS, acidity, sugars, starch and carotenoid contents was observed in the jackfruit bulbs considered in this study. Based on their study, Goswami *et al.* (2011) also concluded that the proximate composition of jackfruit pulps is influenced by both type and place. Geographic and yearly variation in the chemical composition of shea (*Butyrospermum paradoxum*) fruit pulp was investigated by Thomas (2013). The values obtained for moisture content and mineral content of the pulp from different localities did not differ significantly. However, significant differences were observed for crude protein, crude lipid, crude fibre, ash and carbohydrates. Pulp composition was dependent on climatic and soil conditions prevailing each year. According to Li *et al.* (2007), difference in the nutritional composition among various cultivars of Chinese jujube can lead to their different applications. For example, due to its high content of vitamin and sucrose, *Zizyphus jujuba* cv. *Junzao*, is consumed as a fresh fruit.

Biochemical composition of *Adansonia digitata* parts (pulp, leaves and seeds) did not show significant variation between the studied zones as well as within a particular zone. Rather, results showed that physico-chemical characteristics of the soil have an influence on the nutritive value of different baobab parts. Thus, this information could be further used to determine the type and levels of fertilizer application to improve the nutritional value of fruit parts (Assogbadjo *et al.*, 2012).

Nutritional composition of palmyra palm (*Borassus aethiopum*) fruits collected from different agro-climatic zones was analyzed by Ali *et al.* (2010). Significant variation was not observed between the two zones. Thakur *et al.* (2011) made an attempt to study the variations in chemical characteristics of wild pomegranate fruits growing in different locations of Himachal Pradesh. They noted that there was no specific difference for chemical parameters at different locations implying that no single parameter was found dominating at different locations. Jaakkola *et al.* (2012) compared the chemical composition of ripe fruits of *Rubus chamaemorus* grown in open and shaded sites. The concentrations of β carotene varied significantly between the habitats whereas the concentrations of Vitamin C were consistent. As per findings of this study, the amount of sunlight and temperature levels could be the main factors affecting the chemical composition of cloudberry.

Obasuyi and Nwokoro (2006) conducted a study to ascertain some physical and chemical characteristics of breadfruit seeds from different locations. They concluded that selected locations did not affect the characteristics of the seeds measured in their study.

Materials and Methods

3. MATERIALS AND METHODS

The present study "Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district" was carried out to study phenological variations and fruit characteristics of *Artocarpus hirsutus* with respect to two altitudinal zones. The study also aimed to evaluate biochemical and mineral composition of the fruit. The materials and methods adopted for the study are recorded in this section.

3.1 Study Site:

3.1.1 Location

This study was conducted at two altitudinal zones of Thrissur district viz. midlands and lowlands. In midlands, six trees were selected from the vicinity of College of Forestry, Vellanikkara (10° 32' N latitude and 76° 16' E longitude) located at an altitude of 22 m above mean sea level (Plate 1a). Similarly, for lowlands also, six trees were selected from Thalikulam (10° 25' N latitude and 76° 05' E longitude), coastal area of Thrissur district located at an altitude of 7.5 m above mean sea level (Plate 1b).

3.1.2 Climate

The region experiences a warm and humid climate, with a mean annual rainfall of 2903mm (mean corresponding to the twenty year period from 1991-2011), most of which is received during the South- West monsoon (June to August). The mean maximum temperature ranges from 29.6°C (July) to 35.5°C (March) and the mean minimum temperature varies from 22.3°C (January) to 24.8°C (April).

3.2. Phenological parameters

Trees were selected from the two altitudinal zones and monthly observations were taken on various phenological parameters like flowering, fruiting, leaf shedding and leaf flushing by occular means (Plate 2). Other morphological characteristics like girth and height were taken with the help of a tape and Haga altimeter respectively.

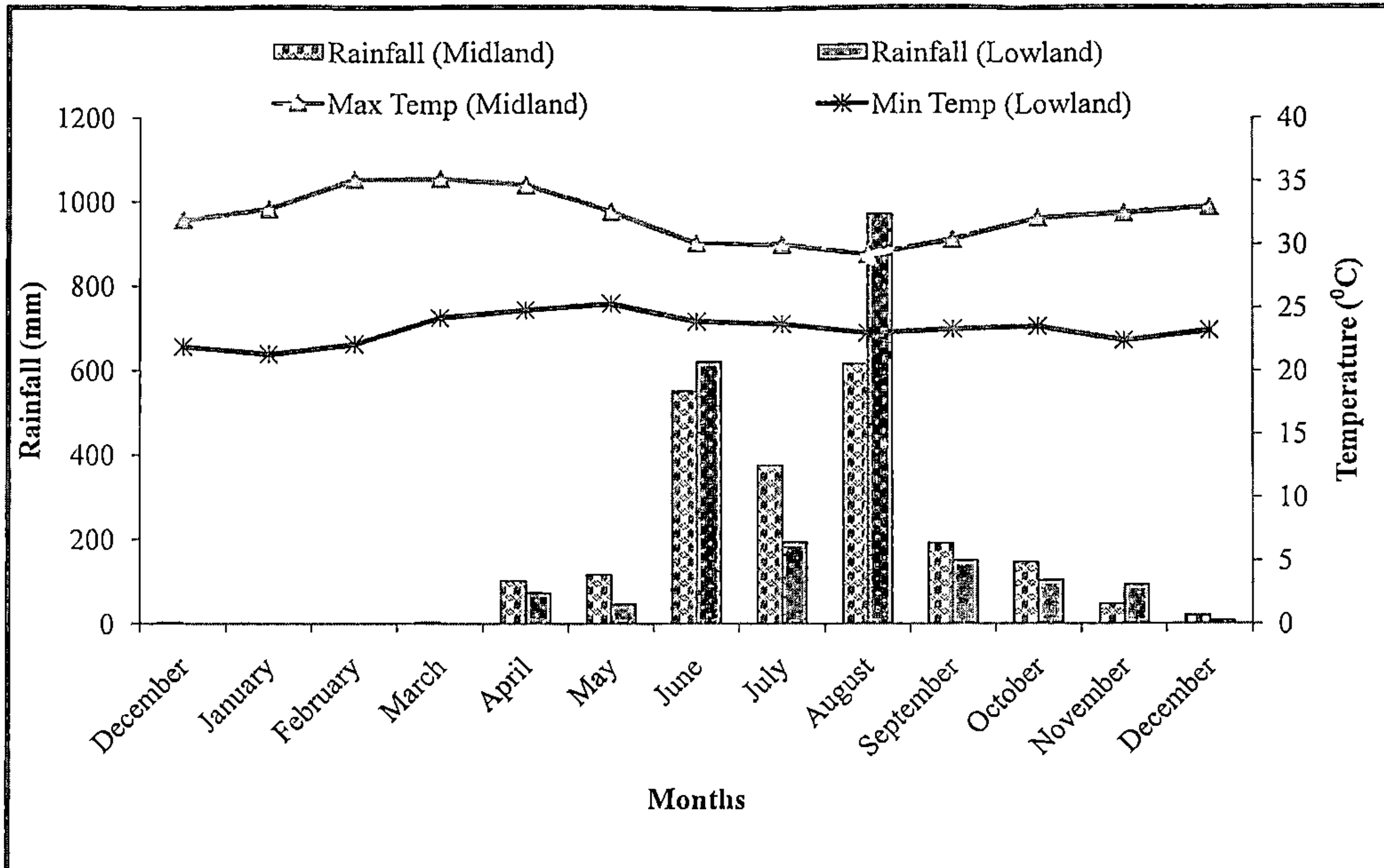
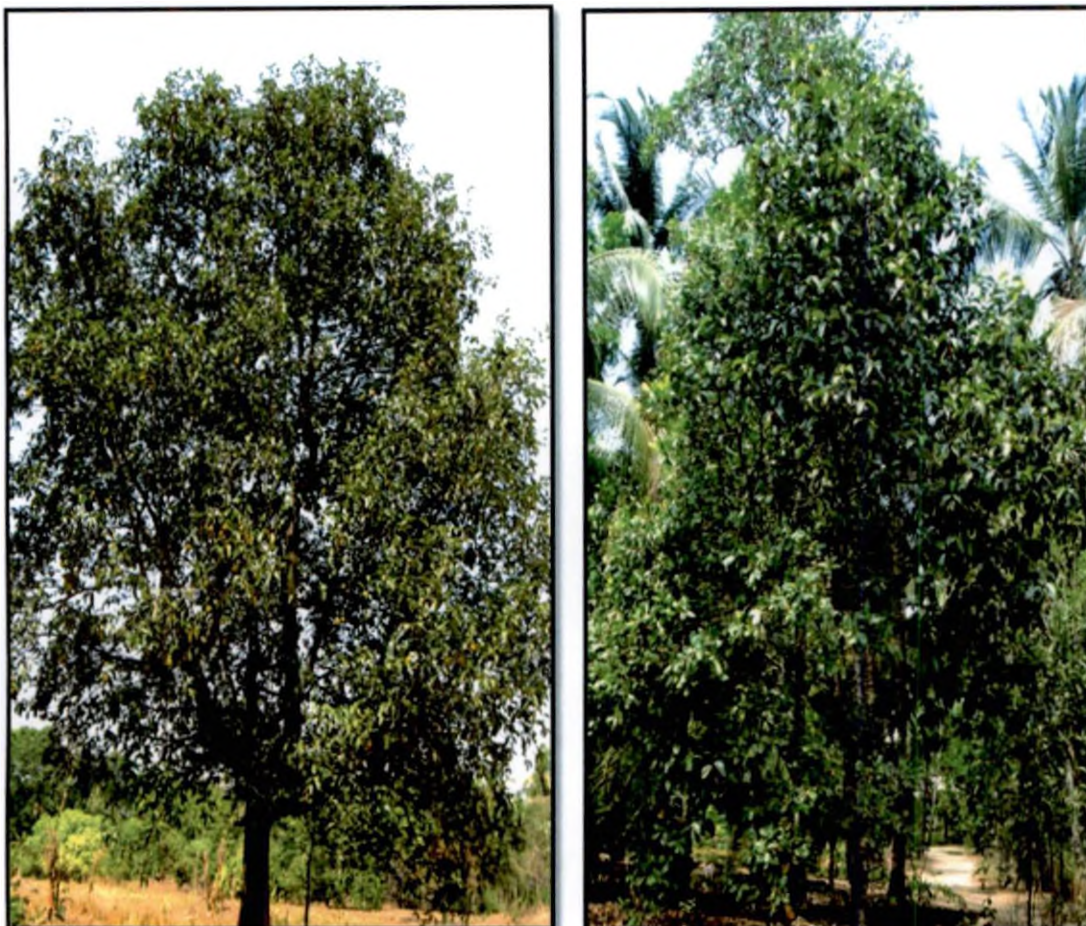


Fig. 1. Ombrothermic diagram showing temperature and rainfall during the study period in midland and lowland of Thrissur district. (Source: Dept. of Agrometeorology, KAU, Vellanikkara and State Seed Farm, Edathiruthy)



(a) **(b)**

Plate 1. *Artocarpus hirsutus* tree in (a) midland and (b) lowland of Thrissur district.

(a)

(b)

Plate 2. Inflorescence of *Artocarpus hirsutus* (a) female inflorescence and (b) male inflorescence

3.3. Quality evaluation of fruit

Quality evaluation of wild jack fruit was carried out using standard procedures.

3.3.1. Physical characters

Various physical characters were recorded which included fruit size, weight and volume.

3.3.1.1. Fruit size

Length and diameter of individual fruit as well as of the fruit core and fruit stalk was determined with the help of a digital vernier caliper and the mean was calculated (Plate 3).

3.3.1.2. Fruit weight

Weight of individual fruit before and after ripening was determined and the mean weight was recorded.

3.3.1.3. Fruit volume

Volume of individual fruit was measured by water displacement method and the mean was taken.

3.3.2. Physical composition

Proportion of pulp, peel, seed and core in a single fruit was evaluated by weighing each component separately and then calculating the percentage proportion of that component off the whole fruit (Plate 4).

3.3.3. Biochemical and nutritional constituents

Biochemical and nutritional qualities of the fruits as well as seeds were assessed using standard procedures. Analysis was carried out for the following constituents.

3.3.3.1. Moisture

To determine the moisture content of fruit, 5 g of the fruit pulp was taken in a petridish and dried in a hot air oven at 60°-70° C, cooled in a desiccator and weighed. The process of heating

(a)

(b)

(c)

Plate 3. *Artocarpus hirsutus* fruit (a) fruit from lowland and midland (b) fruit bulbs attached to the core and (c) fruit core

1. Fruit

2. Peel

3. Bulbs

4. Core

5. Flakes

6. Seeds

Plate 4. Different components of *Artocarpus hirsutus* fruit

and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage (AOAC, 1980).

3.3.3.2. Starch

The starch content was estimated colorimetrically using anthrone reagent as suggested by Sadasivam and Manikam (1992). The sample (0.1 g) was extracted with 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and added 5 ml water and 6.5 ml of 52 per cent perchloric acid and extracted in the cold for 20 minutes. The supernatant was pooled and made up to 100 ml. From this, 0.2 ml of the supernatant was pipetted out and made up to one ml with water and 4 ml of anthrone reagent was added, heated for eight minutes, cooled and OD value read at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph, glucose content of the sample was obtained and the value was multiplied by a factor of 0.9 to arrive at the starch content.

3.3.3.3. Total Soluble Solids

Total Soluble Solids were recorded using a hand refractometer (Erma, Japan) of brix ranging from 0 to 32° at room temperature and the values were expressed in degree brix (Ranganna, 1986).

3.3.3.4. Titrable acidity

Titrable acidity was determined as described by Hooi *et al.* (2004). Ten grams of sample was placed in a beaker and titrated with 0.1 N sodium hydroxide solution using phenolphathalein as an indicator. End point of titration was the transition from colourless to pink. Acidity was expressed as percentage.

3.3.3.5. Reducing sugar

Reducing sugar was estimated by the method given by Lane and Eyon (Ranganna, 1986). To 10 g of sample, 100 ml of distilled water was added and then clarified with neutral lead acetate. Excess lead was removed by adding potassium oxalate. The volume was then made up to

250 ml. An aliquot of this solution was titrated against a mixture of Fehling's solution A and B using methylene blue as indicator. The reducing sugar was expressed as percentage.

3.3.3.6. Total sugar

The total sugar was determined using the method given by Lane and Eyon (Ranganna, 1986). From the clarified solution used for the estimation of reducing sugar, 50 ml was taken and boiled gently after adding citric acid and water. It was later neutralized with NaOH and the volume was made up to 250 ml. An aliquot of this solution was titrated against Fehling's A and B. The total sugar content was expressed as percentage.

3.3.3.7. Fibre

The fibre content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978). Two gram of dried sample was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Filtration through muslin cloth was repeated and the residue was washed with sulphuric acid, water and alcohol in a sequential manner. Residue was transferred to a pre weighed ashing dish and was ignited for 30 minutes in a muffle furnace at 250 °C, cooled in a dessicator and weighed. The fibre content of the sample was calculated from loss in weight on ignition.

3.3.3.8. β carotene

β carotene was estimated by the method suggested by Srivastava and Kumar (1994). Five gram of sample was extracted adding 10 to 15 ml acetone and few crystals of anhydrous sodium sulphate. The supernatant was decanted and 10 to15 ml petroleum ether was added and mixed thoroughly and kept outside for layer separation. The supernatant was collected in a 100 ml volumetric flask and the volume was made up to 100 ml with petroleum ether and intensity of colour was read at 452 nm in a spectrophotometer. The β carotene content was expressed as μg per 100 g.

3.3.3.9. Vitamin C

The vitamin C content was estimated by the method suggested by Sadasivam and Manikam (1992). An exact amount of three grams of fresh sample was extracted with 4 per cent oxalic acid, made up to 100 ml with oxalic acid and supernatant was titrated against the dye solution 2, 6-dichlorophenol indophenol until the appearance of pink colour which persisted for a few seconds. Vitamin C content was expressed in g per 100 g of the sample.

3.3.4. Minerals

Mineral content (Calcium, Phosphorous, Potassium and Iron) was estimated using following procedures.

3.3.4.1. Calcium

The calcium content was estimated by atomic absorption spectrophotometric method using diacid extract prepared from the sample (Perkin-Elmer, 1982). One gram of the sample was predigested with 15 ml of 9:4 mixture of nitric acid and perchloric acid and made up to 50 ml and used directly in atomic absorption spectrophotometer for the estimation of calcium and expressed in mg per 100 g of sample.

3.3.4.2. Iron

Iron content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982). One gram of the sample was predigested with 15 ml of 9:4 mixture of nitric acid and perchloric acid. This solution was read directly in atomic absorption spectrophotometer and the iron content was expressed in mg per 100 g.

3.3.4.3. Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1973), which gives yellow colour with nitric acid vanadomolybdate reagent. To 5 ml of predigested aliquot, 10 ml of nitric acid vanadomolybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes, the OD was read at 420 nm.

A standard graph was prepared using serial dilution of standard phosphorus solution. The phosphorus content of the sample was estimated from the standard graph and expressed in mg per 100 g of sample.

3.3.4.4. Potassium

Potassium content was determined by Flame Photometeric method (Jackson, 1973). One gram of sample was digested with 9:4 mixture of nitric acid and perchloric acid and made up to 50 ml. 10 ml of this aliquot was taken and made up to 50 ml. This solution was directly read in Flame Photometer and potassium content was expressed in mg per 100 g of sample.

3.3.5. Organoleptic evaluation of the fruit

Organoleptic evaluation of the fruits was conducted using score cards by selecting a panel of ten judges.

3.3.5.1. Selection of judges

A series of acceptability trials were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellinek (1985).

3.3.5.2. Preparation of score card

Score card containing the eight quality attributes like appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability was prepared for the assessment of fruit. Each of the above mentioned qualities were assessed by a nine point hedonic scale. The score card used for the evaluation of fruit is given in the Appendix I.

3.4. Statistical analysis of the data

The observations recorded were tabulated and analysed statistically using Completely Randomized Design. The data was collected from six trees from both the zones (midlands and lowlands) and was subjected to ANOVA using SPSS software package. Follow up analysis was conducted using Duncan's Multiple Range Test (DMRT) for pair wise comparison of means.

Results

4. RESULTS

The results pertaining to the study entitled "Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district" are presented in this chapter.

4.1. Phenology of *Artocarpus hirsutus* Lam

Artocarpus hirsutus is a tall tree with orthotropic branching pattern. Leaves are simple and alternate. Petioles of the leaf have tawny hirsute. In young plants, lobed leaves are seen. Thus the tree shows heterophylly. Crown is round to oval in shape while bark is rough and dark grey in appearance. Observations on phenology of *Artocarpus hirsutus* tree from the two zones viz., midland and lowland are presented in the phenograms. Each phenogram gives information on phenological calendar for the species in two different altitudinal zones (Fig. 2).

With regards to the tree phenology, leaf shedding and leaf flushing continues throughout the year. However leaf shedding peaks during dry season i.e. April and leaf flushing peaks before the onset of rainy season. It is a monoecious species bearing both male and female inflorescence on the same individual tree. Male and female inflorescences are solitary, borne on axillary leafy twigs. Male inflorescence i.e. spike is cylindrical in shape while female inflorescence is ovoid. Flowering starts from November and continues till February. Flowering is followed by fruiting that continues till May to June. Fruit is sorosis (multiple fruit) formed from several flowers of a single inflorescence. It is green when unripe and turns to orange yellow when ripened. Flowering and fruiting shows a seasonal pattern (Fig. 2a).

In lowland also, trees showed similar phenological patterns as in midland. Leaf appearance and leaf senescence is a continuous process occurring throughout the year. Leaf fall was maximum during dry season and maximum leaf appearance was observed before the onset of rainy season. Flowering initiated during November continuing till February. Fruiting lasted till June with a peak occurring during March (Fig. 2b).

(a) Midland

(b) Lowland

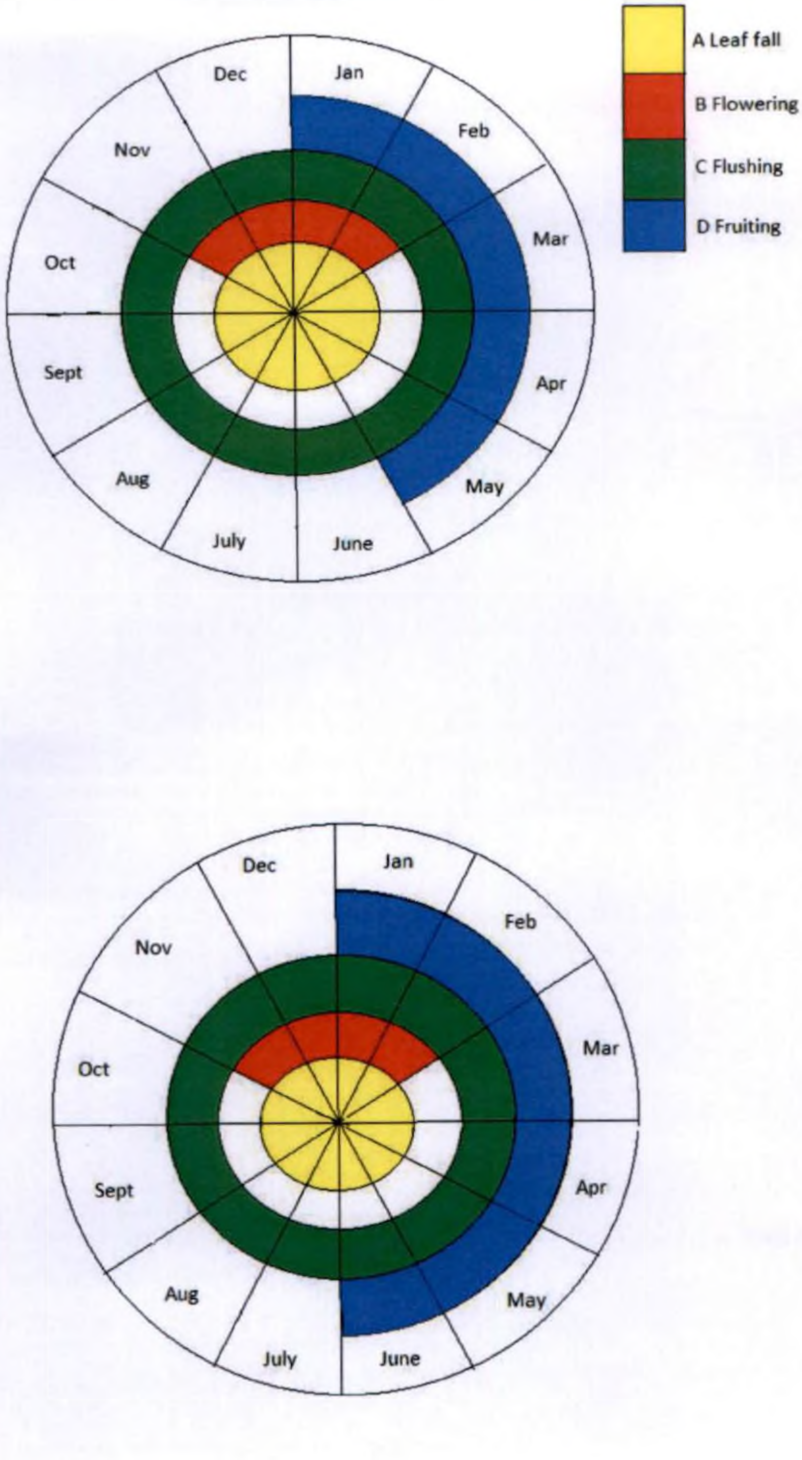


Fig. 2. Phenogram of *Artocarpus hirsutus* in (a) midland and (b) lowland of Thrissur district.

4.2. Physical characteristics of *Artocarpus hirsutus* trees

Among the selected trees in midland, mean girth and mean height was found to be 1.41 m and 16.32 m respectively. Mean leaf length and mean leaf breadth of trees were reported to be 14.91 cm and 9.83 cm respectively (Table 1).

In lowland, mean girth and mean height of the selected trees were 1.22 m and 19.50 m respectively. Mean leaf length and leaf breadth among the selected trees as reported were 15.86 cm and 10.81 cm respectively (Table 1).

4.3. Physical characteristics of *Artocarpus hirsutus* fruits

Fruits of *Artocarpus hirsutus* were analyzed for physical characteristics from two altitudinal zones viz., midland and lowland respectively of Thrissur district. In midland, mean values for fruit weight, volume, length and diameter as recorded were 111.15 g, 83.94 cm^3, 69.57 mm and 63.19 mm respectively (Table 2). For trees in lowland, mean fruit weight, volume, length and diameter were found to be 152.43 g, 116.97 cm^3, 76 mm and 57.04 mm respectively (Table 2).

With regards to physical characteristics of fruits in midland, mean fruit weight, peel weight, bulb weight, pulp weight and seed weight were 88.82 g, 54.96 g, 22.60 g, 10.94 g and 9.71 g respectively. Also, mean number of seeds per fruit was 14.14. Mean core weight, core length and core diameter were 13.03 g, 36.03 mm and 18.72 mm respectively (Table 3). In lowland, physical characters of fruit like mean fruit weight, peel weight, bulb weight, pulp weight and seed weight were found to be 124.57 g, 62.97 g, 48.97 g, 22.28 g and 24.23 g respectively, and mean number of seeds per fruit was 35.76. Mean core weight, core length and core diameter were observed to be 14.93 g, 48.98 mm and 15.59 mm respectively (Table 3).

Table 1. Physical characteristics of *Artocarpus hirsutus* trees in midland and lowland of Thrissur district.

Physical characters of trees	Midland	Lowland
Girth (m)	1.41±0.02	1.22±0.04
Height (m)	16.32±0.21	19.50±0.33
Leaf length (cm)	14.91±0.15	15.86±0.14
Leaf breadth (cm)	9.83±0.11	10.81±0.12

Table 2. Physical characteristics of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

Physical characters of fruit	Midland	Lowland
Weight (g)	111.15±2.88	152.43±6.10
Volume (cm^3)	83.94±2.61	116.97±6.28
Length (mm)	69.57±0.85	76.00±1.22
Diameter (mm)	63.19±0.63	57.04±0.61

Table 3. Physical characteristics of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

Serial No.	Physical characters of fruit	Midland	Lowland
1	Fruit weight (g)	88.82±3.52	124.57±6.13
2	Peel weight (g)	54.96±1.98	62.97±2.37
3	Bulb weight (g)	22.60±1.27	48.97±3.70
4	Pulp weight (g)	10.94±0.56	22.28±1.88
5	Seed weight (g)	9.71±0.60	24.23±1.71
6	No. of seeds/fruit	14.14±0.96	35.76±1.94
7	Core weight (g)	13.03±0.42	14.93±0.48
8	Core length (mm)	36.03±0.73	48.98±1.11
9	Core diameter (mm)	18.72±0.35	15.59±0.27
10	Stalk length (cm)	4.11±0.11	2.49±0.06
11	Stalk weight (g)	0.91±0.04	0.54±0.02

4.3.1. Correlation and Regression equations

A correlation matrix computed for physical parameters like fruit weight, volume, length and diameter showed a significant and positive relation between all these parameters in both midland and lowland (Table 4). Regression equations were prepared by taking fruit weight as an independent variable and rind weight, bulb weight, pulp weight and fruit volume as dependent variable separately for midland and lowland. For both the study areas, regression equations for fruit length (independent variable) and fruit weight and fruit volume (dependent variables) were also worked out. Linear regressions were obtained for these parameters (Fig. 3 and 4).

4.3.2. Proportion of pulp, peel, seed and core

In midland, mean pulp, peel, seed and core percentage was 11.87, 63.28, 10.18 and 14.67 respectively (Table 5 and Fig. 5), while in lowland these values were found to be 15.49, 54.66, 17.87 and 11.98 respectively (Table 5 and Fig. 6).

4.4. Biochemical composition of fruits

Table 6 shows biochemical composition of fruits from midland and lowland regions. In fruits obtained from midland, mean moisture, titrable acidity, starch, fibre, β carotene and vitamin C content were reported to be 69.84 per cent, 1.27 per cent, 14.76 per cent, 2.01 per cent, 4.30 μg/100g, 5.31 mg/100g and respectively. Mean TSS, total sugar and reducing sugar were found to be 19.17 ^{0}Brix, 14.21 per cent and 11.94 per cent respectively.

Fruits collected from lowland recorded mean moisture, titrable acidity, starch, fibre, β carotene and vitamin C content of 70.16 per cent, 0.69 per cent, 15.30 per cent, 2.12 per cent, 2.88 μg/100g and 4.89 mg/100g respectively. Mean TSS, total sugar and reducing sugar were found to be 18.68 ^{0}Brix, 14.9 per cent and 11.47 per cent respectively (Table 6).

Table 4. Correlation between physical characteristics of fruits in midland and lowland of Thrissur district.

Parameters	Weight (g)		Volume (cm^3)		Length (mm)		Diameter (mm)	
	M	L	M	L	M	L	M	L
Weight (g)	1	1	0.94^{**}	0.98^{**}	0.83^{**}	0.91^{**}	0.82^{**}	0.75^{**}
Volume (cm^3)			1	1	0.80^{**}	0.89^{**}	0.80^{**}	0.75^{**}
Length (mm)					1	1	0.82^{**}	0.74^{**}
Diameter (mm)							1	1

*** correlation significant at 0.01 level*
M- Midland
L- Lowland

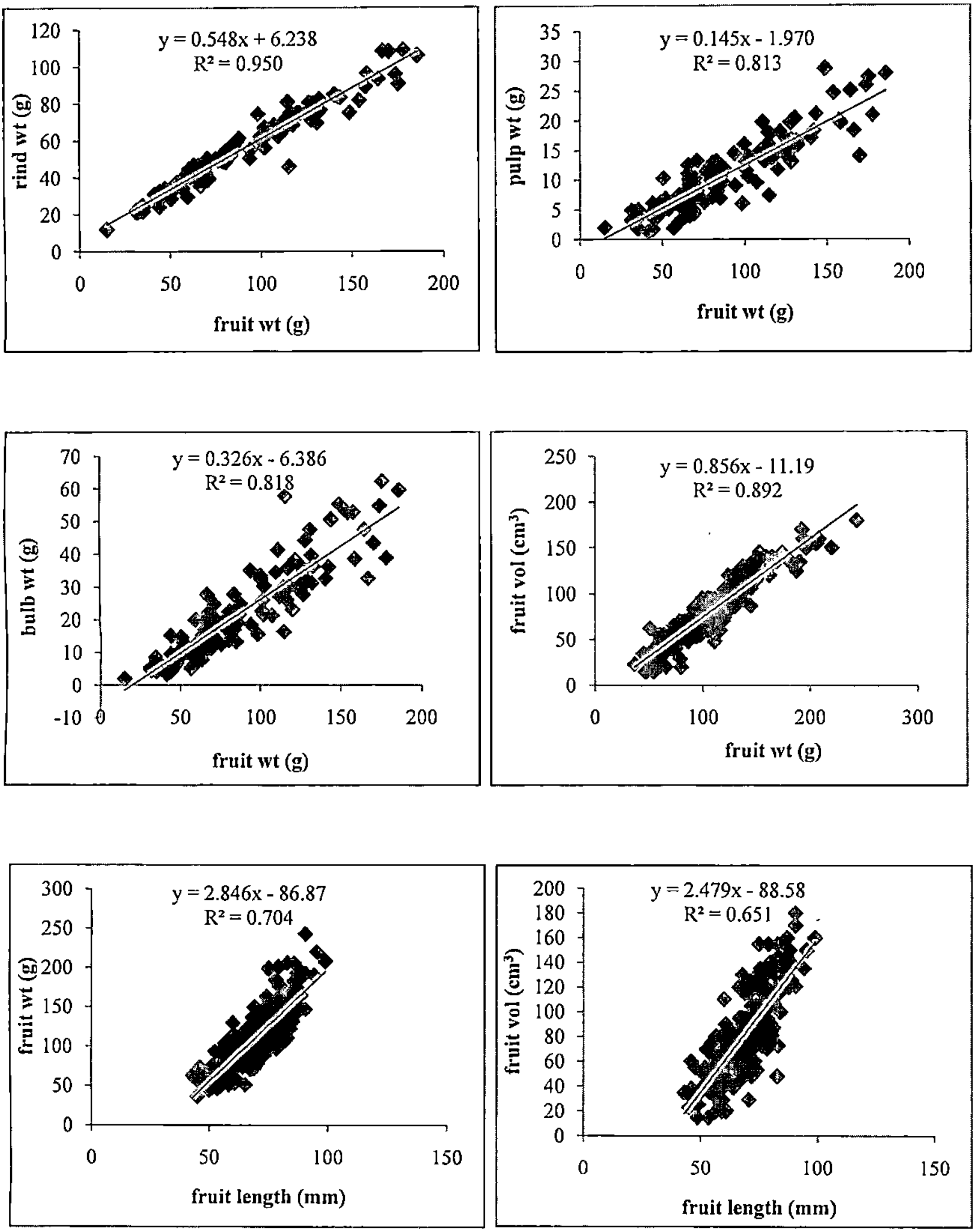


Fig. 3. Regression equations predicting physical characteristics of *Artocarpus hirsutus* fruits in midland of Thrissur district.

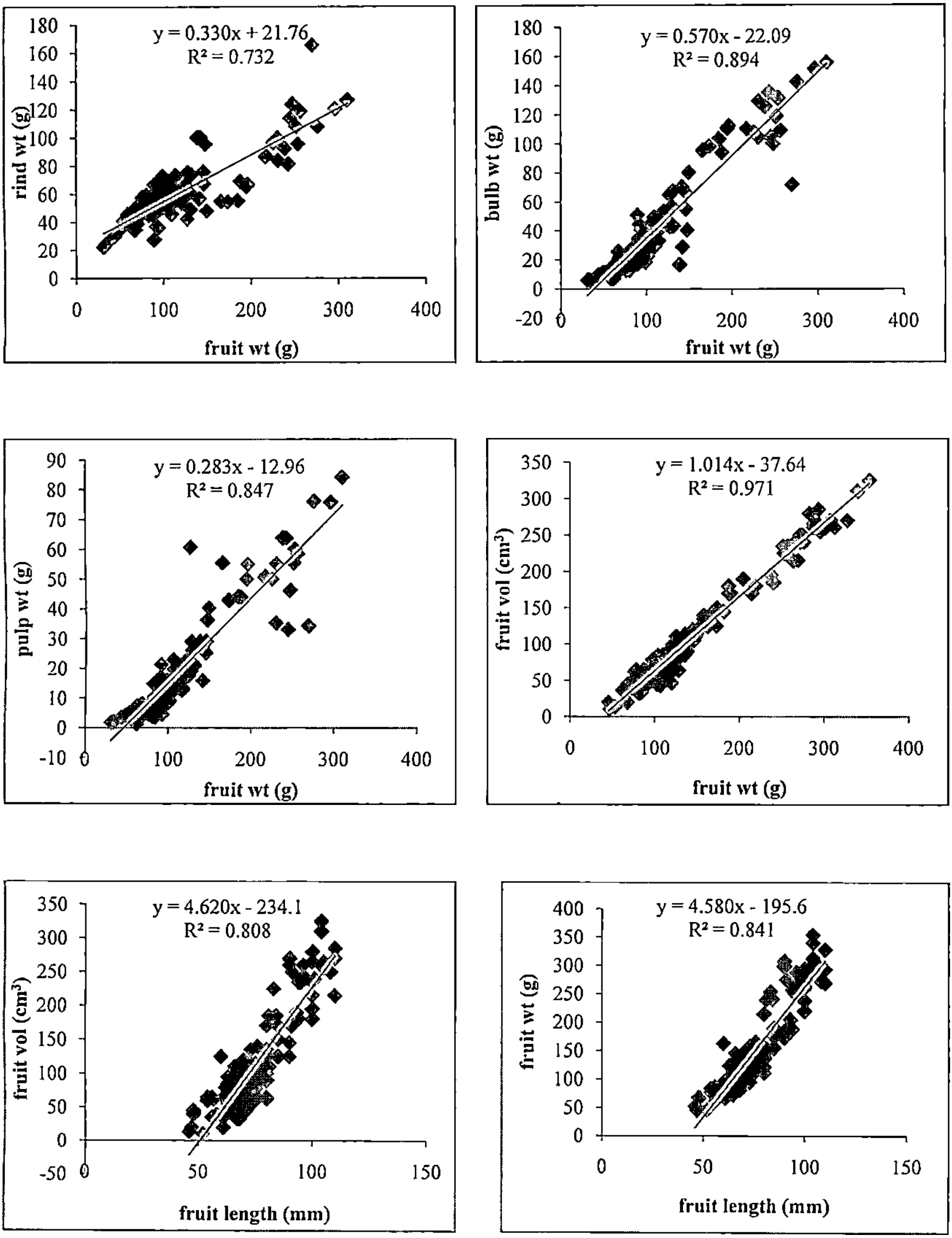


Fig. 4. Regression equations predicting physical characteristics of *Artocarpus hirsutus* fruits in lowland of Thrissur district.

Table 5. Physical composition of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

Physical composition	Midland	Lowland
Pulp (%)	11.87±0.31	15.49±0.72
Peel (%)	63.28±0.55	54.66±1.27
Seed (%)	10.18±0.40	17.87±0.56
Core (%)	14.67±0.25	11.98±0.11

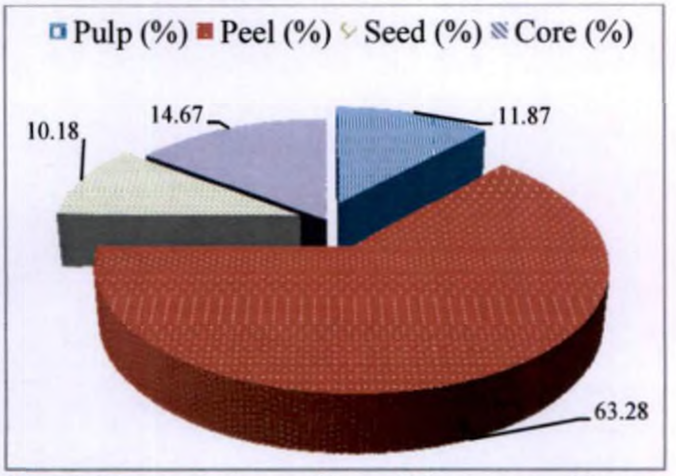


Fig. 5. Physical composition of *Artocarpus hirsutus* fruits in midland of Thrissur district.

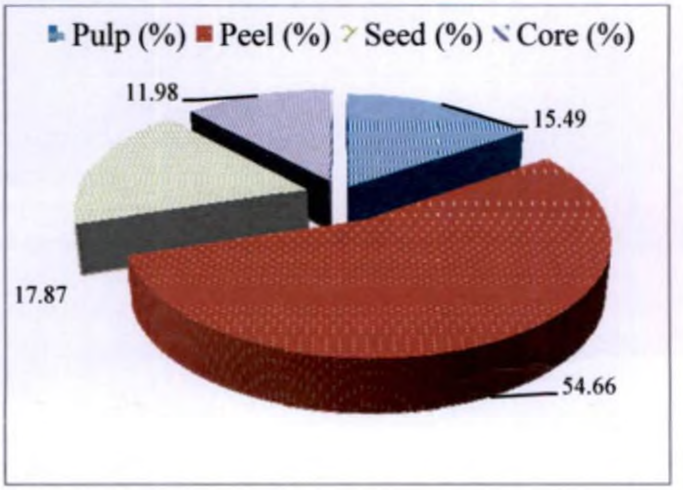


Fig. 6. Physical composition of *Artocarpus hirsutus* fruits in lowland of Thrissur district.

Table 6. Biochemical composition of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

Serial No.	Biochemical composition	Midland	Lowland
1	Moisture (%)	69.84±0.64	70.16±1.28
2	TSS (°Brix)	19.17±0.55	18.68±1.30
3	Titrable acidity (%)	1.27±0.17	0.69±0.04
4	Total sugar (%)	14.21±0.29	14.9±0.49
5	Reducing sugar (%)	11.94±0.37	11.47±0.38
6	Starch (%)	14.76±1.05	15.30±0.63
7	Fibre (%)	2.01±0.07	2.12±0.10
8	β carotene (μg/100g)	4.30±0.14	2.88±0.14
9	Vitamin C (mg/100g)	5.31±0.70	4.89±0.46

Table 7 and Fig. 7 depict the biochemical composition of different fruit size classes from midland. Significant difference was observed for most of the biochemical parameters of different fruit sizes in midland except for beta carotene, vitamin C and fibre content. Overall big fruit size class showed higher values for all the parameters. However, no trend was obtained for biochemical composition of small and medium sized fruits. Among the different fruit size classes selected, mean moisture content ranged from 70.66 per cent to 72.83 per cent. Mean TSS, total sugar and reducing sugar ranged from 20.4 ^{0}Brix to 23.33 ^{0}Brix, 10.78 per cent to 14.07 per cent, and 9.37 per cent to 11.57 per cent respectively. Mean titrable acidity varied from 0.84 per cent to 1.19 per cent. Mean starch content was observed to range from 13.57 per cent to 19.27 per cent. However, no significant variation was observed for β carotene, Vitamin C and fibre content. They were found to be ranging from 3.63 μg/100g to 4.59 μg/100g, 3.17 mg/100g to 3.96 mg/100g and 1.85 per cent to 2.09 per cent respectively.

Table 8 and Fig. 8 show the biochemical composition for different fruit size classes in lowland. Biochemical parameters varied significantly for various size categories of fruit. No significant variation was observed among the size classes for TSS, starch, beta carotene, vitamin C and fibre content. Among all the fruit size classes studied, higher values for biochemical attributes were recorded for big sized fruits. However, in lowland also no trend was observed between medium and smaller fruit size classes. Mean moisture content ranged from 66.66 per cent to 70.00 per cent. With regards to the sugar content; TSS, total sugar and reducing sugar varied from 21.80 ^{0}Brix to 22.33 ^{0}Brix, 14.28 per cent to 17.14 per cent and 9.23 per cent to 12.03 per cent respectively. Mean values for titrable acidity were found to be in the range of 0.72 per cent to 0.91 per cent. Mean values for starch content for different fruit size classes varied from 7.96 per cent to 10.16 per cent. However, TSS, β carotene, vitamin C and fibre content did not show significant variation among the size classes. β carotene ranged from 2.39 μg/100g to 2.89 μg/100g, vitamin C from 3.96 mg/100g to 4.36 mg/100g and fibre content from 1.99 per cent to 2.33 per cent respectively.

Table 7. Biochemical composition of *Artocarpus hirsutus* fruit size classes in midland of Thrissur district.

Fruit size class	Moisture (%)	TSS (°Brix)	Titrable Acidity (%)	Total sugar (%)	Reducing sugar (%)	Starch (%)	Fibre (%)	Beta Carotene (µg/100g)	Vitamin C (mg/100g)
Big	72.83[a] ±0.44	23.33[a] ±0.66	1.19[a] ±0.04	14.07[a] ±0.47	11.57[a] ±0.46	19.27[a] ±0.16	2.09[a] ±0.00	4.59[a] ±0.15	3.57[a] ±0.00
Medium	71.16[b] ±0.16	20.40[b] ±0.30	1.14[a] ±0.03	10.78[b] ±0.78	9.37[b] ±0.12	17.31[b] ±0.53	1.99[a] ±0.09	3.63[a] ±0.24	3.17[a] ±0.79
Small	70.66[b] ±0.33	22.86[a] ±0.06	0.84[b] ±0.04	13.11[a] ±0.41	9.62[b] ±0.21	13.57[c] ±0.30	1.85[a] ±0.09	4.25[a] ±0.43	3.96[a] ±0.39
Overall	71.55 ±0.36	22.20 ±0.50	1.06 ±0.05	12.65 ±0.56	10.18 ±0.37	16.71 ±0.85	1.97 ±0.05	4.16 ±0.20	3.57 ±0.28
F value	11.58*	13.74*	20.55*	8.48*	15.82*	62.73*	2.43[ns]	2.59[ns]	0.60[ns]

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

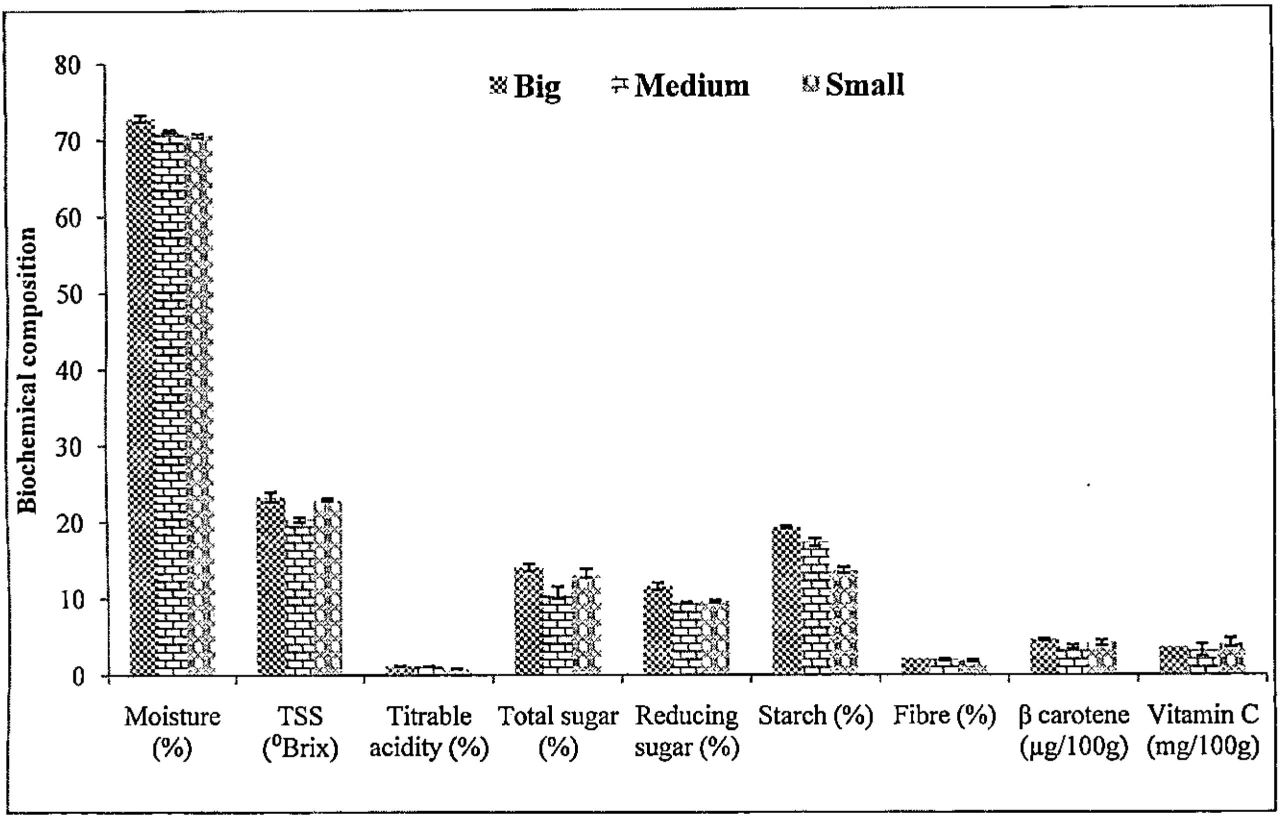


Fig.7. Biochemical composition of *Artocarpus hirsutus* fruit size classes in midland of Thrissur district.

Table 8. Biochemical composition of *Artocarpus hirsutus* fruit size classes in lowland of Thrissur district.

Fruit size class	Moisture (%)	TSS (°Brix)	Titrable Acidity (%)	Total sugar (%)	Reducing sugar (%)	Starch (%)	Fibre (%)	Beta Carotene (µg/100g)	Vitamin C (mg/100g)
Big	70.00^{a} ±1.15	22.33^{a} ±0.33	0.91^{a} ±0.04	16.40^{a} ±0.40	12.03^{a} ±0.46	10.16^{a} ±0.88	2.16^{a} ±0.15	2.89^{a} ±0.25	3.96^{a} ±0.39
Medium	69.83^{a} ±0.72	21.80^{a} ±0.20	0.72^{b} ±0.02	17.14^{a} ±0.10	9.23^{b} ±0.40	7.96^{a} ±0.35	1.99^{a} ±0.04	2.41^{a} ±0.33	4.36^{a} ±0.39
Small	66.66^{b} ±0.44	22.06^{a} ±0.06	0.87^{a} ±0.02	14.28^{b} ±0.00	9.54^{b} ±0.46	9.99^{a} ±0.67	2.33^{a} ±0.09	2.39^{a} ±0.19	4.36^{a} ±0.39
Overall	68.83 ±0.68	22.06 ±0.13	0.83 ±0.03	15.94 ±0.44	10.27 ±0.49	9.37 ±0.48	2.16 ±0.07	2.56 ±0.15	4.23 ±0.20
F value	5.14^{*}	1.37^{ns}	11.83^{*}	38.65^{*}	11.99^{*}	3.31^{ns}	2.39^{ns}	1.09^{ns}	0.33^{ns}

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

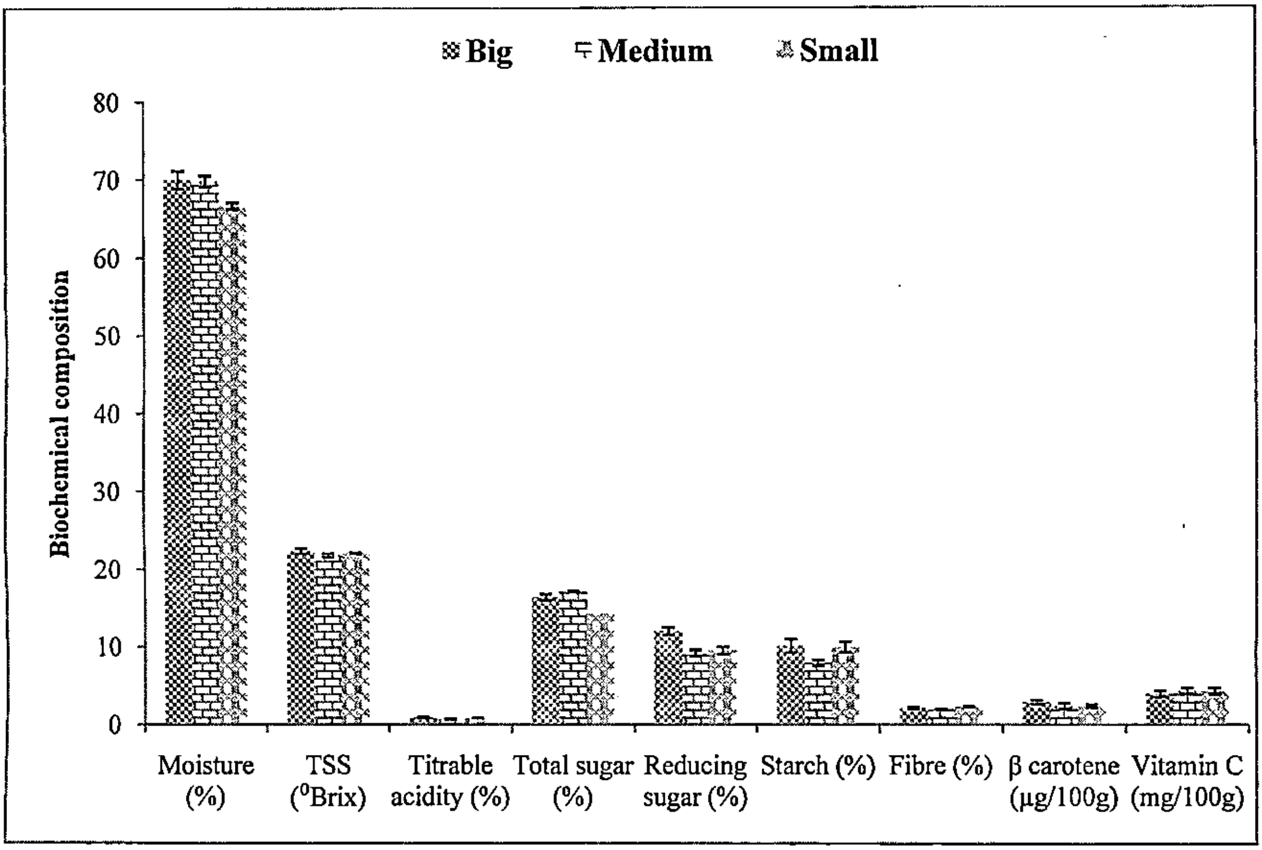


Fig.8. Biochemical composition of *Artocarpus hirsutus* fruit size classes in lowland of Thrissur district.

4.5. Mineral composition of fruits

Mineral content of the fruits collected from both midland and lowland was determined. Mineral composition of fruits in midland is presented in the Table 9. Mean phosphorus, potassium, iron and calcium content ranged as 45.13 mg/100g, 287.35 mg/100g, 1.78 mg/100g and 15.83 mg/100g respectively.

Mineral composition of fruits in lowland is presented in the Table 9. Mean phosphorus, potassium, iron and calcium content ranged as 47.49 mg/100g, 368.76 mg/100g, 1.16 mg/100g and 15.35 mg/100g respectively.

Table 10 and Fig. 9 depict mineral composition of various fruit size classes in midland. Significant variation was observed among the size classes for all the minerals studied. Bigger fruit size class showed highest mineral content. Phosphorus, potassium, iron and calcium content were found to be occurring in the range of 41.33 mg/100g to 47.04 mg/100g, 341.42 mg/100g to 481.33 mg/100g, 1.37 mg/100g to 2.48 mg/100g and 11.53 mg/100g to 20.68 mg/100g respectively for all the size classes.

As observed in midland, fruit size classes in lowland also showed significant variation for mineral composition. Bigger fruit size class showed highest mineral content. Phosphorus among the different fruit size classes did not vary significantly. Phosphorus, potassium, iron and calcium content for various fruit size classes ranged from 47.00 mg/100g to 48.25 mg/100g, 324.97 mg/100g to 437.09 mg/100g, 0.86 mg/100g to 2.23 mg/100g and 15.79 mg/100g to 19.53 mg/100g respectively (Table 11 and Fig. 10).

4.6. Mineral composition of seeds

Mineral composition of seeds of *Artocarpus hirsutus* fruits was determined for fruits collected from both midland and lowland. Table 12 represents the mineral composition for seeds in midland and lowland. Mean moisture content, phosphorus, potassium, iron and calcium content in midland were reported to be 48.18 per cent, 88.57 mg/100g, 388.64 mg/100g, 2.06 mg/100g and 13.08 mg/100g respectively. Mean moisture content, phosphorus, potassium, iron and calcium content in lowland were reported to be 50.18 per cent, 69.23 mg/100g, 311.21 mg/100g, 1.69 mg/100g and 25.10 mg/100g respectively (Table 12).

Table 9. Mineral composition of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

Mineral composition	Midland	Lowland
Phosphorus (mg/100g)	45.13±1.21	47.49±2.29
Potassium (mg/100g)	287.35±26.61	368.76±11.80
Iron (mg/100g)	1.78±0.22	1.16±0.12
Calcium (mg/100g)	15.83±1.67	15.35±1.69

Table 10. Mineral composition of *Artocarpus hirsutus* fruit size classes in midland of Thrissur district.

Fruit size class	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
Big	47.04^{a}±0.93	481.33^{a}±2.14	2.48^{a}±0.13	20.68^{a}±0.76
Medium	41.33^{b}±1.10	372.81^{b}±1.61	1.37^{c}±0.03	15.85^{b}±0.15
Small	42.90^{b}±0.95	341.42^{c}±5.48	1.69^{b}±0.01	11.53^{c}±0.28
Overall	43.75±0.98	398.52±21.26	1.84±0.16	16.02±1.34
F value	8.72*	433.35*	49.35*	91.91*

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

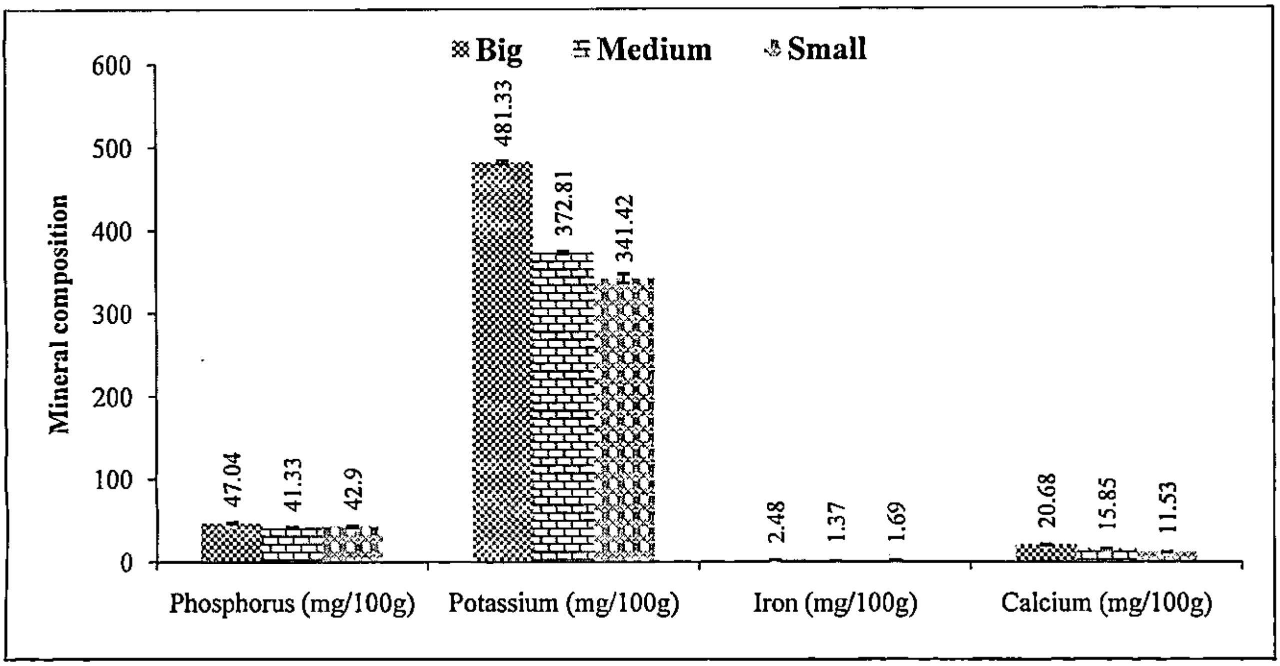


Fig. 9. Mineral composition of *Artocarpus hirsutus* fruit size classes in midland of Thrissur district.

Table 11. Mineral composition of *Artocarpus hirsutus* fruit size classes in lowland of Thrissur district.

Fruit size class	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
Big	$48.25^{a}\pm0.66$	$437.09^{a}\pm4.90$	$1.93^{a}\pm0.14$	$20.31^{a}\pm0.34$
Medium	$48.25^{a}\pm1.14$	$376.00^{b}\pm3.17$	$0.86^{b}\pm0.12$	$15.79^{b}\pm0.70$
Small	$47.00^{a}\pm0.50$	$324.97^{c}\pm7.92$	$2.23^{a}\pm0.20$	$19.53^{a}\pm0.51$
Overall	47.83±0.45	379.35±16.45	1.67±0.22	18.54±0.74
F value	0.77^{ns}	97.52^{*}	19.52^{*}	19.62^{*}

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

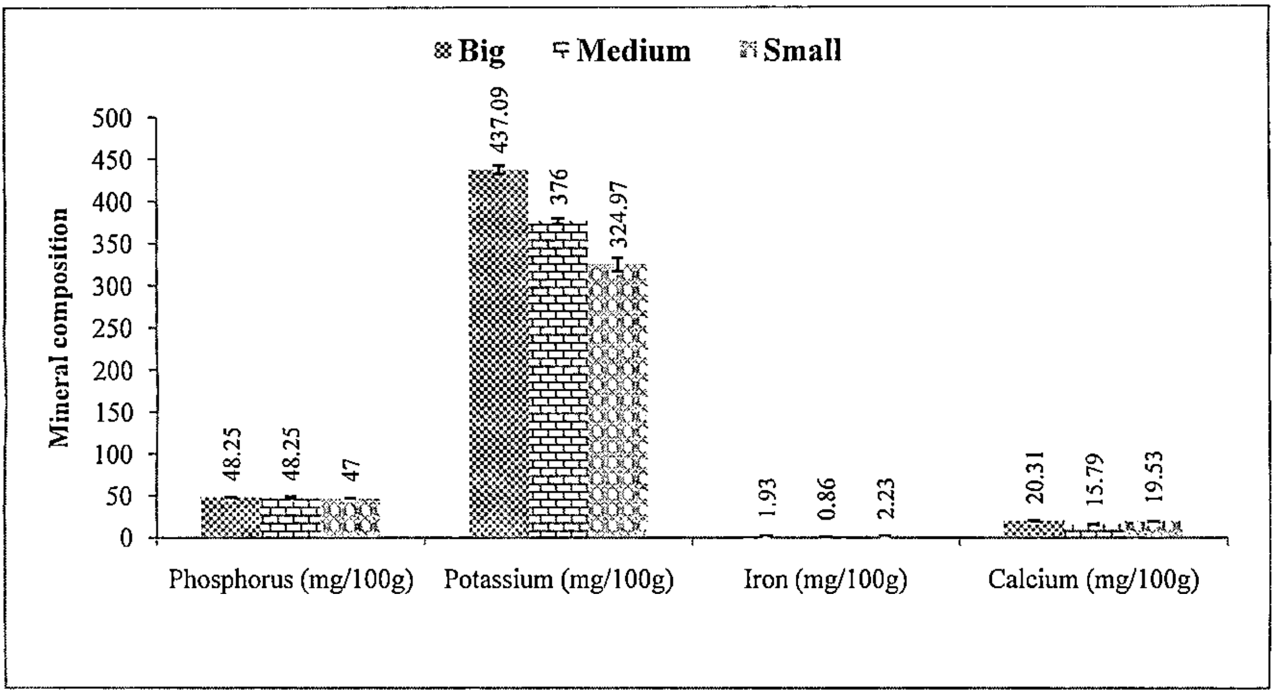


Fig. 10. Mineral composition of *Artocarpus hirsutus* fruit size classes in lowland of Thrissur district.

Table 12. Mineral composition of *Artocarpus hirsutus* seeds in midland and lowland of Thrissur district.

Chemical composition	Midland	Lowland
Moisture (%)	48.18±0.54	50.18±1.82
Phosphorus (mg/100g)	88.57±4.65	69.23±2.83
Potassium (mg/100g)	388.64±7.46	311.21±7.21
Iron (mg/100g)	2.06±0.24	1.69±0.29
Calcium (mg/100g)	13.08±0.21	25.10±1.19

For different fruit sizes in midland, significant difference was observed for potassium content only. Overall seeds of bigger fruit size class showed higher values for mineral contents. Mean moisture, phosphorus, potassium, iron and calcium content for seeds of various fruit size class ranged from 45.57 per cent to 46.09 per cent, 62.50 mg/100g to 77.90 mg/100g, 311.60 mg/100g to 388.14 mg/100g, 1.52 mg/100g to 2.38 mg/100g and 12.20 mg/100g to 16.86 mg/100g respectively (Table 13 and Fig. 11).

Chemical composition of seeds belonging to different fruit size class in lowland varied significantly for potassium content only. In general, seeds of bigger fruit size class showed higher values for mineral contents. Mean moisture, phosphorus, potassium, iron and calcium content for seeds of various fruit size class ranged from 49.04 per cent to 58.23 per cent, 78.41 mg/100g to 93.36 mg/100g, 320.00 mg/100g to 339.01 mg/100g, 1.32 mg/100g to 1.49 mg/100g and 26.41 mg/100g to 34.27 mg/100g respectively (Table 14 and Fig. 12).

4.7. Organoleptic evaluation of fruit

Organoleptic evaluation of the fruit from two zones; midland and highland, was done by a selected panel of ten judges. Table 15 and Fig. 13 depicts the mean scores of organoleptic evaluation of fruits from the two zones. For fruits obtained from midland, mean score for appearance, colour, flavor, texture, odour, taste, after taste and overall acceptability was 7.3, 7.8, 7.3, 7.4, 6.6, 7.7, 7.1 and 7.7 respectively. Similarly, for fruits from lowland mean score for appearance, colour, flavor, texture, odour, taste, after taste and overall acceptability was 8.2, 8.2, 7.6, 7.7, 7, 7.9, and 8.3 respectively. Overall, fruits obtained from lowland showed higher organoleptic scores. From the given figure, it is clear that judges had significant agreement in differentiation of all the parameters.

4.8. Comparison between the zones

A comparison was made between the two zones for leaf characteristics and physical as well as biochemical characteristics of *Artocarpus hirsutus* fruit. Results of these comparisons are presented in the given figures. A comparison between the leaf characteristics from the two zones revealed that the leaf length and leaf width differed significantly between the two zones.

Table 13. Mineral composition of *Artocarpus hirsutus* seeds in midland of Thrissur district.

Fruit size class	Moisture content (%)	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
Big	$46.09^{a}±0.09$	$77.90^{a}±8.14$	$388.14^{a}±2.24$	$2.38^{a}±0.23$	$15.71^{ab}±2.16$
Medium	$46.00^{a}±0.00$	$62.50^{a}±1.93$	$311.60^{b}±2.05$	$1.52^{a}±0.00$	$12.20^{b}±0.05$
Small	$45.57^{a}±0.57$	$74.80^{a}±9.99$	$319.63^{b}±21.71$	$1.69^{a}±0.44$	$16.86^{a}±0.05$
Overall	45.88±0.18	71.73±4.43	339.79±13.69	1.86±0.19	14.92±0.93
F value	0.68^{ns}	1.17^{ns}	11.04^{*}	2.49^{ns}	3.78^{ns}

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

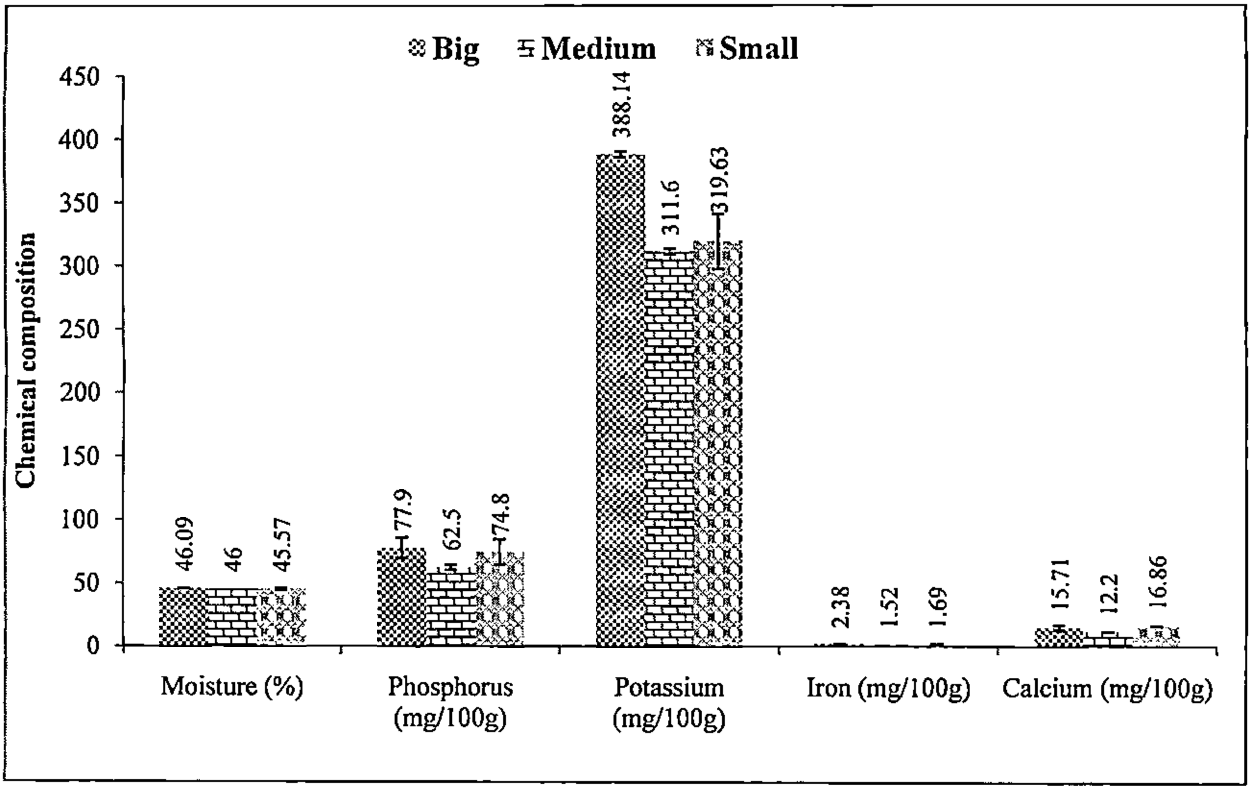


Fig. 11. Mineral composition of *Artocarpus hirsutus* seeds in midland of Thrissur district.

Table 14. Mineral composition of *Artocarpus hirsutus* seeds in lowland of Thrissur district.

Fruit size class	Moisture content (%)	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
Big	$58.23^{a}\pm0.23$	$93.36^{a}\pm12.50$	$339.01^{a}\pm2.03$	$1.40^{a}\pm0.30$	$34.27^{a}\pm0.54$
Medium	$49.04^{c}\pm0.04$	$78.41^{a}\pm9.76$	$336.73^{a}\pm3.36$	$1.49^{a}\pm0.38$	$26.41^{a}\pm4.13$
Small	$56.23^{b}\pm0.23$	$90.66^{a}\pm5.00$	$320.00^{b}\pm0.00$	$1.32^{a}\pm0.10$	$29.06^{a}\pm2.21$
Overall	54.50±1.39	87.48±5.32	331.91±3.20	1.40±0.14	29.91±1.78
F value	630.44^{*}	0.68^{ns}	20.91^{*}	0.09^{ns}	2.14^{ns}

**Significant at 0.05 level*
ns Non significant at 0.05 level
Means followed by same superscript do not differ significantly

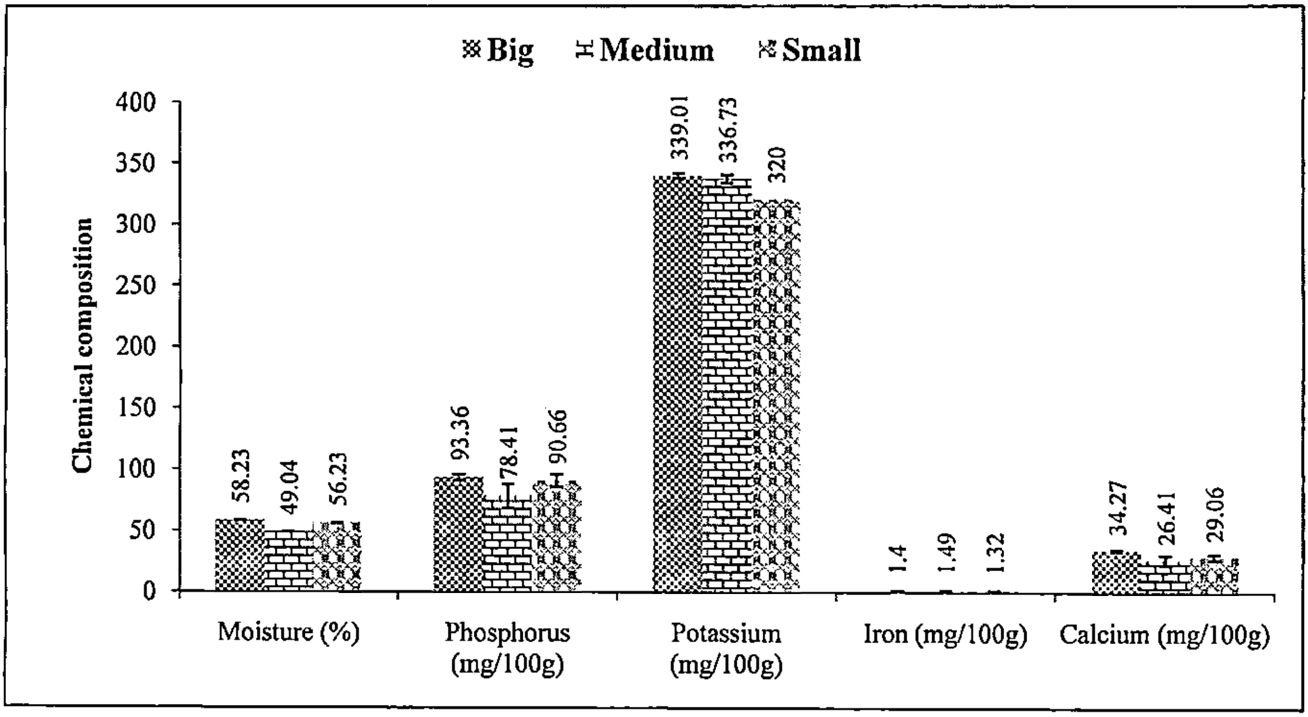


Fig. 12. Mineral composition of *Artocarpus hirsutus* seeds in lowland of Thrissur district.

Table 15. Mean scores for organoleptic evaluation of *Artocarpus hirsutus* fruits from two altitudinal zones of Thrissur district.

Zones	**Appear-ance**	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**
Midland	7.3	7.8	7.3	7.4	6.6	7.7	7.1	7.7
Lowland	8.2	8.2	7.6	7.7	7	7.9	7.9	8.3

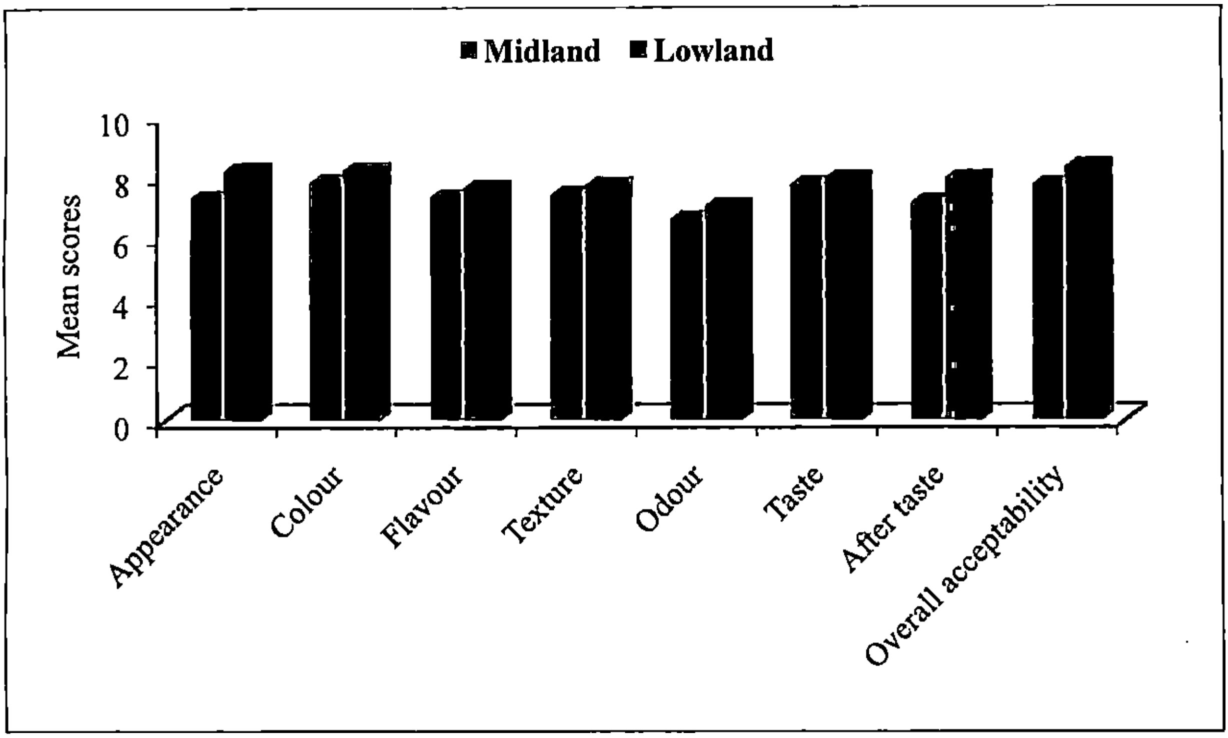


Fig. 13. Mean scores for organoleptic evaluation of *Artocarpus hirsutus* fruits from two altitudinal zones of Thrissur district.

Fruits from lowland recorded higher value for mean leaf length and mean leaf width as 15.86 cm and 10.81 cm respectively (Fig. 14).

Significant variation was observed for physical characteristics of *Artocarpus* fruit between the zones. Maximum mean fruit weight, mean fruit volume and mean fruit length was reported from lowland with the values as 152.43 g, 116.97 cm^3 and 76 mm respectively. However, fruits from midland showed higher value for mean fruit diameter (63.19 mm) as compared to lowland (57.04 mm) (Fig. 15).

For various fruit parameters after ripening, both the zones varied significantly from each other. Maximum values for physical characters of fruits were recorded from lowland. No significant difference was observed for mean core weight of the two zones. Mean fruit weight varied from 88.82 g for midland to 124.57 g for lowland. Significant difference was observed for peel weight between the two zones with lowland showing high mean peel weight 62.97 g. Mean bulb weight varied from lowest value of 22.6 g for midland to highest value of 48.97 g for lowland. Maximum values for mean pulp weight and mean seed weight as reported for lowland were 22.28 g and 24.23 g respectively. Number of seeds per fruit varied from 14.14 to 35.76 for the two zones. Mean core length varied from 36.03 mm to 48.98 mm for midland and lowland respectively. Mean core diameter (18.72 mm), mean stalk length (4.11 cm) and mean stalk weight (0.91 g) for midland were highest (Fig. 16). Proportion of pulp, peel, seed and core varied significantly between midland and lowland. Maximum proportion of pulp (15.49 per cent) and seed (17.87 per cent) were found in fruits of lowland. However, fruits of midland contain higher proportion of peel and core (Fig. 17).

Most of the biochemical parameters did not show significant variation between midland and lowland. Significant variation was observed for titrable acidity and beta carotene in the fruit pulp. Moisture content, total sugar, starch and fibre content in fruits collected from lowland was higher than for midland. Values as reported were 70.16 per cent, 14.89 per cent, 15.29 per cent and 2.11 per cent respectively. On the other hand, fruits of midland contained higher amounts of TSS, titrable acidity, reducing sugar, beta carotene and vitamin C. They were found to be having values as 19.17 ^{o}Brix, 1.27 per cent, 11.94 per cent, 4.3 µg/100g and 5.31 mg/100g respectively (Fig. 18). With regards to mineral content of fruits, no significant variation was observed. The content of different minerals like phosphorus, potassium, iron and calcium in midland and lowland were 45.13 mg/100g and 47.49 mg/100g, 287.12 mg/100g and 368.76 mg/100g, 1.78 mg/100g and 1.16 mg/100g and 15.83 mg/100g and 15.35 mg/100g respectively (Fig. 19).

Potassium and calcium content in the seeds of *Artocarpus hirsutus* fruits showed significant variation between the zones. Seeds of midland reported higher amounts of phosphorus (88.57 mg/100g), potassium (388.63 mg/100g) and iron (2.06 mg/100g) respectively. However, high calcium content (25.1 mg/100g) was noted in seeds from lowland (Fig. 20).

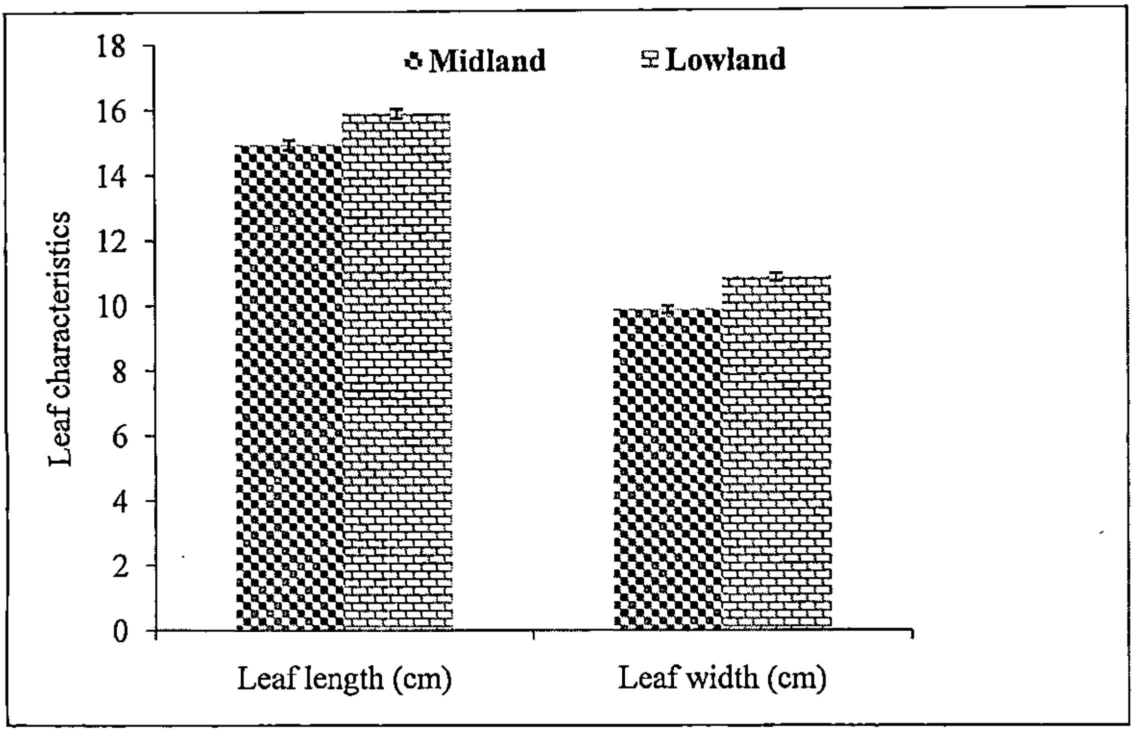


Fig. 14. Morphological characters of *Artocarpus hirsutus* trees in midland and lowland of Thrissur district.

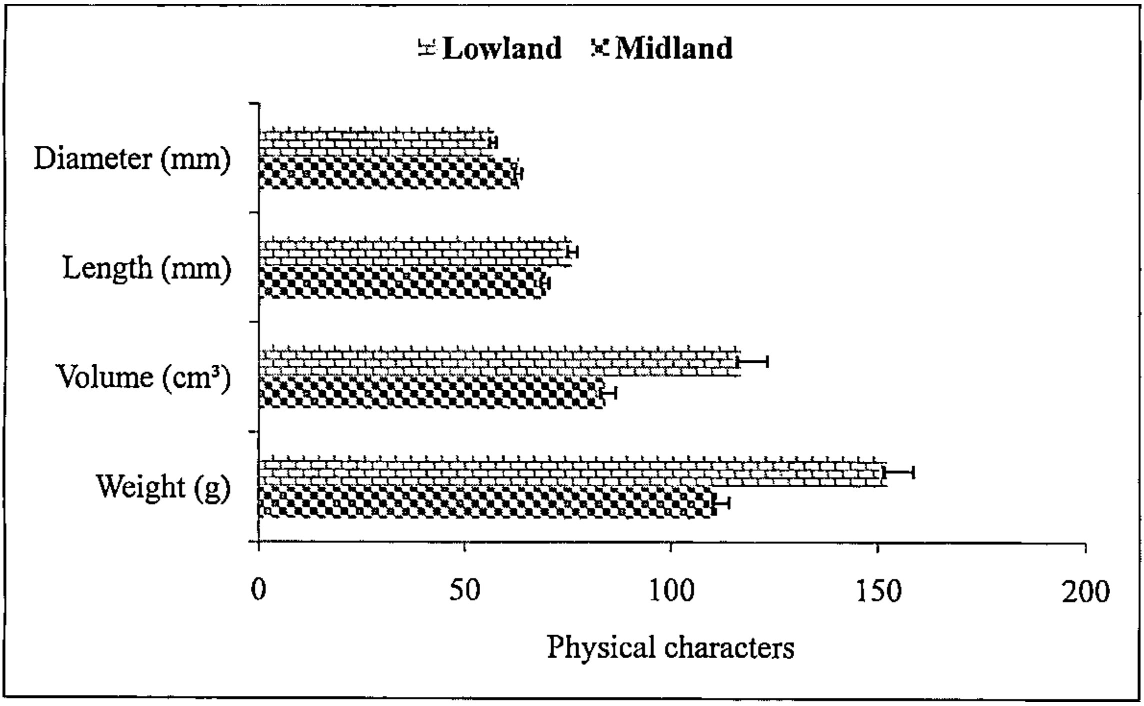


Fig. 15. Physical characters of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

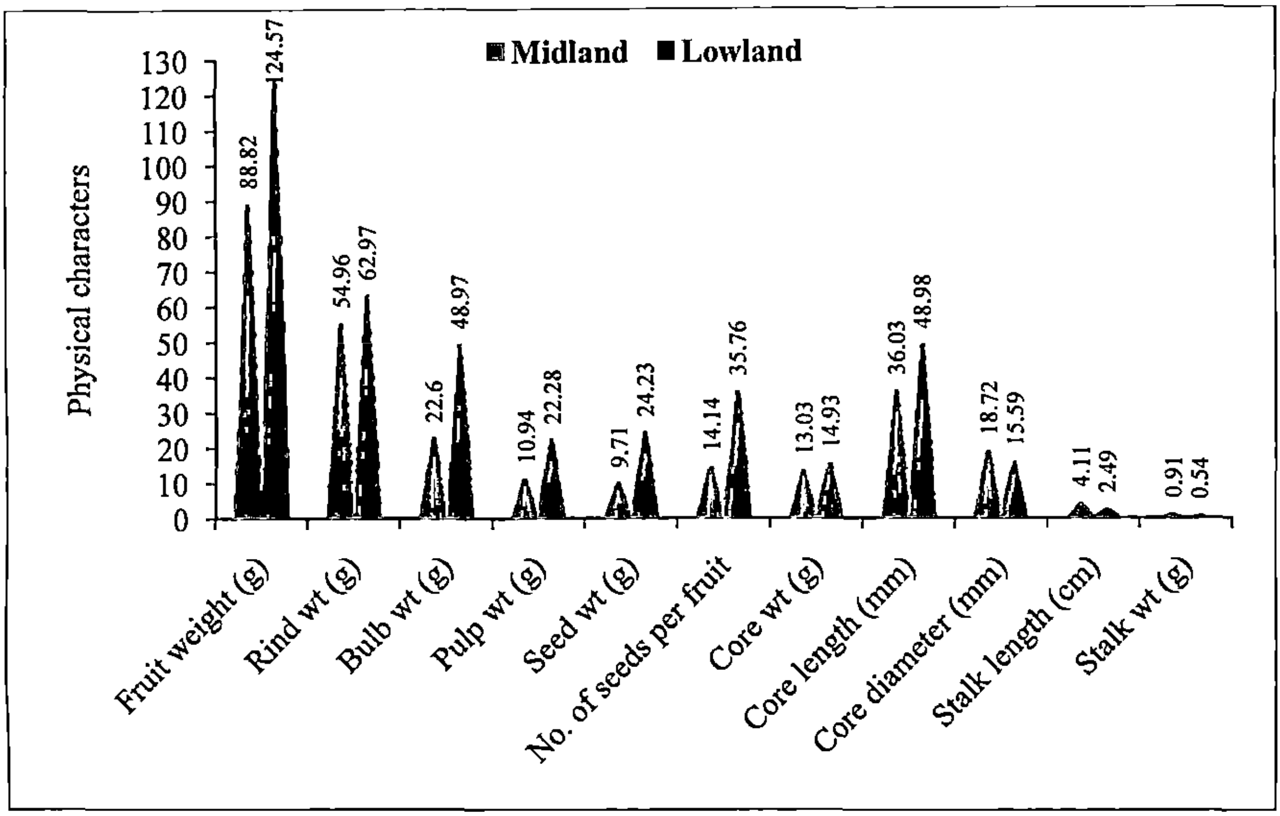


Fig. 16. Physical characteristics of *Artocarpus hirsutus* fruits in midland and lowland of Thrissur district.

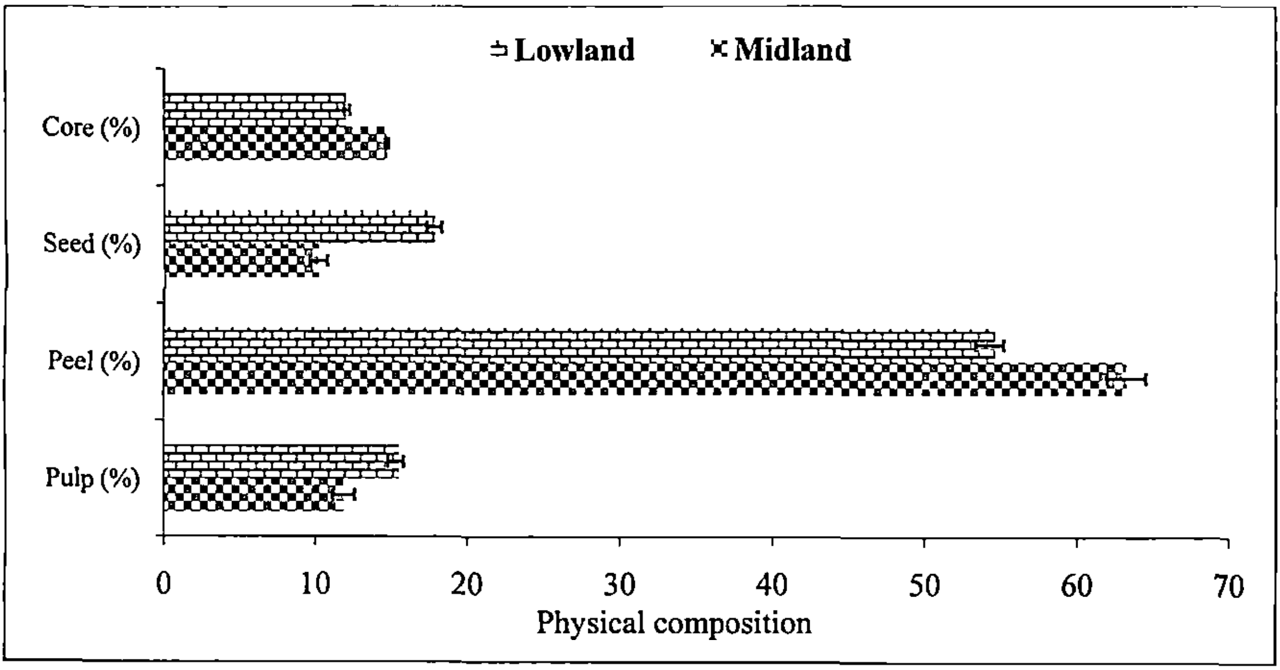


Fig. 17. Physical composition of *Artocarpus hirsutus* fruits in two different zones of Thrissur district.

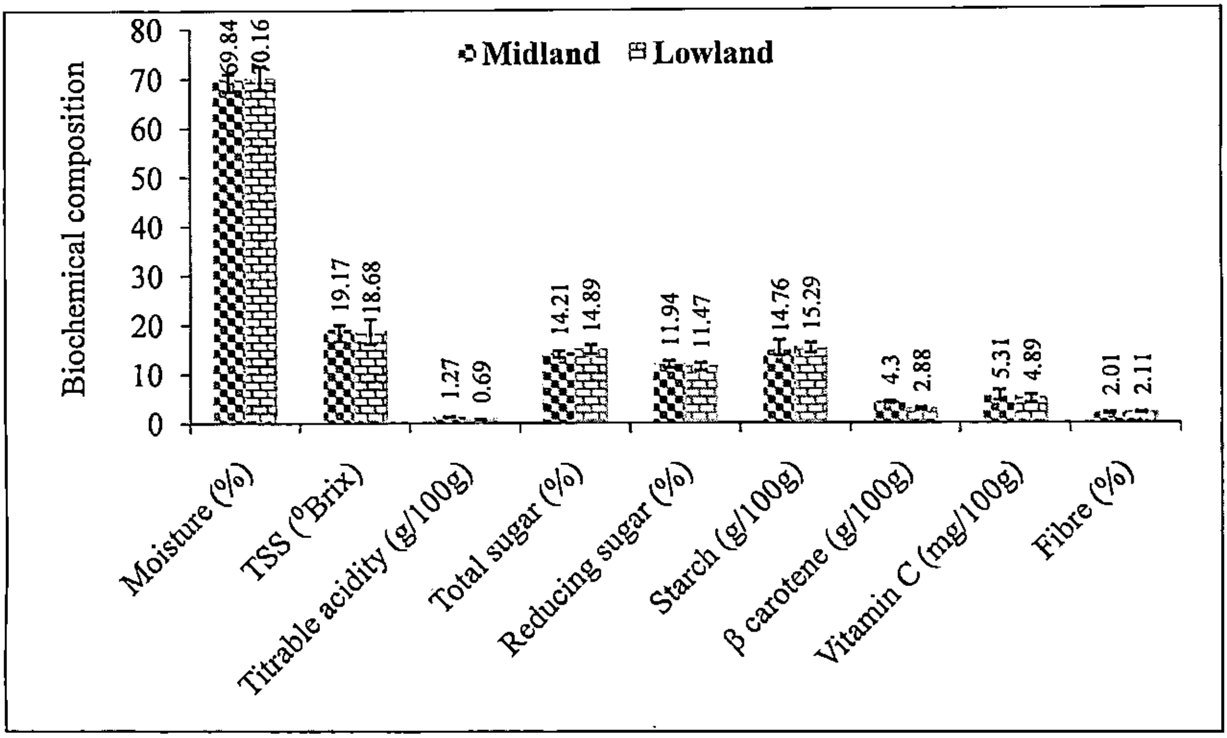


Fig. 18. Biochemical composition of *Artocarpus hirsutus* fruits in two different zones of Thrissur district.

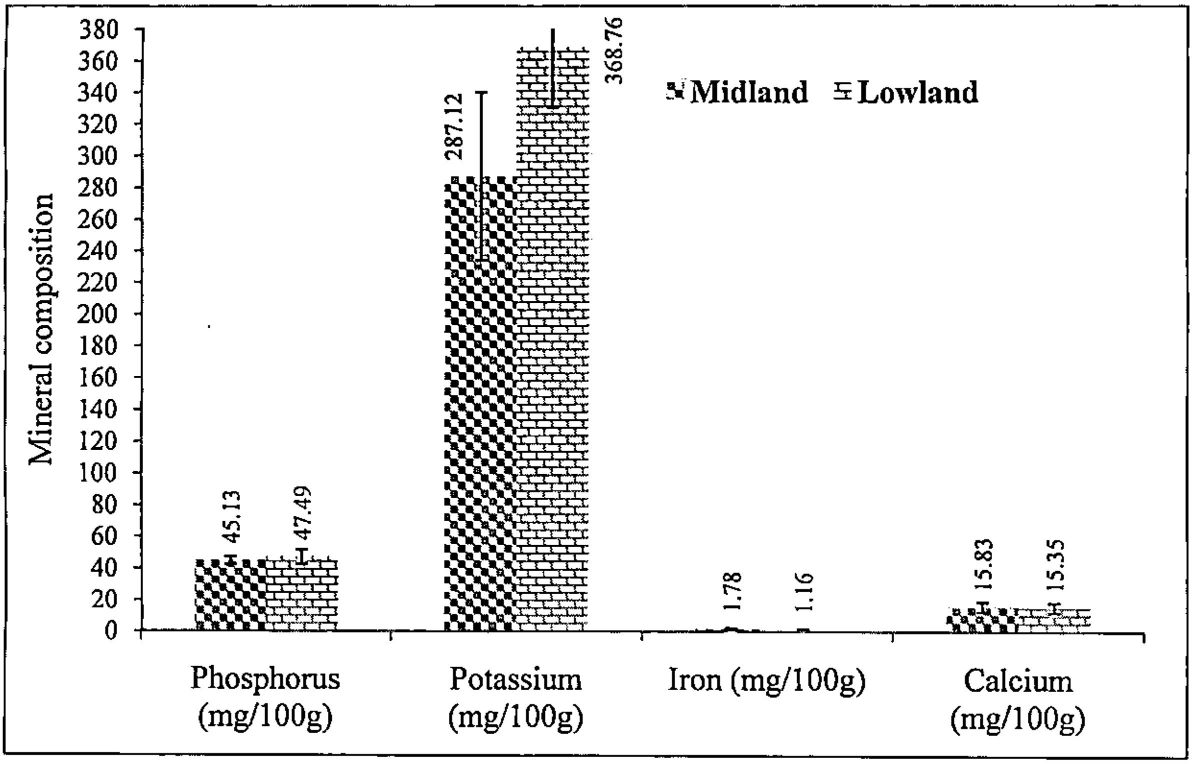


Fig. 19. Mineral composition of *Artocarpus hirsutus* fruits in two different zones of Thrissur district.

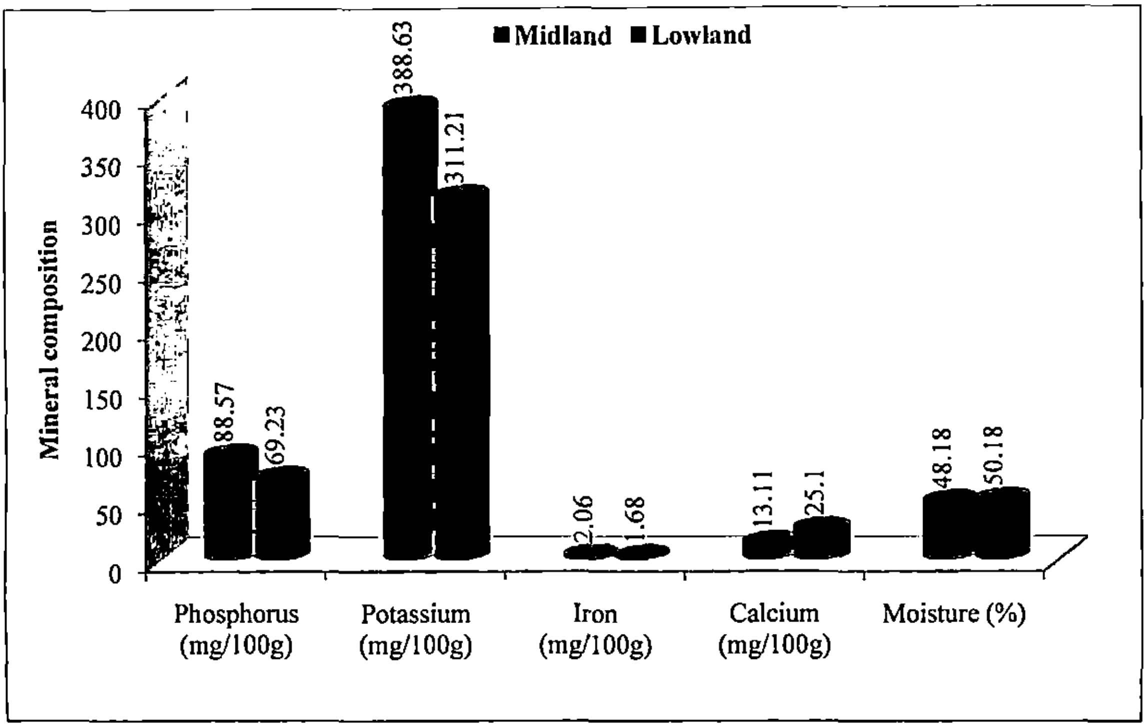


Fig. 20. Mineral composition of seeds of *Artocarpus hirsutus* fruits in two different zones of Thrissur district.

Discussion

5. DISCUSSION

The discussion of the results for the study entitled "Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district" are presented in this chapter.

5.1. Phenology of *Artocarpus hirsutus*

Information on phenology of a species is of utmost importance for plantation development programmes. Apart from this, an insight into reproductive phenology is crucial in understanding forest regeneration dynamics as the pronounced seasonality affects reproductive performances such as seed production, germination, survival and seedling growth (Augspurger, 1981).

Tropical plant communities show conspicuous seasonal pattern in vegetative and reproductive phenologies at both community and species levels (Frankie *et al.*, 1974; Chapman *et al.*, 1999; and Williams-Linera, 2003). According to Borchert (2005), in tropical forests many tree species flush and flower at the same species specific time each year. In *Artocarpus hirsutus*, leaf shedding and leaf flushing continues throughout the year where leaf fall peaks during the dry season and leaf flush before the onset of rainy season (Fig. 2). According to Das and Das (2013) *A. heterophyllus* also shows continuous leaf fall and continuous flushing. Similar leafing phenology has been reported in *Ficus fulva* and *Artocarpus altilis* (Harrison *et al.*, 2000; and Ragone, 2006). Results obtained in this work corroborate the findings of Reich (1995); and Sundarapandian *et al.* (2005) on the evergreen species of tropical forest. In evergreen species, peak of leaf flushing towards the end of dry season and before the onset of rains may be attributed to high temperature whereas peak period of leaf senescence during dry season may be adopted as a mechanism to avoid water stress (Shukla and Ramakrishnan, 1982; and Nanda *et al.*, 2011).

In evergreen species there occurs a synchronization of flowering with dry season as trees are said to flower during stress period (Richards, 1952). Flowering in *Artocarpus hirsutus* starts from November and continues till February (Fig. 2). It shows a single flowering peak every year. These findings are in agreement with those reported in *Artocarpus hirsutus*, *A. heterophyllus* and *A. altilis* (Falcao *et al.*, 2001; and Troup and Bor, 2009). Dry season flowering can be attributed to attract the pollinators as insect activity is greatest in the months with dry periods (Janzen, 1967; Kaul *et al.*, 1986; and Schaik, 1986).

In majority of evergreen species, fruit ripening is observed close to the onset of rainy season in order to enhance dispersal, escape predation and avoid pathogen infection (Prasad and Hegde, 1986). In the present study, it was found that flowering is followed by fruiting that continues till May (Fig. 2). Flowering and fruiting shows a seasonal pattern. Occurrence of seasonal fruiting pattern in tropical forests has been reported by Lieberman (1982). Similar observations have been noted in *Artocarpus spp.* (Troup and Bor, 2009). Like flowering, fruiting also peaked during dry season in the tropical forests (Gopakumar, 1994). Fruiting prior to rainy season can be attributed to provide favourable germination conditions to the seeds (Bhat, 1992).

5.2. Physical characteristics of *Artocarpus hirsutus* trees

Artocarpus hirsutus is a tall evergreen tree, attaining a height of 45.73 m and a girth of 4.57m or more, with a straight clean stem and dense foliage (Troup and Bor, 2009). Mean girth and mean height for the trees in midland was reported to be 1.41 m and 16.32 m respectively while in lowland it was found to be 1.22 m and 19.50 m respectively (Table 1). In *A. heterophyllus, A. altilis* and *A. mariannensis*, girth and height have been found to occurring in almost same range (Morton, 1987; Elevitch and Manner, 2006; Haq, 2006; Ragone and Manner, 2006; and Ragone, 2006).

Leaves are elliptic, rhomboid or ovate, pinnatified, and rounded at base with petioles and nerves densely tawny hispid (CSIR, 1985; and Pascal and Ramesh, 1987). Mean leaf length and leaf breadth for the selected trees in midland was 14.91 cm and 9.83 cm respectively and in lowland, it was 15.86 cm and 10.81 cm respectively (Table 1). In *Artocarpus hirsutus,* leaf length and leaf breadth ranges from 10 cm to 25 cm and 5 cm to 15 cm respectively (CSIR, 1985).

5.3. Physical Characters of *Artocarpus hirsutus* fruits

Physical parameters of fruits are important indicators of their maturation, internal and external quality and act as decisive factors for accomplishment of market demands (Cavalcante *et al.*, 2012).

Quality attributes like fruit shape and size are important in order to properly design machines for harvesting, processing and storage (Duckworth, 1966). Mean values of fruit weight for the two zones varied as 111.15 g to 152.43 g (Table 2). Findings of this work were more or less comparable with those reported in *Artocarpus lakoocha* (Joshee *et al.*, 2002). However, fruits of *A. heterophyllus* and *A. odoratissimus* are heavier than fruits of *A. hirsutus* (Morton, 1987 and Tang *et al.*, 2013). Fruit size in *Adansonia digitata, Averrhoa carambola* and *Anona sp.* also lies in the same range (Nour *et al.*, 1980; and Pathak and Chakraborthy, 2006). Mean fruit volume in the two zones viz., midland and lowland was 83.94 cm^3 and 116.97 cm^3 respectively (Table 2). Similarly, in *Punica granatum* cultivars, fruit volume was found to be varying from 99.41 cm^3 to 547.88 cm^3 (Akbarpour *et al.*, 2009).

A positive and significant correlation between fruit weight, volume, length and diameter obtained in this study, indicates the possibility of selecting the fruits based on size for further processing. Mean fruit length for the two zones varied as 69.57 mm and 76 mm respectively (Table 2). Fruit of *Artocarpus hirsutus* is about the size of a lemon with the length of 50 mm (CSIR, 1985). However, fruit length in *A. heterophyllus* and *A. odoratissimus* are reported to be 42.72 cm and 16 cm respectively (Pathak and Chakraborthy, 2006; and Coronel, 1983). For midland and lowland, mean fruit diameter ranged from 57.04 mm to 63.19 mm (Table 2). However, fruit diameter of lower than 40 mm has been mentioned by CSIR (1985) for the same species. Results obtained for fruit diameter in this study were closely related to those obtained by Joshee *et al.* (2002) in *Artocarpus lakoocha* where it ranges from 50 mm to 120 mm. In *A. heterophyllus* and *A. odoratissimus* fruit diameter is reported to be 36.96 cm and 13 cm respectively (Pathak and Chakraborthy, 2006; and Coronel, 1983).

Higher fruit weight, pulp weight and low peel weight are desirable attributes for processing. Mean peel weight, bulb weight, pulp weight and seed weight in the fruit were found to be occurring in the range from 54.96 g to 62.97 g, 22.60 g to 48.97 g, 10.94 g to 22.28 g and 9.71 g to 24.23 g respectively (Table 3). However, higher pulp weight, peel weight and seed weight has been reported by Pathak and Chakraborthy (2006) in *Artocarpus heterophyllus* as 2025 g, 2775 g and 588.25 g respectively. Pulp weight and seed weight in other tropical fruits have been reported to be 67.85 g and 4.38 g in sapota, 3.91 g and 1.42 g in jamun, 103.16 g and 11.53 g in custard apple and 112.50 g and 1.32 g in carambola respectively (Pathak and

Chakraborthy, 2006). Mean number of seeds per fruit was found to be 14.14 in midland and 35.76 in lowland (Table 3). These values were in consonance with those of Joshee *et al.* (2002) who concluded that single fruit of *Artocarpus lakoocha* contains 20-30 seeds. In contrast, *A. heterophyllus* may contain about 100 to 150 seeds per fruit (Morton, 1987).

Higher pulp recovery should be obtained while going for processing and value addition of a fruit. Mean percentage of pulp, peel and seed as reported ranged from 11.87 per cent to 15.49 per cent, 54.66 per cent to 63.28 per cent and 10.18 per cent to 17.87 per cent respectively (Table 5, Fig. 5 and 6). From the findings, it was clear that more the pulp and seed weight, lesser is the peel weight and vice-versa. However, pulp, peel and seed percentage in *Artocarpus heterophyllus* has been reported to be 37.07 per cent, 47.16 per cent and 9.40 per cent (Azad, 2000). In *A. odoratissimus*, peel, core, pulp and seed constitutes about 48 per cent, 13 per cent, 29 per cent and 10 per cent of the total fruit respectively (Tang *et al.*, 2013). Edible portion in *A. integer* has been reported to be 22 per cent (Dignan *et al.*, 1994 and Wenkam, 1990). Although the pulp and seed constitutes less proportion of whole fruit compared to peel, but it can be compensated with the yield of large quantities of fruits from a single tree.

5.3.1. Correlation and Regression

Correlation matrix revealed significant and positive relation between physical parameters like fruit weight, volume, length and diameter in both midland and lowland (Table 4). Positive and significant correlation was also obtained for various quality parameters like fruit length, fruit diameter, fruit weight etc. in *Artocarpus heterophyllus* by Senjam *et al.* (2012). Significant correlation was obtained for fruit and kernels of *Sapindus mukrossii* (Guleria *et al.*, 2011). High correlation could be attributed to close association of these physical parameters (Hossain and Abdul, 2007). Linear regressions were obtained for physical parameters of fruit in both the zones with significant r^2 values (Fig. 3 and 4). These regressions can be useful in predicting rind weight, pulp weight, bulb weight and fruit volume based on fruit weight. Similarly, based on fruit length; fruit weight and fruit volume can be determined. Regression models have been developed for fruits of *Terminalia indica* (Sood *et al.*, 2009) and *Vitellaria paradoxa* (Nyarko *et al.*, 2012).

5.4. Biochemical composition of fruits

Suitability of fruits for value addition depends upon their physico-chemical attributes. Biochemical composition determines the utilization potential of a fruit. Different products are prepared based on the proportion of biochemical contents present in a particular fruit (Cavalcante *et al.*, 2012).

Water content of a fruit indicates its perishability and is also important in determining the nutritive value of food sample (Boamponsem *et al.*, 2013). Mean moisture content in the fruits ranged from 69.84 per cent to 70.16 per cent (Table 6). Observed values closely agreed to that reported in *Artocarpus heterophyllus* (Morton, 1987; and Love and Paull, 2011) and *A. odoratissimus* (Tang *et al.*, 2013). *A. altilis* and *A. integer* have been reported to contain 62 per cent and 67 per cent moisture content respectively (Dignan *et al.*, 1994 and Wenkam, 1990).

Total soluble solids mainly include sugars and minerals. Mean total soluble solids were found to be ranging from 18.68 °Brix to 19.17 °Brix (Table 6). Total soluble solids in *Artocarpus heterophyllus* fruit were found to be lower as 17.63 °Brix (Pathak and Chakraborthy, 2006). Almost similar values for TSS have been reported in custard apple, carambola and sapota (Pathak and Chakraborthy, 2006). Higher brix indicates better nutrition and higher mineral content indicates an increase in vitamins content as well (Boampson *et al.*, 2013). Total soluble solids acidity ratio is a useful parameter for deciding its use for preparation of different products (Yadav *et al.*, 2006). According to Patil *et al.* (2009), high total soluble solids and low acidity can be an ideal combination for product development like syrup.

Acidity imparts sour taste to fruits and has a governing role in determining likeness of a fruit (Markose, 2008). Acidity is directly related to pH of a fruit. Mean titrable acidity varied from 0.69 g/100g to 1.27 g/100g (Table 6). Higher values (0.69 g/100g to 5.26 g/100g) have been reported in *Artocarpus heterophyllus* (Muthulakshmi, 2003). For other fruits like custard apple, jamun, sapota, bael etc., acidity was reported to be lower (Pathak and Chakraborthy, 2006). However, these findings were in accordance with those reported by Sood *et al.* (2010) and Narain *et al.* (2001) in *Berberis lyceum* and *Averrhoa carambola* respectively.

Apart from their nutritional value, sugars have other functions in foods. They function as flavor producing agents, texturizing agents and sweeteners (Manay and Shadaksharaswamy, 2001). Data pertaining to mean total sugars revealed that it was in the range of 14.21 per cent to 14.99 per cent (Table 6). Similar findings have been observed in *Artocarpus heterophyllus* by Pathak and Chakraborthy (2006), Goswami *et al.* (2011) and Muthulakshmi (2003). The results obtained in this work also corroborates with the results obtained in other tropical species like custard apple, jamun, sapota and cashew apple (Pathak and Chakraborthy, 2006; and Suman, 2006). Total sugar obtained in this fruit was found to be higher than that reported in wild fruits like *Alangium salvifolium, Antidesma ghaesembilla, Baccaurea courtallensis* etc. (Nazarudeen, 2010). Higher sugar acid ratio of jamun highlighted its feasibility in preparation of beverages (Hema, 1997).

Reducing sugar content in food is partly responsible for browning as a result of Maillard reaction. However, this reaction does not pose any problem in those samples with low level of reducing sugars (Adewusi *et al.*, 1995). Perusal of data analysis revealed reducing sugars to be varying from 11.47 to 11.94 per cent (Table 6). However compared to the reducing sugar content in *Artocarpus heterophyllus* (1.63 to 5.23 per cent) higher values were reported in the present study (Muthulakshmi, 2003; and Pathak and Chakraborty, 2006). High reducing sugar in this fruit can be attributed to the presence of low amounts of non-reducing sugars compared to other fruits.

Starch provides a reserve energy source in plants and supply energy in nutrition (Dauthy, 1995). It contributes to the texture and sensory properties of the processed foods and thus offers a scope to develop a variety of fabricated food products having varied texture and mouthfeel (Tharanathan, 2005). For starch content, mean values as reported were found to be varying from 14.76 per cent to15.30 per cent (Table 6). However, these results were found to be higher than the findings of Goswami *et al.* (2011) who mentioned that starch content ranged from 6.11 to 8.34 per cent in different varieties of *Artocarpus heterophyllus*. In *A. altilis* it has been found to be 18.5 per cent on dry weight basis (Rincon and Padilla, 2004).

Among the well known phytochemicals in fruits, beta carotene and lycopene are the most powerful antioxidants (Sarma, 2003). Mean beta carotene content of the fruits ranged from 2.88µg/100g to 4.30 µg/100g (Table 6). According to Ragone and Cavaletto (2006) carotene content in cultivars of *Artocarpus altilis* ranged from 8.3 to 19.8 µg/100g, higher than the findings of this study. A wide difference in carotene content of these fruits may be attributed to the predominance of other pigments which need to be investigated further.

Vitamin C is very important in the daily food as it has a variety of roles in life processes (Nazarudeen, 2010). In food industry, it has a dual role i. e. it acts as a nutrient as well as a food antioxidant and product improver (Johnson and Mergens, 1991). Data on mean vitamin C content was 4.89 to 5.31 mg/100g (Table 6). The present results were closely related to the findings of Pathak and Chakraborthy (2006) and Mannan *et al.* (2005) in *Artocarpus heterophyllus*. Reported values are not comparable with the high amount of vitamin C in *A. altilis* (21 mg/100g), *Annona muricata* (13.59 to 64.70 mg/100g), *Tamilnadia uliginosa* (62.19 mg/100g), *Alangium salvifolium* (117.8 mg/100g), *Antidesma ghaesembilla* (111.2 mg/100g) (CSIR, 1985; Patil *et al.*, 2009; and Nazarudeen, 2010). The TSS has been found to be negatively and significantly correlated with the vitamin C content. Fruits with more TSS have less Vitamin C content (Kishore *et al.*, 2010).

Fibre is known for reducing cholesterol level in the body and hence helps in maintenance of human health (Bello *et al.*, 2008). Mean values for fibre content as observed were 2.01 to 2.12 per cent (Table 6). Similar range of values has been obtained in other species such as *Artocarpus heterophyllus, A. altilis*, and in *A. odoratissimus* (Love and Paull, 2011 and; Dignan *et al.*, 1994 and Wenkam, 1990). However, crude fibre in Saba fruit (13.52 per cent) as noted by Boamponsem *et al.* (2013) and in wild fruits like *Spondias mombin, Dialium guineense* and *Mordii whytii* (0.6 to 11.8 g/100g) as noted by Adepoju (2009) were higher than observed values. Low fibre implies that it can be used in weaning foods as high fibre level in weaning diet can lead to reduced digestibility, vitamin and mineral availability in infants (Eromosele and Eromosele, 1993).

5.5. Mineral composition of fruits

Mineral ions are of prime importance in determining the nutritional value of fruit, major ones being potassium, calcium, and magnesium. The importance of minerals like potassium, calcium, sodium etc. to human health is well known. Required amounts of these elements must be in human diet to pursue a good healthy life (San *et al.*, 2009). Amount of mineral elements present in plants depends to a high degree on the soils abundance, including the intensity of fertilization (Kruczek, 2005).

Phosphorus is needed for bone growth, kidney function and cell growth (Fallon and Enig, 2001). It participates in some of the vital metabolic processes by supplying energy, increase acid neutralization, sugar synthesis resulting in less acidic fruits (Kader, 2008). In the present study, mean phosphorus content of the fruits ranged from 45.13 mg/100g to 47.49 mg/100g (Table 9). Values obtained were in consonance with those in *Artocarpus heterophyllus* and *A. altilis* as reported by Love and Paull, (2011); and Dignan *et al.* (1994) and Wenkam (1990) respectively. Phosphorus content in *Artocarpus lakoocha* as observed by Shajib *et al.* (2013) and in *A. integer* and *A. odoratissimus* as reported by Dignan *et al.* (1994) and Wenkam (1990) were lower than the current findings. Fruits of *Persea americana* showed almost similar values for phosphorus (Arukwe *et al.*, 2012).

Potassium is an important element for synthesis of amino acids and proteins (Malik and Srivastava, 1982). Mean range of value obtained for potassium content in the fruit was 287.35 to 368.76 mg/100g (Table 9). Reported values were close to the range given by Dignan *et al.* (1994) and Wenkam (1990) and Love and Paull (2011) in *Artocarpus heterophyllus*, by Shajib *et al.* (2013) in *A. lakoocha,* by Tang *et al.* (2013) in *A. odoratissimus* and by Dignan *et al.* (1994) and Wenkam (1990) in *A. integer*. Potassium content among the other tropical fruit like shea, was comparable with that of wild jackfruit (Thomas, 2013). However potassium content of this fruit was lower than that of *Ficus racemosa* (1922 mg/100g) as reported by Valvi and Rathod (2011) and *Zizyphus mauritiana* (1865 to 2441 mg/100g) as reported by Nyanga *et al.* (2013) which showed very high values.

Iron assists in the functioning of central nervous system and is an essential trace element for haemoglobin formation (Adeyeye and Otokiti, 1999). Mean iron content ranged from 1.16 to 1.78 mg/100g (Table 9). Lower values have been reported in *Artocarpus heterophyllus* (0.5 mg/100g), *A. lakoocha* (0.77 mg/100g), *A. altilis* (0.26 mg/100g) and *A. odoratissimus* (0.3 to 0.5 mg/100g) respectively (Dignan *et al.*, 1994 and Wenkam, 1990; Love and Paull, 2011; Shajib *et al.*, 2013; and Tang *et al.*, 2013). These readings corroborated with the findings of Nazarudeen (2010) in wild edible fruits of Kerala, Narain *et al.* (2001) in *Averrhoa carambola* and Erturk *et al.* (2006) in chestnut.

Calcium is an essential part of plant cell wall structure and provides for normal transport and retention of other elements as well as strength of plant (Okello, 2010). Calcium content was found to be occurring in the range of 15.35 to 15.83 mg/100g (Table 9). Calcium content reported in the study was lower than that of *Artocarpus heterophyllus*, *A. lakoocha*, *A. altilis* and *A. integer* where it ranges from 22 to 37 mg/100g (Dignan *et al.*, 1994 and Wenkam, 1990 and; Love and Paull, 2011; and Shajib *et al.*, 2013). In some tropical fruits, very high calcium content has been reported such as *Antidesma velutinosum* (325 mg/100g) as noted by Judprasong *et al.* (2013) and in *Tamarindus indica* and *Ziziphus spina christi* (450 mg/100g) as reported by Adekunle and Adenike (2012).

5.6. Mineral composition of seeds

Data pertaining to mineral composition of seeds revealed that moisture content ranged from 48.18 to 50.18 per cent (Table 12). In seeds of *Artocarpus heterophyllus*, moisture content varied from 21.10 to 42.25 per cent (Abedin *et al.*, 2012) and 51.6 to 57.77 per cent (Morton, 1987; and Love and Paull 2011). Seeds of *A. odoratissimus* also contain 31.0 to 55.0 per cent moisture (Tang *et al.*, 2013).

In fruits from the two zones, phosphorus content ranged from 69.23 to 88.57 mg/100g (Table 12). Reported findings were lower than that of *Artocarpus heterophyllus* seeds where phosphorus content was 119.3 to 139 mg/100g (Abedin *et al.*, 2012) and that of *A. altilis* seeds that contains 189 mg/100g of phosphorus (McIntoch and Manchew, 1993). However, lower values have been found in the seeds of *Tamarindus indica* (Yusuf *et al.*, 2007) and *Ziziphus spina christi* (Adekunle and Adenike, 2012). Compared to *Artocarpus hirsutus* pulp, seeds possessed high amounts of phosphorus. Similarly, seeds of *A. heterophyllus* also contained higher phosphorus than the fruit pulp (CSIR, 1985).

Potassium content in the seeds ranged from 311.21 to 388.64 mg/100g (Table 12). The present results were found to be closer to the findings of Bello *et al.* (2008); Tang *et al.* (2013) and; McIntoch and Manchew (1993) in *Artocarpus heterophyllus*, *A. odoratissimus* and *A. camansi* respectively. *Annona muricata* seeds also contains significant amount of potassium (Kimbonguila *et al.*, 2010) which is comparable with the values obtained for wild jackfruit.

Iron content in the seeds was 1.69 to 2.06 mg/100g (Table 12). These were found to be in accordance with that reported in *Artocarpus altilis* (Murai *et al.*, 1958), *A. odoratissimus* (Tang *et al.*, 2013) and *A. heterophyllus* (Love and Paull, 2011). Higher iron content in the seeds of *Tamarindus indica* (75.9 mg/100g) and *Ziziphus spina christi* (58.53 mg/100g) has been reported by Yusuf *et al.* (2007) and Adekunle and Adenike (2012) respectively.

For *Artocarpus hirsutus* seeds, calcium content varied from 13.08 to 25.10 mg/100g (Table 12). However, lower values have been reported in jackfruit by Love and Paull (2011) and in *A. odoratissimus* by Tang *et al.* (2013). Seeds of other species like *Tamarindus indica* and *Persea americana* reported similar values for calcium content as observed by Yusuf *et al.* (2007) and Arukwe *et al.* (2012) respectively. However, seeds of *Annona muricata* reported higher amounts (149 mg/100g) of calcium content (Kimbonguila *et al.*, 2010).

Overall, mineral content in the seeds of *A. hirsutus* fruit recorded higher values compared to the fruit pulp. Perusal of this data analysis highlights the importance of seed for further processing and incorporation into human diet based on its high mineral composition (Yusuf *et al.*, 2007).

5.7. Organoleptic evaluation of fruit

Organoleptic evaluation of the fruit from two zones revealed that overall scores for the fruits collected from lowland were higher than the fruits collected from midlands (Table 15 and Fig. 13). High scores obtained for the fruits collected from lowland may be due to its better appearance, colour and texture. Variations that occur in the contents of chemical compounds may be due to differences in the intensity of solar radiation and temperature ranges that influence the organoleptic characteristics of fruits (Ali *et al.*, 2011; and Siriwoharn *et al.*, 2004).

5.8. Sizewise variation in biochemical and mineral composition

In both the zones, significant variation was observed with respect to most of the biochemical parameters (Table 7 to 8 and Fig. 7 to 8) and mineral parameters of fruits as well as of seeds (Table 10 to 11, Fig. 9 to 10; and Table 13 to 14, Fig.11 to 12) according to size class, with big fruit size class showing maximum values. Differences in biochemical characteristics according to fruit size class can be identified as one of the criteria for preparation of various products. Variation was observed among different size classes of fruits in Malay rose apple (*Syzygium malaccense*) in terms of titrable acidity, total sugars and non-reducing sugar. Based on composition of different fruit size classes, they used big sized fruits for preparation of osmodehydrated products and small sized fruits for pickling (Markose, 2008). Similarly, jamun fruits of smaller types are used in beverage industry as they contain higher amounts of tannin and anthocyanin content (Anon., 1986).

5.9. Comparison between the zones

Leaf characteristics from the two zones revealed that the leaf length and leaf width differed significantly between the two zones (Fig. 14). Higher leaf length and leaf breadth as reported for lowland may be attributed to location and environmental influences. While studying *Artocarpus heterophyllus* germplasm at two different sites, Sarker and Zuberi (2011) also observed that quantitative characters like leaf blade length and breadth showed significantly different values for the studied sites. Wide variation was noticed by Muthulakshmi (2003) at different topographical levels with respect to leaf length and width in *A. heterophyllus*. Similarly, variations have been reported for the leaf parameters (laminar width, petiole and laminar length) of *Vitellaria paradoxa* studied from different zones in Ghana (Nyarko *et al.*, 2012).

Significant variation was observed for physical characteristics of *Artocarpus* fruit between the zones (Fig. 15 and 16). Higher values for physical parameters as reported in lowland was probably due to large fruit size in this zone. Hence, the proportion of pulp, peel and seed was significantly higher in lowland (Fig. 17). Sarker and Zuberi (2011) also reported significant variations among *Artocarpus heterophyllus* germplasms from different sites in terms of fruit parameters such as fruit length and diameter. Similar findings were reported by Muthulakshmi (2003) in jackfruit. According to Goswami *et al.* (2011), variation in the physical characteristics of jackfruit is influenced by location. Sood *et al.* (2009) observed significant variation in the fruits of *Terminalia bellirica* from different geographic sources with respect to physical parameters. Variations have also been reported by Kishore *et al.* (2010) and Iqbal *et al.* (2010) while working on physico-chemical characteristics of fruits of *Citrus reticulata* and Morus species respectively collected from different regions, which may be due to difference in genotypes, climate, fertility status of soils. Thakur *et al.* (2011) also concluded that variability existed for physical parameters (fruit size and weight) of wild pomegranate fruit collected from different districts. Cosmulescu *et al.* (2010) observed that the difference in physical characteristics of *Juglans regia* was caused probably by different agro-climatic conditions and genetic characteristics. This variability in physical characteristics could be utilized for selection of genotypes suitable for plantation and utilization in making different value added products (Sood *et al.*, 2009).

Most of the biochemical parameters and mineral contents of the fruit did not show significant variation between the study zones (Fig. 18 and 19). However, significant variation was observed for titrable acidity and starch content in the fruit pulp. Variation in starch content has been noted by Jagadeesh *et al.* (2007) among *A. heterophyllus* selections. This variation may be due to the difference in the inherent capacity to accumulate starch and amylase activity in the bulb tissues, leading to differences in the rates of hydrolysis of starch of genetically dissimilar jackfruit selections. Similarly, no significant variation was observed by Ali *et al.* (2010) while analyzing the nutritional composition of palmyra palm (*Borassus aethiopum*) fruits collected from different agro-climatic zones. From their study, Thakur *et al.* (2011) also concluded that there was no specific difference for chemical parameters in wild pomegranate collected from different locations, indicating that no single parameter was found dominating at multiple locations. Significant variation was not observed for vitamin C content of *Rubus chamaemorus* fruits collected from two different sites (Jaakkola *et al.*, 2012). As per the opinion of Erturk *et al.* (2006), chemical composition of fruits may vary depending on the source from where the fruits are collected.

Biochemical composition of *Adansonia digitata* parts (pulp, leaves and seeds) did not show significant variation between the studied zones as well as within a particular zone. Rather, results showed that physico-chemical characteristics of the soil have an influence on the nutritive value of different baobab parts. Thus, this information can be used to determine the type and levels of fertilizer application to improve the nutritional value of fruit parts (Assogbadjo *et al.*, 2012).

Perusal of the data analysis revealed that chemical composition of seed between the two zones showed no significant variations (Fig. 20). These results were supported by the findings of Obasuyi and Nwokoro (2006) who also concluded that there was no significant difference between different locations for physical and chemical characters of *Artocarpus altilis* seed.

Artocarpus hirsutus is a tall, evergreen tree producing about 200 fruits per tree. Although the fruit size of *Artocarpus hirsutus* is small as compared to the cultivated jackfruit. Analysis of biochemical and mineral composition revealed that this fruit ranked almost equal to *Artocarpus heterophyllus* for most of the parameters studied. Total soluble solids and starch content were reported to be higher in this fruit. Higher amount of nutrients in this fruit makes it a potential contributor towards balanced diet. Underutilized fruits have tremendous potential for introducing a variety of new products of commercial and nutritional importance and in turn finding their uses in human diet for high nutritive value (Hiremath *et al.*, 2006). Therefore, consumption of this fruit needs to be promoted through value addition as it can contribute to the income as well as diet of rural people.

Summary

6. SUMMARY

The project entitled "Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district" was conducted to study the phenology of *Artocarpus hirsutus* and also to evaluate physico-chemical characteristics of the fruit in the two altitudinal zones of Thrissur district. The results obtained from the experiments are summarized in this chapter.

1. In *Artocarpus hirsutus,* leaf shedding and leaf flushing continues throughout the year where leaf fall peaks during the dry season and leaf flush during rainy season. Flowering starts from November and continues till February. Flowering is followed by fruiting that continues till May–June. Flowering and fruiting shows a seasonal pattern.

2. Mean girth and mean height for the trees in midland were reported to be 1.41 m and 16.32 m respectively while in lowland it was found to be 1.22 m and 19.50 m respectively. Mean leaf length and leaf breadth for the selected trees in midland were 14.91 cm and 9.83 cm respectively and in lowland values as recorded were 15.86 cm and 10.81 cm respectively.

3. Mean fruit weight in the study zones varied as 111.15 g to 152.43 g. Mean fruit volume was 83.94 cm^3 in midland and 116.97 cm^3 in lowland respectively. Mean fruit length in the study zones as observed was 69.57 mm and 76 mm respectively. For midland and lowland, mean fruit diameter was 63.19 mm and 57.04 mm respectively. Mean peel weight, bulb weight, pulp weight and seed weight of the fruit from the respective zones were found to be occurring in the range of 54.96 g to 62.97 g, 22.60 g to 48.97 g, 10.94 g to 22.28 g and 9.71 g to 24.23 g respectively. Mean number of seeds per fruit was found to be 14.14 in midland and 35.76 in lowland. Mean percentage of pulp, peel, seed and core as recorded in the two zones ranged from 11.87 per cent to 15.49 per cent, 54.66 per cent to 63.28 per cent, 10.18 per cent to 17.87 per cent and 11.98 per cent to 14.67 per cent respectively. Correlation matrix revealed significant and positive relation between physical parameters like fruit weight, volume, length and diameter in both midland and lowland. Linear regressions were obtained for physical parameters of fruit in both the zones with significant r^2 values.

4. Biochemical analysis of *Artocarpus hirsutus* fruits from the two zones revealed that mean moisture content, total soluble solids, titrable acidity, total sugar, reducing sugar, starch, fibre, beta carotene and vitamin C content were found to be ranging from 69.84 per cent to 70.16 per cent, 18.68 ^{0}Brix to 19.17 ^{0}Brix, 0.69 per cent to 1.27 per cent, 14.21 per cent to 14.9 per cent, 11.47 per cent to 11.94 per cent, 14.76 per cent to 15.30 per cent, 2.01 per cent to 2.12 per cent, 2.88 μg/100g to 4.30 μg/100g and 4.89 mg/100g to 5.31 mg/100g and respectively.

5. Mineral analysis of fruit collected from the respective zones revealed that mean phosphorus, potassium, iron and calcium content ranged from 45.13 mg/100g to 47.49 mg/100g, 287.35 mg/100g to 368.76 mg/100g, 1.16 mg/100g to 1.78 mg/100g and 15.35 mg/100g to 15.83 mg/100g respectively.

6. Data pertaining to chemical composition of seeds revealed that moisture content, phosphorus, potassium, iron and calcium content varied from 48.18 per cent to 50.18 per cent, 69.23 mg/100g to 88.57 mg/100g, 311.21 mg/100g to 388.64 mg/100g, 1.69 mg/100g to 2.06 mg/100g and 13.08 mg/100g to 25.10 mg/100g respectively. Overall, mineral content in seeds were found to be higher than the fruit pulp.

7. Significant variation was observed with respect to most of the biochemical and mineral constituents of the fruits as well as seeds according to fruit size class with bigger fruits showing maximum values.

8. Organoleptic evaluation of fruits from the two zones revealed that overall scores for fruits collected from lowland were higher than that of the fruits collected from midland.

9. Leaf characteristics from the two zones revealed that the leaf length and leaf width differed significantly between the two zones with lowland showing higher values. Significant variation was observed for physical characteristics of *Artocarpus* fruit between the zones. Higher values for physical parameters as reported in lowland was probably due to large fruit size in this zone. Most of the biochemical and mineral constituents of the fruit did not show significant variation between the study zones. With regards to chemical composition of seeds, potassium and calcium content in the seeds from the two zones showed significant variations.

References

REFERENCES

Abedin, M. S., Nuruddin, M. M., Ahmed, K. U., and Hossain, A. 2012. Nutritive compositions of locally available jackfruit seeds (*Artocarpus heterophyllus*) in Bangladesh. *Int. J. Biosciences* 2(8): 1–7.

Adekunle, A. I. and Adenike, J. O. 2012. Comparative analysis of proximate, minerals and functional properties of *Tamarindus indica* pulp and *Ziziphus spina christi* fruit and seed. *Greener J. Agric. Sci.* 2(1): 21–25.

Adepoju, O. T. 2009. Proximate composition and micronutrient potentials of three locally available wild fruits in Nigeria. *Afr. J. Agric. Res.* 4(9): 887–892.

*Adewusi, S. R. A., Udio, A. J., and Osuntogun, B. A. 1995. Studies on the carbohydrate content of breadfruit (*Artocarpus communis* Forst) from South-western Nigeria. *Starch Nutr.* 8S: 289–294.

*Adeyeye, E. I. and Otokiti, M. K. O. 1999. Proximate composition and some nutritionally valuable minerals of two varieties of *Capsicum annum* (Bell and Cherry peppers). *Discovery and Innovation,* 11: 75–81.

Ajayi, I. A. 2008. Comparative study of the chemical composition and mineral element content of *Artocarpus heterophyllus* and *Treculia africana* seeds and seed oils. *Bioresource Technol.* 99(11): 5125–5129.

Akbarpour, V., Hemmati, K., and Sharifani, M. 2009. Physical and chemical properties of pomegranate (*Punica granatum* L.) fruit in maturation stage. *American-Eurasian J. Agric. Environ. Sci.* 6(4): 411–416.

*Alabi, D. A. 1987. Proximate analysis of food and mineral contents of eleven cultivars of okra (*Abelmoschus esculentus* (L) Moench). In: *Proceedings of Horticulture Society Nigeria*, 9: 75–83.

Alabi, D. A. and Alausa, A. A. 2006. Evaluation of the mineral nutrients and organic food contents of the seeds of *Lablab purpureus*, *Leucaena leucocephala* and *Mucuna utilis* for domestic consumption and industrial utilization. *Wld. J. Agric. Sciences* 2(1): 115–118.

Ali, A., Alhadji, D., Tchiegang, C., and Saïdou, C. 2010. Physico-chemical properties of palmyra palm (*Borassus aethiopum* Mart.) fruits from Northern Cameroon. *Afr. J. Food Sci.* 4(3): 115–119.

*Ali, L., Sevensson, B., Alsanius, B. W., and Olsson, M. E. 2011. Late season harvest and storage of *Rubus* berries- major antioxidant and sugar levels. *Scientia Horticulturae* 129(3): 376–381.

*Anonymous, 1986. *Research highlights.* ICAR, New Delhi, 27p.

A.O.A.C. 1980. *Official and Tentative Methods of Analysis*. Thirteenth edition. Association of Official Analytical Chemists, Washington, D. C., 1218p.

Arukwe, U., Amadi, B. A., Duru, M. K. C., Agomuo, E. N., Adindu, E. A., Odika, P. C., Lele, K. C., Egejuru, L., and Anudike, J. 2012. Chemical composition of *Persea americana* leaf, fruit and seed. *IJRRAS* 11(2): 346–349.

Assogbadjo, A. E., Chadare, F. J., Kakai, R. G., Fandohan, B., and Baidu–Forson, J. J. 2012. Variation in biochemical composition of baobab (*Adansonia digitata*) pulp, leaves and seeds in relation to soil types and tree provenances. *Agric., Ecosystems Environ.* 157: 94–99.

Augspurger, C. K. 1981. Reproductive synchrony of a tropical shrub: experimental studies on effects of pollinator and seed predators on *Hybanthus pruniformis* (Vioraceae). *Ecol.* 62: 775–788.

*Azad, A. K. 2000. Genetic diversity of jackfruit in Bangladesh and development of propagation methods. Ph.D. Thesis, University of Southampton, U.K.

Bajpai, O., Kumar, A., Mishra, A. K., Sahu, N., Behera, S. K., and Chaudhary, L. B. 2012. Phenological study of two dominant tree species in tropical moist deciduous forest from the Northern India. *Int. J. Bot.* 8: 66–72.

Baldwin, E., Manthey, J. A., Luzio, G., Goodner, K., Plotto, A., Mahattanatawee, K., and Gmitter, F. 2008. Healthful and nutritional components in select Florida tropical fruits. In: *Proceedings of the tropical fruits in human nutrition and health conference*; 8–11 November, 2008–2009; Gold coast Australia, pp. 60–66.

Ballestrini, C., Tezara, W., and Herrera, A. 2011. Environmental drivers of leaf phenology in trees of the tropical species *Ficus obtusifolia*. *Brazilian Soc. Plant Physiol.* 23(2): 113–122.

Bello, M. O., Falade, O. S., Adewusi, S. R. A., and Olawore, N. O. 2008. Studies on the chemical compositions and anti nutrients of some lesser known Nigeria fruits. *Afr. J. Biotech.* 7(21): 3972–3979.

Bentos, T. V., Mesquita, R. C. G., and Williamson, G. B. 2008. Reproductive phenology of Central Amazon pioneer trees. *Trop. Conserv. Sci.* 1(3): 186–203.

Beyer, M., Hahn, R., Peschel, S., and Harz, M. 2002. Analysing fruit shape in sweet cherry (*Prunus avium* L.). *Scientia Hort.* 96: 139–150.

Bhanu, M. U., Melanta, K. R., and Gowda, A. P. M. 2006. Developmental changes during growth and maturation in few elite jackfruit (*Artocarpus heterophyllus* Lam.) clones. *J. Asian Hort.* 2(3): 176–181.

Bhasker, B. and Shantaram, M. 2013. Morphological and biochemical characteristics of *Averrhoa* fruits. *Int. J. Pharmaceutical Chem. Biological Sciences* 3(3): 924–928.

Bhat, D. M. 1992. Phenology of tree species of tropical moist forest of Uttara Kannada district, Karnataka. *J. Biosci.* 17(3): 325–352.

Bhat, D. M. and Murali, K. S. 2001. Phenology of understorey species of tropical moist forest of Western Ghats region of Uttara Kannada district in South India. *Curr. Sci.* 81(7): 799–805.

Boamponsem, G. A., Johnson, F. S., Mahunu, G. K., and Awiniboya, S. F. 2013. Determination of biochemical composition of *Saba senegalensis* (Saba fruit). *Asian J. Plant Sci. Res.* 3(1): 31–36.

Bora, P. S., Narain, N., Holschuh, H. J., and Vasconcelos, M. A. da S. 1991. Changes in physical and chemical composition during maturation of yellow mombin (*Spondias mombin*) fruits. *Food Chem.* 41(3): 341–348.

Borchert, R. 2005. The phenology of tropical trees and its environmental control. Available: http://www.biology.ku.edu/tropical_tree_phenology/index.html accessed [21 March 2013]

Cardoso, F. C. G., Marques, R., Botosso, P. C., and Marques, M. C. M. 2012. Stem growth and phenology of two tropical trees in contrasting soil conditions. *Plant Soil* 354: 269–281.

Cavalcante, I. H. L., Cavalcante, L. F., Miranda, J. M. de Sousa, and Martins, A. B. G. 2012. Physical and Chemical Characteristics of Tropical and Non-Conventional Fruits. In: Valdez, B. (ed.) *Food Industrial Processes - Methods and Equipment*. In Tech Publishers 418p.

Chandrashekara, U. M. and Sankar, S. 2004. Influence of tree canopy architecture and management regimes on growth and yield of undercrops in homegarden agroforestry systems in Kerala. Final Technical Report. KFRI, Peechi, Thrissur, Kerala. 34p.

Chapman, C. A., Wrangham, R. W., Chapman, L. J., Kennard, D. K., and Zanne, A. E. 1999. Fruit and flower phenology at two sites in Kibale, National Park, Uganda. *J. Trop. Ecol.* 15: 189–211.

Chopra, S. L. and Kanwar, J. S. 1978. *Analytical Agricultural Chemistry.* Kalyani Publishers, Ludhiana, 178p.

Clarke, P. J. and Myerscough, P. J. 1991. Floral biology and reproductive phenology *Avicennia marina* in South-eastern Australia. *Aust. J. Bot.* 39: 283–93.

*Coronel, R. 1983. *Promising fruits of Philippines*. College of Agriculture, University of the Philippines, Los Banos: 500–502.

Cosmulescu, S., Botu, M., and Trandafir, I. 2010. Mineral composition and physical characteristics of walnut (*Juglans regia* L.) cultivars originating in Romania. *Selçuk Tarım ve Gıda Bilimleri Dergisi* 24(4): 33–37.

CSIR, 1985. *The wealth of India (Raw Materials) Volume I: A.* Publications and Information Directorate, CSIR, New Delhi, India, pp. 444–455.

Das, T. and Das, A. K. 2013. Vegetative and reproductive phenology of some multipurpose tree species in the homegardens of Barak valley, northeast India. *Int. J. Biometeorol* 57: 185–196.

Dash, A. K., Pradhan, R. C., Das, L. M., and Naik, S. N. 2008. Some physical properties of simarouba fruit and kernel. *Int. Agrophysics* 22: 111–116.

Dauthy, M. E. 1995. *Fruit and vegetable processing.* FAO Agricultural Services Bulletin No. 119. Food and Agriculture Organization of the United Nations, Rome. 249p.

Desai, P. B. and Patel, N. K. 2010. Phenological study of tree species of Satlasana range forest (North Gujarat). *Life Sciences Leaflets* 3: 41–46.

*Dhamanitayankul, P. 1979. The phenology of trees in dry evergreen forest and application to timing for logging operations. Forestry Research Bulletin, Faculty of Forestry, Kasetart University, 64(6): 10p.

Dibinlal, D., Sathish Sekar, D., and Senthil Kumar, K. L. 2010. Pharmacognostical studies on the bark of *Artocarpus hirsutus* Lam. *Hygeia J. Drugs Medicines* 2(1): 22–27.

*Dignan, C. A., Burlingame, B. A., Arthur, J. M., Quigley, R. J., and Milligan, G. C. 1994. *The Pacific Islands food composition tables*. Palmerston North: South Pacific Commission, New Zealand Institute for Crop and Food Research, INFOODS. 169p.

Duckworth, R. B. 1966. *Fruits and vegetables*. Pergamon Press Limited. 306p.

Elevitch, C. R. and Manner, H. I. 2006. *Artocarpus heterophyllus (Jackfruit)*. Species profile for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Hōlualoa, Hawaii. 17p.

Elliott, S., Promkutkaew, S., and Maxwell, J. F. 1994. Flowering and seed production phenology of dry tropical forest trees in northern Thailand. In: *Proceedings of International symposium on genetic conservation and production of tropical forest tree seed*; 14–16 June, 1993; Chiang Mai, Thailand, pp. 52–62.

*Eromosele, I. O. and Eromosele, C. O. 1993. Studies on chemical composition and physicochemical properties of seeds of some wild plant: Netherland. *Plant Food Hum. Nutr.* 43: 251–256.

Erturk, U., Mert, C., and Soylu, A. 2006. Chemical composition of fruits of some important chestnut cultivars. *Brazilian Arch. Biol. Technol.* 49(2): 183–188.

Falcao, M. de A., Clement, C. R., Gomes, J. B. M., Flores, W. B. C., Santiago, F. F., and Freitas, V. P. 2001. Phenology and yield of breadfruit (*Artocarpus altilis*) and jackfruit (*A. heterophyllus*) in Central Amazonia. *Acta Amazonica* 31(2): 179–191.

*Fallon, S. and Enig, M. G. 2001. *Nourishing traditions: The cookbook that challenges politically correct nutrition and the diet dictocrats.* New Trends Publishing, U.S., pp. 40–45.

Figueiredo, R. A. de, and Sazima, M. 1997. Phenology and pollination ecology of three Brazilian fig species (Moraceae). *Botanica Acta* 110(1): 73–78.

FORRU. Forest Restoration Research Unit. 2006. *How to plant a forest: the principles and practice of restoring tropical forests*. Biology Department, Science Faculty, Chiang Mai University, Thailand, 200p.

*Frankie, G. W., Baker, H. G., and Opler, P.A. 1974. Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica. *J. Ecol.* 62: 881–919.

*Gauch, H. G. 1957. Mineral nutrition of plants. *Annu. Rev. Plant Physiol.* 8: 31–62.

Gomez-Casero, M. T., Galan, C., and Dominguez-Vilches, E. 2007. Flowering phenology of Mediterranean *Quercus* species in different locations (Cordoba, SW Iberian Peninsula). *Acta Botanica Malacitana* 32: 127–146.

Gopakumar, S. 1994. Pheno-morphological studies of selected tree species in a tropical forest ecosystem. MSc. thesis, Kerala Agricultural University, Thrissur, 105p.

Gopikumar, K. 2009. Productivity studies in selected commercial tree species of tropics. *Int. J. Agric. Sciences* 5(2): 363–368.

Gopikumar, K. and Mahato, K. C. 1993. Germination and growth behaviour of selected tree species in the nursery. *Indian Forester* 119(2): 154–156.

Goswami, C., Hossain, M. A., Kader, H. A., and Islam, R. 2011. Assessment of physicochemical properties of jackfruits' (*Artocarpus heterophyllus* Lam) pulps. *J. Hort. For. Biotech.* 15(3): 26–31.

Guleria, V., Gupta, A., and Vashisth, A. 2011. Assessing the variability and relationship among fruit and seed characters of soap yielding *Sapindus mukorossii* Gaertn. *J. Farm Sci.* 1(1): 43–48.

Gurjar, M. M., Khan, M. I., and Gaikwad, S. M. 1998. Alpha-Galactoside binding lectin from *Artocarpus hirsuta*: characterization of the sugar specificity and binding site. *Biochemica et Biophysica Acta* 1381(2): 256–264.

Haciseferogullari, H., Ozcan, M., Sonmete, M. H., and Ozbek, O. 2005. Some physical and chemical parameters of wild medlar (*Mespilus germanica* L.) fruit grown in Turkey. *J. Food Engng.* 69(1): 1–7.

Haggerty, B. P. and Mazer, S. J. 2008. *The Phenology Handbook, a guide to phenological monitoring for students, teachers, families and nature enthusiasts.* University of California, Santa Barbara, California, 40p.

Haq, N. 2006. *Jackfruit Artocarpus heterophyllus.* Southampton Centre for underutilized crops, University of Southampton, Southampton, U.K., 192p.

Harrison, R. D., Yamamura, N., and Inoue, T. 2000. Phenology of a common roadside fig in Sarawak. *Ecological Res.* 15: 47–61.

*Hema, S. R. 1997. Development, diversification and shelf life of jamun based products. MSc. (Home Sci.) thesis, Kerala Agricultural University, Vellayani; 105p.

*Hiremath, S. M., Nagaraju, H. R., and Gowda, D. S. M. 2006. Processing, value addition and marketing of underutilized fruit- a case study. In: Abstracts on National Symposium on Underutilized Horticultural Crops; 8-9 June, Bangalore. Indian Institute of Horticultural Research, Bangalore. Abs No. 93.

Hooi, R., Barbano, D. M., Bradley, R. L., Budde, D., Bulthaus, M., Chettiar, M., Lynch, J., Reddy, R., and Arnold, E. A. 2004. Moisture and Solids Tests. In: Wehr, H. M. and Frank, J. F. (eds) *Standard Methods for the Examination of Dairy Products*. American Public Health Association, Washington, DC. 573p.

*Hossain, S. A. and Abdul Matin, M. 2007. Seed morphology and germination studies of *Dalbergia sissoo* Roxb. at nursery stage in Bangladesh. *Res. J. Agric. Biol. Sci.* 3(1): 35–39.

Iqbal, M., Khan, M. K., Jilani, M. S., and Khan, M. M. 2010. Physico-chemical characteristics of different mulberry cultivars grown under agro-climatic conditions of Miran Shah, North Waziristan (Khyber Pakhtunkhwa), Pakistan. *J. Agric. Res.* 48(2): 209–217.

*Isaac, S. R. and Nair, M. A. 2002. Effect of wild jack (*Artocarpus hirsuta* Lamk.) leaf litter decomposition on the physico-chemical properties of soil. *Myforest* 38(4): 329–337.

Jaakkola, M., Korpelainen, V., Hoppula, K., and Virtanen, V. 2012. Chemical composition of ripe fruits of *Rubus chamaemorus* L. grown in different habitats. *J. Sci. Food Agric.* 92: 1324–1330.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India (Pvt.) Limited, New Delhi, 299p.

Jagadeesh, S. L., Reddy, B. S., Swamy, G. S. K., Gorbal, K., Hegde, L., and Raghavan, G. S. V. 2007. Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India. *Food Chem.* 102: 361–365.

Jagadeesh, S. L., Reddy, B. S., Basavaraj, N., Swamy, G. S. K., and Hegde, L. 2010. Variability studies in physico-chemical qualities of jackfruit (*Artocarpus heterophyllus* Lam.) of coastal zone of Karnataka. *Karnataka J. Agric. Sci.* 23(2): 293–297.

Jagtap, U. B. and Bapat, V. A. 2010. *Artocarpus*: a review of its traditional uses, phytochemistry and pharmacology. *J. Ethnopharmacol.* 129(2): 142–166.

*Janzen, D. H. 1967. Synchronization of sexual reproduction of trees within the dry season in Central America. *Evolution* 21: 620–637.

Jellinek, G. 1985. *Sensory Evaluation of Food, Theory and Practices.* Ellis Horwood Limited, Chichester, England, 204p.

Jamaludheen, V. and Kumar, B. M. 1999. Litter of multipurpose trees in Kerala, India: variations in the amount, quality, decay rates and release of nutrients. *Forest Ecol. Manage.* 115(1): 1–11.

Johnson, L. E. and Mergens, W. J. 1991. Added ascorbates and tocopherols as antioxidants and food improvers. In: Banernfeind, J. C. and Lachance, P. A. (eds) *Nutrient Additions to Food: Nutritional, Technological and Regulatory Aspects*. Trumbull: Food and Nutrition Press. pp. 433–458.

Joshee, N., Bastola, D. R., Agrawal, V. P., and Yadav, A. K. 2002. Lakoocha: A multipurpose tree of warm climate. In: Janick, J. and Whipkey, A. (eds) *Trends in new crops and new uses.* ASHS Press, Alexandria, VA, pp. 405–406.

Judprasong, K., Charoenkiatul, S., Thiyajai, P., and Sukprasansap., M. 2013. Nutrients and bioactive compounds of Thai indigenous fruits. *Food Chem.* 140(3): 507–512.

Kader, A. A. 2008. Perspective flavor quality of fruits and vegetables. *J. Sci. Food Agric.* 88(11): 1863–1868.

*Kaul, R. B., Abbe, E. C. and Abbe, L. B. 1986. Reproductive phenology of the Oak family (Fagaceae) in the low land rainforest of Borneo. *Biotropica* 18: 51–55.

Khanna, L. S. 2009. *Principles and practice of silviculture*. Khanna Bandhu, 7 Tilak Road, Dehradun, 473p.

Khatibu, A. I., Carpenter, A. J., Makame, M. H., and Saleh, M. M. 1985. Climatic effects on the flowering and fruiting of woody perennial fruit trees in Zanzibar. *Acta Horticulturae* 153: 61p.

Kikim, A. and Yadava, P. S. 2001. Phenology of tree species in subtropical forests of Manipur in north eastern India. 2001. *Trop. Ecol.* 42(2): 269–276.

Kimbonguila, A., Nzikou, J. M., Matos, L., Loumouamou, Ndangui, C. B. 2010. Proximate composition and physicochemical properties on the seeds and oil of *Annona muricata* grown in Congo-Brazzaville. *Res. J. Environ. Earth Sciences* 2(1): 13–18.

Kishore, K., Kumar, A., Rahman, H., Monika, N., and Pandey, B. 2010. Physico-chemical and sensorial attributes of Sikkim mandarin (*Citrus reticulata*). *Indian J. Agric. Sciences* 80(2): 164–7.

Kottaimuthu, R. 2008. Ethnobotany of the Valaiyans of Karandamalai, Dindigul District, Tamil Nadu, India. *Ethnobotanical Leaflets* 12: 195–203.

*Kruczek, A. 2005. Effect of row fertilization with different kinds of fertilizers on the maize yield. *Acta Sci. Pol. Agric.* 4(2): 37–46.

Kuaraksa, C., Elliott, S., and Hossaert-Mckey, M. 2012. The phenology of dioecious *Ficus* spp. tree species and its importance for forest restoration projects. *Forest Ecol. Manage.* 265: 82–93.

Law, B., Mackowski, C., Schoer, L., and Tweedie, T. 2000. Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. *Austral Ecol.* 25(2): 160–178.

*Lechaudel, M. Joas, J., Caro, Y., Genard, M., and Jannoyer, M. 2005. Leaf:fruit ratio and irrigation supply affect seasonal changes in minerals, organic acids and sugars of mango fruit. *J. Sci. Food Agric.* 85: 251–260.

Leith, H. 1974. Purposes of a phenology book. In: Leith, H. (ed.), *Phenology and seasonality modeling, Ecological studies 8.* Springer Verlag, New York, pp. 3–19.

Li, J., Fan, L., Ding, S., and Ding, X. 2007. Nutritional composition of five cultivars of Chinese jujube. *Food Chem.* 103(2): 454–460.

Lieberman, D. 1982. Seasonality and phenology in a dry tropical forest in Ghana. *J. Ecol.* 70: 791–806.

Love, K. and Paull, R. E. 2011. *Jackfruit Fruits and Nuts.* [Cooperative Extension Service], College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa, 7p.

Magaia, T., Uamusse, A., Sjoholm, I., Skog, K. 2013. Dietary fibre, organic acids and minerals in selected wild edible fruits of Mozambique. *SpringerPlus* 2(1): 88p.

*Mahadevan, N. P. 1991. Phenological observations of some forest tree species as an aid to seed collection. *J. Trop. For.* 7(3): 243–247.

Mahapatra, A. K., Mishra, S., Basak, U. C., and Panda, P. C. 2012. Nutrient analysis of some selected wild edible fruits of deciduous forests of India: an explorative study towards non conventional bio-nutrition. *Advance J. Food Sci. Technol.* 4(1): 15–21.

Maiti, C. S. 2010. Correlation and path coefficient analysis for some morphological and biochemical constituents of jackfruit genotypes. *Indian J. Hort.* 67(2): 169–172.

*Malik C.P. and A.K. Srivastava, 1982. Textbook of Plant Physiology. New Delhi: Ludhiana.

Manay, S. N. and Shadaksharaswamy, M. 2001. *Food: Facts and principles.* New Age International, New Delhi, 564p.

Manilal, K. S. 2003. *Hortus Malabaricus* (English edition) University of Kerala, Thiruvananthapuram. 3: 49-52.

Mannan, M. A., Sultana, S., and Gain, P. 2005. Fruit characteristics of some off-season jackfruit germplasms. *J. Bangladesh Soc. Agric. Sci. Technol.* 2(3&4): 69–72.

Markose, A. M. 2008. Evaluation and value addition of watery rose apple (*Syzygium aqueum* (Burm) *Alston*) and Malay apple (*Syzygium malvaceae* (L.) *Mernil and Perry*). 2008. MSc. (Hort.) thesis Kerala Agricultural University, Thrissur, 102p.

Mathew, S. P., Mohandas, A., Shareef, S. M., and Nair, G. M. 2006. Biocultural diversity of the endemic 'Wild jack tree' on the Malabar coast of South India. *Ethnobotany Res. Appl.* 4:25–40.

McCarthy, B. C. and Quinn, J. A. 1989. Within and among tree variation in flower and fruit production in two species of *Carya* (Juglandaceae). *Am. J. Bot.* 76(7): 1015–1023.

McIntoch, C. and Manchew, P. 1993. The breadfruit in nutrition and health. Tropical Fruits Newsletter. 6: 5–6.

Medeiros, D. P. W. de, Lopes, A. V., and Zickel, C. S. 2007. Phenology of woody species in tropical coastal vegetation, northeastern Brazil. *Flora* 202: 513–520.

Mishra, R. K., Upadhyay, V. P., Bal, S., Mohapatra, P. K., and Mohanty, R. C. 2006. Phenology of species of moist deciduous forest sites of Similipal biosphere reserve. *Lyonia* 11(1): 5–17.

Morellato, L. P. C., Talora, D. C., Takahasi, A., Bencke, C. C., Romera, E. C., and Zipparro, V. B. 2000. Phenology of Atlantic rain forest trees: A comparative study. *Biotropica* 32(4b): 811–823.

Morton, J. 1987. Jackfruit. In: Morton, J. F. (ed.), *Fruits of warm climates*. Miami, Florida, pp. 58–64.

*Mulik, N. G. and Bhosale, L. J. 1989. Flowering phenology of the mangroves from the west coast of Maharashtra. *J. Bombay Nat. Hist. Soc.* 86(3): 355–359.

Murai, M., Pen, P., and Miller, C. D. 1958. *Some tropical Pacific foods.* University of Hawaii, Honolulu. 159p.

Murali, K. S. and Sukumar, R. 1993. Leaf flushing phenology and herbivory in a tropical dry deciduous forest, Southern India. *Oecologia* 94: 114–119.

Muthulakshmi, P. 2003. Genetic diversity and canopy management in jackfruit (*Artocarpus heterophyllus* Lam.). MSc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 203p.

Naderiboldaji, M., Khadivi khub, A., Tabatabaeefar, A., Varnamkhasti, G. M., and Zamani, Z. 2008. Some physical properties of sweet cherry (*Prunus avium* L.) fruit. *American-Eurasian J. Agric. Environ. Sci.* 3(4): 513–520.

Nagaraja, B. C., Somashekar, R. K., and Swamy, H. R. 2001. An assessment of the performance of native tree species in the wastelands of Western Ghats, Karnataka, India. *Forests- trees and livelihoods.* 11(4): 365–368.

Nanda, A., Prakasha, H. M., Krishna Murthy, Y. L., and Suresh, H. S. 2011. Phenology of leaf flushing, flower initiation and fruit maturation in dry deciduous and evergreen forests of Bhadra Wildlife Sanctuary, Karnataka, Southern India. *Our Nat.* 9: 89–99.

Narain, N., Bora, P. S., Holschuh, H. J., and Vasconcelos, M. A. Da S. 2001. Physical and chemical composition of carambola fruit (*Averrhoa carambola* L.) at three stages of maturity. *Ciencia y Tecnologia Alimentaria* 3(3): 144–148.

Nazarudeen, A. 2010. Nutritional composition of some lesser-known fruits used by the ethnic communities and local folks of Kerala. *Indian J. Traditional Knowledge* 9(2): 398–402.

Newstrom, L. E., Frankie, G. W., and Baker, H. G. 1994. A new classification for plant phenology based on flowering patterns in lowland tropical rain forest trees at La Selva, Costa Rica. *Biotropica* 26: 141–159.

Nitta, I. and Ohsawa, M. 1997. Leaf dynamics and shoot phenology of eleven warm-temperate evergreen broad-leaved trees near their northern limit in central Japan. *Plant Ecol.* 130: 71–88.

Nord, E. A. and Lynch, J. P. 2009. Plant phenology: a critical controller of soil resource acquisition. *J. Exp. Bot.* 60(7): 1927–1937.

Nour, A. A., Magboul, B. I., and Kheiri, N. H. 1980. Chemical composition of baobab fruit (*Adansonia digitata* L.). *Trop. For.* 22(4): 383–388.

Nunes, Y. R. F., Luz, G. R. da, and Braga, L. de Lima. 2012. Phenology of tree species populations in tropical dry forests of Southeastern Brazil. In: Dr. Zhang, X. (ed.) *Phenology and climate change* InTech open, 320p.

Nyanga, L. K., Gadaga, T. K., Nout, M. J. R., Smid, E. J., Boekhout, T., and Zwietering, M. H. 2013. Nutritive value of masau (*Ziziphus mauritiana*) fruits from Zambezi valley in Zimbabwe. *Food Chem.* 138: 168–172.

Nyarko, G., Mahunu, G. K., Chimsah, F. A., Yidana, J. A., Abubakari, A. H., Abagale, F. K., Quainoo, A., and Poudyal, M. 2012. Leaf and fruit characteristics of Shea (*Vitellaria paradoxa*) in Northern Ghana. *Res. Plant Biol.* 2(3): 38–45.

Obasuyi, J. O. I. and Nwokoro, S. O. 2006. Physical and chemical characteristics of breadfruit (*Artocarpus alyilis*) seeds collected from three locations in Edo state, Nigeria. *Pakistan J. Nutrition* 5(3): 212–214.

Okello, J. 2010. Morphological and nutritional characteristics of *Tamarindus indica* (Linn) fruits in Uganda. MSc. Dissertation, Makerere University, 63p.

Ong, B. T., Nazimah, S. A. H., Osman, A., Quek, S. Y., Voon, Y. Y., Hashim, D. M., Chew, P. M., and Kong, Y. W. 2006. Chemical and flavor changes in jackfruit (*Artocarpus heterophyllus* Lam.) cultivar J3 during ripening. *Postharvest Biol. Technol.* 40(3): 279–286.

Onyechi, Uchenna, A., Ibeanu, Nkiruka, V., Eme, Eze, P., Kelechi, and Madubike. 2012. Nutrient, phytochemical composition and sensory evaluation of soursop (*Annona muricata*) pulp and drink in South Eastern Nigeria. *Int. J. of Basic Appl. Sciences* 12(6): 53–57.

Parinitha, M., Harish, G. U., Vivek, N. C., Mahesh, T., and Shivanna, M. B. 2004. Ethno-botanical wealth of Bhadra wild life sanctuary in Karnataka. *Indian J. Traditional Knowledge* 3(1): 37–50.

Pascal, J. P. and Ramesh, B. R. 1987. *A field key to the trees and lianas of the evergreen forests of the Western Ghats (India)*. Institut Francais De Pondichery, India, 236p.

Pathak, P. K. and Chakraborty, I. 2006. Studies on physico-chemical characters of some potential underutilized tropical fruits. In: *Proceedings of National Symposium on Production, Utilization and Export of Underutilized Fruits with Commercial Potentialities*; 22–24 November, 2006; Kalyani, Nadia, West Bengal, India, pp. 271–274.

Patil, S., Shirol, A. M., and Kattimani, K. N. 2009. Variability studies in physico-chemical parameters in kokum (*Garcinia indica* Choicy) for syrup preparation. *Karnataka J. Agric. Sci.* 22(1): 244–245.

Pereira, R. A. S., Rodrigues, E., and Menezes Jr, A. de Oliveira. 2007. Phenological patterns of *Ficus citrifolia* (Moraceae) in a seasonal humid subtropical region in Southern Brazil. *Plant Ecol.* 188: 265–275.

Perkin-Elmer. 1982. *Analytical Methods for Atomic Absorption Spectrophotometry*. Perkin-Elmer Corporation, USA, 114p.

*Prakash, V. R., Venugopal, S., and Thomas, S. 2007. First report of macrophomina leaf spot (*Macrophomina phaseolina*) on *Artocarpus hirsutus* in India. *Plant Arch.* 7(2): 929–930.

*Prasad, S. N. and Hegde, M. 1986. Phenology and seasonality in the tropical deciduous forest of Bandipur, South India. *Proc. Indian Acad. Sci. (Plant Sci.)*. 96: 121–133.

*Purseglove, J. W. 1968. *Tropical crops. Dicotyledons Vol. 2.* John Wiley and sons, Inc., New York, pp. 384–387.

Pushpakumara, D. K. N. G. 2006. Floral and fruit morphology and phenology of *Artocarpus heterophyllus* Lam. (Moraceae). *Sri Lankan J. Agric. Sci.* 43: 82–106.

Ragone, D. 2006. *Artocarpus altilis* (breadfruit). Species profile for Pacific Island Agroforestry. Hōlualoa, Hawaii: Permanent Agriculture Resources (PAR). 17p.

Ragone, D. and Cavaletto, C. G. 2006. Sensory evaluation of fruit quality and nutritional composition of 20 breadfruit (*Artocarpus*, Moraceae) cultivars. *Economic Bot.* 60(4): 335–346.

Ragone, D. and Manner, H. I. 2006. *Artocarpus mariannenesis* (dugdug). Species profile for Pacific Island Agroforestry. Hōlualoa, Hawaii: Permanent Agriculture Resources (PAR). 13p.

Rahman, M. A., Nahar, N., Mian, A. J., and Mosihuzzaman, M. 1999. Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions. *Food Chem.* 65: 91–97.

Rai, S. N. 1978. *Nursery and planting of some tropical evergreen and semi-evergreen species.* Karnataka Forest Department, Madikeri, 49p.

*Rai, S. N. and Sarma, C. R. 1993. Diameter increment in *Artocarpus hirsuta, Dalbergia latifolia* and *Grewia tilaefolia* in the mixed deciduous forests of Wynaad (Kerala). *Indian Forester* 119(1): 11–16.

Rajendran, R. 1992. *Artocarpus altilis* (Parkinson) Fosberg. In: Verheij, E.W.M. and Coronel, R.E. (eds), *Plant Resources of South-East Asia* No. 2, *Edible Fruits and Nuts*. Pudoc–DLO, Wageningen, pp. 83–86.

*Ramesh, B. R. and Pascal, J. P. 1997. *Atlas of Endemics of the Western Ghats (India): distribution of tree species in the evergreen and semi-evergreen forests*. Institut Francais de Pondichery, Pondicherry, 403p.

Ranganna, S. 1986. *Manual of Analysis of Fruits and Vegetable Products.* Tata Mc Graw Hill Publishing Co. Ltd., New Delhi, 594p.

*Reich, P. B. 1995. Phenology of tropical forests: patterns, causes, and consequences. *Can. J. Bot.* 73: 164–174.

Rincon, A. M. and Padilla, F. C. 2004. Physicochemical properties of Venezuelan breadfruit (*Artocarpus altilis*) starch. *Arch Latinoam Nutr.* 54(4): 449–456.

*Richards, P. W. 1952. *The tropical rain forest: An ecological study.* Cambridge University Press, London.

Rosalizan, M. S., Rohani, M. Y., and Khatijah, I. 2010. Physico-chemical characteristics of *Morinda citrifolia* fruit during growth and maturation. *J. Trop. Agric. Food Sci.* 38(1): 21–30.

Ruml, M. and Vulic, T. 2005. Importance of phenological observations and predictions in agriculture. *J. Agric. Sci.* 50(2): 217–225.

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Limited and Tamilnadu Agricultural University, Coimbatore, 255p.

Sadiq, I. S., Dangoggo, S. M., Hassan, L. G., Manga, S. B., Thompson, I., and Itodo, A. U. 2012. Nutritional composition of Aduwa fruit (*Balanites aegytiaca*) from semi-arid region, North-Western Nigeria. *Int. J. Food Nutr. Sci.* 1(2): 7–9.

Salinas-Peba, L. and Parra-Tabla, V. 2007. Phenology and pollination of *Manilkara zapota* in forest and homegardens. *Forest Ecol. Manage.* 248: 136–142.

*San, B., Yildirim, A. N., Pola, T. M., and Yildirim, F. 2009. Mineral composition of leaves and fruits of some promising Jujube (*Zizyphus jujube* Miller) genotypes. *Asian J. Chem.* 21(4): 2898–2902.

Sarker, S. R. and Zuberi, M. I. 2011. Assessment of morphological characters and ethnobotanical survey of jackfruit germplasm in two sites of Rajshahi, Bangladesh. *Geneconserve* 10(40): 110–128.

*Sarma, R. K. V. 2003. Antioxidants in foods. *Nutrition.* 37: 1–3.

Sasi, R. and Rajendran, A. 2012. Diversity of wild fruits in Nilgiri hills of the Southern Western Ghats-Ethnobotanical aspects. *Int. J. Appl. Biol. Pharmaceutical Technol.* 3(1): 82–87.

*Saunders, E. 2007. Disorders of magnesium and phosphorous. Available at http://www.preserarticle.com/component/option_articleman.

*Schaik C. P., Van. 1986. Phenological changes in Sumatran rain forest. *J. Trop. Ecol.* 2: 327–347.

Selwyn, M. A. and Parthasarathy, N. 2007. Fruiting phenology in a tropical dry evergreen forest on the Coromandel coast of India in relation to plant life-forms, physiognomic groups, dispersal modes, and climatic constraints. *Flora* 202: 371–382.

Senjam, P., Singh, S. R., and Narayanaswamy, P. 2012. Positive correlation between yield and quality parameters in jackfruit (*Artocarpus heterophyllus* Lam.). *Environ. Ecol.* 30(3): 458–462.

Shajib, T. I., Kawser, M., Miah, N., Begum, P., Bhattacharjee, L., Hossain, A., Fomsgaard, I. S., and Islam, S. N. 2013. Nutritional composition of minor indigenous fruits: cheapest nutritional source for the rural people of Bangladesh. *Food Chem.* 140(3): 466–470.

Sharma, S. K., Singh, A. K., and Singh, O. P. 2006. Character association among various quantitative traits in jack fruit (*Artocarpus heterophyllus* Lamk). *Adv. Plant Sciences* 19(2): 633–638.

Shukla, R. P. and Ramakrishnan, P. S. 1982. Phenology of trees in a sub-tropical humid forest in north eastern India. *Vegetatio* 49(2): 103–109.

Singh, D. B., Attri, B. L., Sharma, T. V. R. S., Sreekumar, P. V. 2001. Nutrient composition of some wild edible fruits of Andaman and Nicobar Islands. *J. Appl. Hort.* 3(1): 60–62.

Singh, J. S. and Singh, V. K. 1992. Phenology of seasonally dry tropical forest. *Curr. Sci.* 63(11): 684–689.

Singh, K. P. and Kushwaha, C. P. 2005. Paradox of leaf phenology: *Shorea robusta* is a semi-evergreen species in tropical dry deciduous forests in India. *Curr. Sci.* 88(11): 1820–1824.

Singh, K. P. and Kushwaha, C. P. 2006. Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Ann. Bot.* 97: 265–276.

*Siriwoharn, T., Wrolstad, R. E., Finn, C. E. and Pereira, C. B. 2004. Influence of cultivar, maturity and sampling on blackberry (*Rubus* L. Hybrids) anthocyanins, polyphenolics, and antioxidant properties. *J. Agric. Food Chem.* 52(26): 8021–8030.

Soepadmo, E. 1992. *Artocarpus heterophyllus* Lamk. In: Verheij, E.W.M. and Coronel, R.E. (eds), *Plant Resources of South-East Asia*, No. 2, *Edible Fruits and Nuts*. Pudoc–DLO, Wageningen, pp. 86–91.

Sood, K. K., Saleem, M., and Singh, P. 2009. Variability studies on fruit characteristics of *Terminalia bellirica. J. of Res.* 8(1): 86–91.

Sood, P., Modgil, R., and Sood, M. 2010. Physico-chemical and nutritional evaluation of indigenous wild fruit Kasmal, *Berberis lycium* Royle. *Indian J. Nat. Products Resources* 1(3): 362–366.

*Sparks, T. H. and Menzel, A. 2003. Observed changes in seasons: an overview. *Int. J. Climatology* 22: 1715–1725.

*Srivastava, R. P. and Kumar, S. 1994. *Fruit and vegetable preservation: Principles and practices*. International Book Distributing Co. Limited, Lucknow.

Stevenson, P. R., Castellanos, M. C., Cortes, A. I., and Link, A. 2008. Flowering patterns in a seasonal tropical lowland forest in Western Amazonia. *Biotropica* 40(5): 559–567.

Suman, K. T. 2006. Physico-chemical and nutritional attributes of cashew apple and its products. M. Sc. (Home Sci.) thesis, Kerala Agricultural University, Thrissur, 145p.

Sundarapandian, S. M., Chandrasekaran, S., and Swamy, P. S. 2005. Phenological behaviour of selected tree species in tropical forests of Kodayar in the Western Ghats, Tamil Nadu, India. *Curr. Sci.* 88(5): 805–810.

Suresh, H. S. and Sukumar, R. 2011. Vegetative phenology of tropical montane forests in the Nilgiris, South India. *J. Natl. Sci. Foundation Sri Lanka.* 39(4): 333–343.

Tambat, B., Rajanikanth, G., Ravikanth, G., Shaanker, R. U., Ganeshaiah, K. N., and Kushalappa, C. G. 2005. Seedling mortality in two vulnerable tree species in the sacred groves of Western Ghats, South India. *Curr. Sci.* 88(3): 350–352.

Tang, Y. P., Linda, B. L. L., and Franz, L. W. 2013. Proximate analysis of *Artocarpus odoratissimus* (Tarap) in Brunei Darussalam. *Int. Food Res. J.* 20(1): 409–415.

Tesfaye, G., Teketay, D., Fetene, M., and Beck, E. 2011. Phenology of seven indigenous tree species in a dry Afromontane forest, Southern Ethiopia. *Trop. Ecol.* 52(3): 229–241.

Thakur, N. S., Dhaygude, G., and Gupta, A. 2011. Physico-chemical characteristics of wild pomegranate fruits in different locations of Himachal Pradesh. *Int. J. Frm. Sciences* 1(2): 37–44.

Tharanathan, R. N. 2005. Starch–value addition by modification. *Critical Reviews in Food Sci. and Nutr.* 45: 371–384.

Thomas, A. O. 2013. Geographic and yearly variation in nutrient content of shea butter (*Butyrospermum paradoxum* Gaertn f.) fruit pulp. *Int. J. AgriScience* 3(5): 406–413.

Troup, R. S. and Bor, N. L. 2009. *Encyclopaedia of Indian forest trees*–Volume 3. Asiatic Publishing House, Delhi, pp. 876–878.

Valvi, S. R. and Rathod, V. S. 2011. Mineral composition of some wild edible fruits from Kolhapur district. *Int. J. Appl. Biol. Pharmaceutical Technol.* 2 (1): 392–396.

*Webster, G. C. and Varner, J. E. 1954. Mechanism of enzymatic synthesis of gama-glutamycystine. Fed. Proc., 13: 1049–1052.

*Wenkam, N. S. 1990. *Foods of Hawaii and the Pacific Basin. Fruits and fruit products: raw, processed, and prepared: Vol. 4: Composition.* Honolulu (HI): University of Hawaii. 96p. (Research Extension Series; RES-110).

*Williams-Linera, G. 2003. Temporal and spatial phenological variation of understorey shrubs in a tropical montana cloud forest. *Biotropica* 35: 28–36.

Xiao, X., Hagen, S., Zhang, Q., Keller, M., and Moore III, B. 2006. Detecting leaf phenology of seasonally moist tropical forests in South America with multi-temporal MODIS images. *Remote Sensing Environ.* 103: 465–473.

Yadav, V. K., Sah, V. K., Singh, A. K., and Sharma, S. K. 2006. Variations in morphological and biochemical characters of Seabuckthorn (*Hippophae salicifolia* D. Don) populations growing in Harsil area of Garhwal Himalaya in India. *Trop. Agric. Res. Extension* 9: 1–7.

Yusuf, A. A., Mofio, B. M., and Ahmed, A. B. 2007. Proximate and mineral composition of *Tamarindus indica* Linn 1753 seeds. *Sci. Wld. J.* 2(1): 1–4.

Zhang, G., Song, Q., and Yang, D. 2006. Phenology of *Ficus racemosa* in Xishuangbanna, Southwest China. *Biotropica* 38(3): 334–341.

*Originals not seen

Appendices

APPENDICES

Appendix I. Score card for organoleptic evaluation of fruit

Evaluation of organoleptic qualities of *Artocarpus hirsutus* fruit

Name of judge:
Date:

Characteristics	Midland	Lowland
Appearance		
Colour		
Flavour		
Texture		
Odour		
Taste		
After taste		
Overall acceptability		

9 Point Hedonic Scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Appendix II. ANOVA table for comparison of leaf sizes from the two zones

		Sum of Squares	df	Mean Square	F	Sig.
length	Between Groups	35.722	1	35.722	19.383	0.000
	Within Groups	283.810	154	1.843		
	Total	319.532	155			
breadth	Between Groups	37.338	1	37.338	34.123	0.000
	Within Groups	168.511	154	1.094		
	Total	205.849	155			

Appendix III. ANOVA table for comparison of physical characters of fruits from the two zones

		Sum of Squares	df	Mean Square	F	Sig.
Fruit Wt.	Between Groups	140907.313	1	140907.313	44.446	0.000
	Within Groups	1071561.715	338	3170.301		
	Total	1212469.029	339			
Volume	Between Groups	90214.307	1	90214.307	28.821	0.000
	Within Groups	1057976.432	338	3130.108		
	Total	1148190.738	339			
Length	Between Groups	3414.148	1	3414.148	19.840	0.000
	Within Groups	58163.053	338	172.080		
	Total	61577.201	339			
Diameter	Between Groups	3135.377	1	3135.377	45.630	0.000
	Within Groups	23225.253	338	68.714		
	Total	26360.630	339			

Appendix IV. ANOVA table for comparison of physical characters of fruits from the two zones

		Sum of Squares	df	Mean Square	F	Sig.
Fruit wt.	Between Groups	71461.760	1	71461.760	27.277	0.000
	Within Groups	584228.070	223	2619.857		
	Total	655689.830	224			
Rind wt.	Between Groups	259.877	1	259.877	.687	0.408
	Within Groups	84381.627	223	378.393		
	Total	84641.504	224			
Bulb wt.	Between Groups	38890.717	1	38890.717	50.905	0.000
	Within Groups	170367.834	223	763.981		
	Total	209258.552	224			
Pulp wt.	Between Groups	7203.203	1	7203.203	37.524	0.000
	Within Groups	42808.163	223	191.965		
	Total	50011.367	224			
Seed wt.	Between Groups	11777.754	1	11777.754	71.303	0.000
	Within Groups	36834.989	223	165.179		
	Total	48612.744	224			
No. of seeds/ fruit	Between Groups	26163.656	1	26163.656	108.112	0.000
	Within Groups	53967.073	223	242.005		
	Total	80130.729	224			
Core wt.	Between Groups	.918	1	0.918	0.039	0.843
	Within Groups	5222.114	223	23.418		
	Total	5223.032	224			
Core length	Between Groups	9376.100	1	9376.100	98.516	0.000
	Within Groups	21223.609	223	95.173		
	Total	30599.709	224			
Core dia.	Between Groups	546.239	1	546.239	45.979	0.000
	Within Groups	2649.277	223	11.880		

	Total	3195.516	224			
Stalk length	Between Groups	147.347	1	147.347	139.995	0.000
	Within Groups	234.710	223	1.053		
	Total	382.057	224			
Stalk wt.	Between Groups	7.927	1	7.927	42.016	0.000
	Within Groups	42.071	223	0.189		
	Total	49.997	224			
Pulp (%)	Between Groups	732.063	1	732.063	23.393	0.000
	Within Groups	6978.532	223	31.294		
	Total	7710.595	224			
Peel (%)	Between Groups	12472.366	1	12472.366	68.570	0.000
	Within Groups	40561.979	223	181.892		
	Total	53034.345	224			
Seed (%)	Between Groups	3306.703	1	3306.703	126.473	0.000
	Within Groups	5830.459	223	26.146		
	Total	9137.162	224			

Appendix V. Independent Samples Test for comparison of biochemical and mineral constituents of fruits from the two zones

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Moisture	Equal variances assumed	0.971	-0.09667	2.47426
	Equal variances not assumed	0.971	-0.09667	2.47426
TSS	Equal variances assumed	0.862	0.49000	2.64885
	Equal variances not assumed	0.868	0.49000	2.64885
Titrable acidity	Equal variances assumed	0.044	0.33000	0.11338
	Equal variances not assumed	0.045	0.33000	0.11338
Total Sugar	Equal variances assumed	0.552	-0.68667	1.05846
	Equal variances not assumed	0.564	-0.68667	1.05846
Reducing Sugar	Equal variances assumed	0.679	0.46667	1.04769
	Equal variances not assumed	0.679	0.46667	1.04769
Starch	Equal variances assumed	0.845	-0.46667	2.24301
	Equal variances not assumed	0.849	-0.46667	2.24301
Beta carotene	Equal variances assumed	0.001	1.61333	0.20226
	Equal variances not assumed	0.006	1.61333	0.20226
Vit. C	Equal variances assumed	0.668	0.68333	1.48060
	Equal variances not assumed	0.679	0.68333	1.48060
Fibre	Equal variances assumed	0.516	-0.12667	0.17808
	Equal variances not assumed	0.521	-0.12667	0.17808
P	Equal variances assumed	0.592	-2.59000	4.45839
	Equal variances not assumed	0.600	-2.59000	4.45839
K	Equal variances assumed	0.277	-72.09000	57.31458

	Equal variances not assumed	0.301	-72.09000	57.31458
	Equal variances assumed	0.280	0.62000	0.49641
Fe	Equal variances not assumed	0.298	0.62000	0.49641
Ca	Equal variances assumed	0.932	-0.49333	5.43026
	Equal variances not assumed	0.932	-0.49333	5.43026

Appendix VI. ANOVA table for comparison of chemical composition of seeds from the two zones

		Sum of Squares	df	Mean Square	F	Sig.
Moisture	Between Groups	6.000	1	6.000	0.302	0.612
	Within Groups	79.374	4	19.843		
	Total	85.374	5			
P	Between Groups	561.247	1	561.247	5.888	0.072
	Within Groups	381.282	4	95.321		
	Total	942.529	5			
K	Between Groups	8990.785	1	8990.785	54.685	0.002
	Within Groups	657.641	4	164.410		
	Total	9648.426	5			
Fe	Between Groups	.217	1	0.217	0.382	0.570
	Within Groups	2.266	4	0.567		
	Total	2.483	5			
Ca	Between Groups	215.520	1	215.520	31.096	0.005
	Within Groups	27.723	4	6.931		
	Total	243.244	5			

PHENOLOGY AND FRUIT CHARACTERIZATION OF *ARTOCARPUS HIRSUTUS* LAM IN TWO ALTITUDINAL ZONES OF THRISSUR DISTRICT

by

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study on "Phenology and fruit characterization of *Artocarpus hirsutus* Lam in two altitudinal zones of Thrissur district" was conducted in two different zones viz. midlands (22m above MSL) and lowlands (7.5m above MSL) of Thrissur district. Trees were selected and monthly observations on phenological parameters were taken. Fruits collected from the two zones were evaluated for their quality parameters and a comparison was made. Also, mineral composition of the seeds from the two zones was analyzed and compared.

Artocarpus hirsutus is an evergreen tree with leaf shedding and leaf flushing continuing throughout the year. The tree starts flowering from November and continues till February which is followed by fruiting that continues till May–June. Mean height and mean girth for the trees in the study zones ranged from 16.32 m in midland to 19.50 m in lowland and 1.22 m in lowland to 1.41 m in midland respectively. Between the zones, leaf characteristics like leaf length and leaf width differed significantly ranging from 14.91 cm in midland to 15.86 cm in lowland and 9.83 cm in midland to 10.81 cm in lowland respectively. Physical characteristics of the *Artocarpus hirsutus* fruit also varied between these zones. Mean fruit weight, volume, length and diameter for the two zones ranged from 111.15 g in midland to 152.43 g in lowland, 83.94 cm^3 in midland to 116.97 cm^3 in lowland, 69.57 mm in midland to 76 mm in lowland and 57.04 mm in lowland to 63.19 mm in midland respectively. Correlation matrix revealed a significant and positive relation among the studied physical parameters. In terms of organoleptic evaluation, fruits collected from lowland recorded higher scores. Not much variation was observed for biochemical and mineral attributes of the fruit and seed between the study zones. In the two study zones, mean moisture, total sugar, starch and fibre content varied from 69.84 per cent in midland to 70.16 per cent in lowland, 14.21 per cent in midland to 14.9 per cent in lowland, 14.76 per cent in midland to 15.30 per cent in lowland and 2.01 per cent in midland to 2.12 per cent in lowland respectively. Also, total soluble solids, titrable acidity, reducing sugar, beta carotene and vitamin C content ranged from 18.68 ^{0}Brix in lowland to 19.17 ^{0}Brix in midland, 0.69 per cent in lowland to 1.27 per cent in midland, 11.47 per cent in lowland to 11.94 per cent in midland, 2.88 μg/100g in lowland to 4.30 μg/100g in midland and 4.89 mg/100g in lowland to 5.31 mg/100g in midland respectively. Minerals like phosphorus, potassium, iron and calcium in the fruit from the different zones were found to be ranging from 45.13 mg/100g in midland to

47.49 mg/100g in lowland, 287.35 mg/100g in midland to 368.76 mg/100g in lowland, 1.16 mg/100g in lowland to 1.78 mg/100g in midland and 15.35 mg/100g in lowland to 15.83 mg/100g in midland respectively. Mineral content in the seeds were higher than that in the fruit pulp with the values in the two zones as phosphorus (69.23 mg/100g to 88.57 mg/100g), potassium (311.21 mg/100g to 388.64 mg/100g), iron (1.69 mg/100g to 2.06 mg/100g) and calcium (13.08 mg/100g to 25.10 mg/100g) respectively. Based on fruit size class, significant variation was observed within each zone for biochemical and mineral parameters. Overall, irrespective of the zones nutritional composition of this fruit was found to be almost equal to that of cultivated jackfruit.

Based on its nutritional composition, this study highlights the significance of underutilized fruits like *Artocarpus hirsutus* for commercial exploitation and further widens the scope for value addition of such fruits involving rural communities who are the major user of such species.