SCREENING OF JACK TREES (*Artocarpus heterophyllus* Lam.) FOR QUALITY TIMBER PRODUCTION

By

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(2017-17-003)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled "**SCREENING OF JACK TREES (*Artocarpus heterophyllus* Lam.) FOR QUALITY TIMBER PRODUCTION**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Dedicated to my dear
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CONTENTS

CHAPTER	TITLE	PAGE NO.
1.	INTRODUCTION	1-4
2.	REVIEW OF LITERATURE	5-20
3.	MATERIALS AND METHODS	21-38
4.	RESULTS	39-81
5.	DISCUSSION	82-88
6.	SUMMARY	89-91
7.	REFERENCES	i-xiv
8.	ABSTRACT	
9.	APPENDICES	

LIST OF TABLES

Table No.	Title	Page No.
1	Details of seed sources (*varikka*) used in the study	22
2	Details of seed sources (*koozha*) used in the study.	23
3	Variation in height (cm) of seedlings from different seed sources.	40
4	Variation in collar diameter (mm) of seedlings from different seed sources.	41
5	Variation in taproot length (cm) of seedlings from different seed sources.	43
6	Variation in stem fresh weight (g) of seedlings from different seed sources	45
7	Variation in leaf fresh weight (g) of seedlings from different seed sources.	46
8	Variation in root fresh weight (g) of seedlings from different seed sources.	48
9	Variation in stem dry weight (g) of seedlings from different seed sources	49
10	Variation in leaf dry weight (g) of seedlings from different seed sources.	51
11	Variation in root dry weight (g) of seedlings from different seed sources.	52
12	Variation in number of leaves of seedlings from different seed sources.	54

13	Variation in leaf area (cm^2) of seedlings from different seed sources.	55
14	Variation in leaf area ratio (cm^2g^{-1}) of seedlings from different seed sources.	57
15	Variation in specific leaf area (cm^2g^{-1}) of seedlings from different seed sources.	58
16	Variation in absolute growth rate (cm day^{-1}) of seedlings from different seed sources	60
17	Variation in relative growth rate (g g^{-1} day^{-1}) of seedlings from different seed sources	61
18	Variation in net assimilation rate (g g^{-1} day^{-1}) of seedlings from different seed sources	63
19	Grouping of plus trees from various seed sources into different clusters based on morphological and biometric characters	64
20	Variation in vessel and ray morphology of six month old seedling from different seed sources	68
21	Variation in fibre morphology of six month old seedling from different seed sources.	69
22	Variation in Height (cm) and Collar Diameter (mm) of seedlings 30 days after field planting	72
23	Variation in anatomical features of *varikka* and *koozha* varieties of *Artocarpus heterophyllus* wood samples collected from the Jack Gene Sanctuary at ARS, Mannuthy	76
24	Mean rank of respondents in Thrissur and Palakkad district based on Mann –Whitney test	79
25	Approval rate of statements regarding Farmers' perception towards growing jack tree as a timber species	80

LIST OF FIGURES

Figure No.	Title	Page No.
1	Dendrogram of hierarchial cluster analysis of seedlings of *Artocarpus heterophyllus* based on sixteen traits	65
2	Variation in vessel area (μm^2) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.	67
3	Variation in ray height (μm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district	70
4	Variation in ray width (μm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district	70
5	Variation in fibre length (μm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district	71
6	Variation in fibre wall thickness (μm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district	71
7	Farmers' perception towards growing jack tree as a timber species in Thrissur district	78
8	Farmers' perception towards growing jack tree as a timber species in Palakkad district	78
9	Perception percentage scored against each statement in Thrissur District	81
10	Perception percentage scored against each statement in Palakkad district.	81

LIST OF PLATES

Table No.	Title	Page No.
1	Selected Plus trees of *Artocarpus heterophyllus* Lam. from Thrissur and Palakkad Districts. a. Madakkathara panchayat- *koozha.* b. Avinissery panchayat- *koozha.* c. Ongallur Panchayat- *koozha.* d. Vadanappally panchayat- *varikka.* e. Nenmara panchayat- *varikka.* f. Nalleppally panchayat- *varikka*	25
2	Collection of seeds from mature ripened fruits	26
3	Leaf area estimation using Leaf Area Meter (Model LI-Cor, Nebraska, USA)	26
4	Estimation of root fresh weight using Weighing balance	26
5	Collection of wood samples using Increment borer	26
6	Seedlings at 60 days after planting in the nursery	29
7	Seedlings at 150 days after planting in the nursery	29
8	Seedlings at 120 days after planting in the nursery uprooted for morphometric measurement	30
9	Variation in taproot length of seedlings at 120 days after planting.	30
10	Establishing a field trial plot near the International Hostel at KAU, Vellanikkara.	36
11	Seedlings at 30 days after field planting	36
12	Anatomical features of mature wood of *Artocarpus heterophyllus* Lam. from ARS, Mannuthy. a. TS (4X). b. TS (10	74

	X). c. TLS (4X). d. TLS (10X). e. Fibre (Maceration, 10 X). f. Fibre (Maceration, 40X).	
13	Anatomical features of six month old *Artocarpus heterophyllus* Lam seedlings. a. TS (10 X). b. TLS (10 X). c. Fibre (Maceration, 10 X). d. Fibre (Maceration, 40X).	75

Introduction

1. INTRODUCTION

Artocarpus heterophyllus Lam, belonging to the family Moraceae and popularly known as jackfruit or Ceylon Jack tree, is one of the important and commonly found trees in the home gardens of certain parts of India and Bangladesh (Anon, 2006; Bose, 1985; Elevitch and Manner, 2006; Haq, 2006; Narasimham, 1990; Prakash *et al.*, 2009; Reddy *et al.*, 2004; Samaddar, 1985). The place of origin of jack tree is unknown, however it is believed to be indigenous to the rainforests of the Western Ghats (Morton, 1987).

In India, the trees are found distributed continuously in places where rainfall is high and, sporadically in areas where it is low (Muralidharan *et al.*, 1997; Narasimham, 1990; Singh *et al.*, 1963). Jackfruit is a very popular food and ranks third in total annual production after mango and banana in South India (Morton, 1987). The tree is also gaining importance, as jackfruit was recently declared as the state fruit of Kerala.

Jack tree is a medium - sized, evergreen tree that typically attains a height of 8 – 25 m and a stem diameter of 30 – 80 cm. The canopy shape is usually conical or pyramidal in young trees and becomes spreading and domed in older trees. It is monoecious and both male and female inflorescences are found on the same tree (Bose, 1985; Morton, 1987). From the time of successful pollination, the complete process of fruit development takes about three to seven months. The fruit, a gigantic syncarp, is the largest of all cultivated fruits, weighing up to 50 kg, and is a popular fruit of Indo-Malaysia.

As fertilization is by cross-pollination and propagation, mostly through seeds, numerous types of jackfruits are observed. This when categorized according to the phenotypic and organoleptic characteristics (like the size of the tree, structure of the leaf, fruit form, age of fruit bearing, quality of the fruit pulp, their size, shape, density of spines, colour, texture, odour, quality and period of maturity) has accounted to a great variety of fruits (Elevitch and Manner, 2006; Haq, 2006). Depending on the variety, the bulb can be cream, white, light yellow, yellow, deep yellow, lemon yellow light saffron, saffron, deep saffron or orange in colour (Jagadeesh *et al.*, 2007). Depending on the consistency of the fruit and its pulp two types of morphotypes are recognized, one that has fruits with small, fibrous, soft and spongy flakes with very sweet carpels and good aroma, while the other variety is crunchy, though not as sweet, with crisp carpels (Elevitch and Manner, 2006; Odoemelam, 2005; Shyamalamma *et al.*, 2008). These types are apparently known in different areas by various local names. Generally, the former is known as *Koozha* and latter as *Varikka.*

Wood is yellow to yellowish brown in colour, with a specific gravity of 0.6 - 0.7. It is classified as medium hardwood. It is resistant to termite attack, fungal and bacterial decay and is easy to season. It takes polish beautifully. Though not as strong as teak, *Artocarpus heterophyllus* wood is considered superior to teak (*Tectona grandis*) for furniture, construction, turnery and inlay work, masts, oars, implements and musical instruments because of its availability. The wood is widely used in India and Sri Lanka and is even exported to Europe. Roots are highly prized for carvings and picture framing. (Orwa *et al.*, 2009)

The fruits are of dietary use and are an important source of carbohydrate, protein, fat, minerals and vitamins. The bark, roots, leaves, and fruit are endowed with diverse medicinal properties and are used in the various traditional and folk systems of medicine to treat a range of ailments. Preclinical studies have shown that jackfruit possesses antioxidant, anti-inflammatory, antibacterial, anticariogenic, antifungal, antineoplastic, hypoglycemic, has wound healing effects and causes a transient decrease in the sexual activity. Clinical studies have also shown that the decoction of the leaves possesses hypoglycemic effects in both healthy individuals and non-insulin-dependent diabetic patients.

Pollination in this genus, as in many other genera in the Moraceae, is not well understood (Brantjes, 1981). Although jack tree is considered entomophilous (Jarrett, 1959; Purseglove, 1968), some observers report a lack of insects visiting either the male or female inflorescences (Sambamurty and Ramalingam, 1954). It is not known whether the high failure of fruit set, common in this genus, is a result of non-fertilization or whether abortion occurs soon after fertilization. Propagation is usually sexual and, as may be expected from an out-breeding plant, the seedlings are morphologically very variable.

Both Purseglove (1968) and Barrau (1976) have pointed out that no significant plant breeding effort or clonal selection has been initiated to improve the jack tree and in particular it's wood quality. They suggested the need for a deliberate breeding program if the considerable potential of the species were to be exploited. Taking trees successfully to non-forest areas can be achieved only through proper extension support (Mahapatra and Mitchell, 2001). The interest shown by a farmer for raising tree crops in his land are mainly influenced by the sociological, economic, demographic and environmental factors surrounding his life. These factors influence the choice of a farmer for the "adoption of a new technology", and this is especially in a subsistence farming system, which is a typical farm scenario in Kerala (Nair and Sreedharan, 1986; Jose, 1992). Restrictive legal provisions, lack of institutional mechanisms to supply quality planting stock, absence of public policy and credit support and inadequate knowledge about post-harvest processing techniques are major deterrents in this respect (Kumar and Peter, 2002).

Jack fruit tree is known as a multipurpose tree, because of its variegated uses. Because of the fragmented households and pressure over land, there is a growing interest for planting dwarf varieties over tall varieties in the recent years. Being one of the cheapest timber, this trend can detrimentally affect the availability of a good quality timber yielding species in our market. Wood of jack tree can be used for almost all household and industrial purposes. Being such a wood species with versatile and manifold uses there is a pertinent need to increase the planting of tall varieties of jack tree. There is also a need to spread understanding among people about the raising tree crops in households, as to conserve indigenous timber tree.

Against this backdrop this study is designed with the following objectives:

- Selection of plus trees of jack (*Artocarpus heterophyllus* Lam.) from different regions of Thrissur and Palakkad districts, nursery raising of seedlings and evaluation of their growth performance.
- Assessing farmers' perception towards growing jack tree as a timber species in homesteads of these districts.

Review of Literature

2. REVIEW OF LITERATURE

2.1 Taxonomy and Distribution

Jack tree (*Artocarpus heterophyllus* Lam.) is a member of the family Moraceae. The family encompasses about 1000 species in 67 genera, most of which are tropical shrubs, trees and a few herbs. The genus Artocarpus includes about 110 tropical species (Hutchinson, 1967). The name Artocarpus originated from the Greek words artos ("bread") and karpos ("fruit"). The species epithet of jack tree, heterophyllus, is a compilation of two Greek words, *hetero*, meaning different, and *phyllus*, which means leaf (Gupta, 2012).

All Artocarpus species are laticiferous trees that has leaves and stems capable of producing a milky sap. Even if the flora type is monoecious, jack tree produces both bisexual and unisexual flowers. The plants have small, greenish female flowers that grow on tiny, fleshy plumps. Following pollination, the flowers grow up into a syncarpous fruit capable of rising into huge sizes (Raihandhany *et al*., 2018). Artocarpus family includes a number of cost effective species (Sundarraj and Vasudevan, 2018). Numerous species of the genus bear edible fruit eg. *Artocarpus altilis* (breadfruit), *Artocarpus integer* (cempedak), *Artocarpus heterophyllus* (jack tree), *Artocarpus hypargyreus* (kwaimuk), and *Artocarpus hirsutus* (anjily). Breadfruit and jack tree are cultivated extensively in tropical regions of Southeast Asia. Jack tree has been cultivated since prehistoric times and has naturalized in many parts of the tropics, where it is today an important tree of India, Burma, China, Sri Lanka, Malaysia, Indonesia, Thailand, and Philippines. It is also grown in parts of Africa, Brazil, Suriname, the Caribbean, Florida, and Australia (Elevitch and Manner, 2006).

2.2 Source of variation and selection

The immediate objective of any tree improvement programme is to identify promising genotypes which provide maximum yield per unit area in the shortest possible time. It can be achieved by the screening of intra specific genetic variations and selection. Plus-tree selection involves the application of genetic principles but, the selection of trees in the forest, will be carried out most effectively if a general plan of the program exists (Morgenstern *et al.*, 1975). The majority of economic traits such as yields of crops, diameter and height of trees, differ in degree. The phenotypic expression of these quantitative traits, is much influenced by environment and genes. Inheritance of qualitative traits must be studied on the basis of measurement of populations and genetic variances (Falconer, 1960). Once trees are examined systematically for differences in easily recognizable traits, a great deal of variation is found (Morgenstern *et al.*, 1975).

In a breeding programme, variation is usually defined at a number of levels (Zobel and Talbert, 1984) such as; (i) Species; (ii) Geographic (provenance) variation; (iii) Variation among sites within provenances; (iv) Differences between families within provenances; (v) Differences between trees within families; and (vi) Within trees. The phenotype, is determined by both the genotype and the environment and phenotype within a population has a variance resulting from the addition of genetic and environmental variance. The correlation between traits that is directly observed is phenotypic correlation, since the expression of every trait is influenced by genotype and environment. The genetic correlation can be obtained when the influence of environment is removed, as in an appropriate analysis of progenies from open-pollinated or control-pollinated parents, and the progenies have been grown in replicated experiments on several sites (Becker, 1967). Spatial structuring of genetic differences is common in most plant species throughout their range (Hamrick and Godt, 1990). This is mainly the result of adaptation and evolutionary process of the species (Namkoong, 1979). This provides evolutionary flexibility and determines the responsiveness to future variations in the genetic and external environments (Namkoong, 1979; Lande and Shannon, 1996). Therefore, trees from different areas of the same species performed differently when planted at a single location. Species grown together under same environmental condition can perform differently.

In the short-term, genetic variability is usually less critical than other determinants of population persistence but in the long-term, it can play the decisive role in allowing a population to persist and adapt in a changing environment (Lande, 1996). It is not only important to know the relative role of genetic variance, but also its composition to successfully plan a breeding program. Genetic variance is made up of additive variance and dominance variance, and the relative contribution of each to the inheritance of a given trait is obtained from controlled crosses (Morgenstern *et al.*, 1975). The progeny of a cross has roughly average value of the parents in additive genetic variance, when environmental effects are absent. Additive variance makes selection predictable, and the ease with which a quantitative trait can be improved depends upon additive variance. A large dominance variance in quantitative traits makes selection less predictable than with large additive variance and requires more complicated selection procedures to improve a crop (Morgenstern *et al.*, 1975).

Genetically improved plantations are critical to maintaining sustainable wood supplies. Investment in genetic improvement has increased forest productivity and enhanced timber supply (Li *et al.*, 1999). Many studies on genetic correlations have concentrated on the relationships between juvenile growth and mature tree size (Squillace and Gansel, 1974; Pollard and Logan, 1979; Lambeth, 1980; Lambeth *et al.*, 1983, Waxler and van Buijtenen, 1981). Seeds of good genetic potential are needed for maximising adaptability and yield potentials (Goel and Behl, 2001). Seeds collected from open-pollinated plus trees were germinated and were established in plantations for seed production. A few seedling seed orchards have been planted with the intention of combining progeny testing with seed production (Wright and Bull, 1963), but due to the incompatibility of these the two functions this is not generally possible.

The impact of the North Carolina State University-Industry Cooperative Tree Improvement Program on forest productivity was studied through the two cycles of breeding, testing and selection (Li *et al.*, 1999). Trees grown from seeds of first- generation seed orchards had produced 17 - 19 per cent more volume per hectare at harvest than trees grown from wild seeds. With additional improvement in value from quality traits like stem straightness, disease resistance and wood density, the estimated genetic gain from first-generation breeding was about 20 per cent (Talbert *et al.*, 1985).

Rouging undesirable trees in seed orchards has been the most common method used to enhance the genetic quality based on their offsprings' performance in field progeny tests (McKeand *et al.*, 2003). The "breeder's dilemma" of gain versus risk of reducing diversity has long been recognized as an issue in tree improvement programs (Zobel and Talbert, 1984). This problem has been particularly important in tree improvement programs where the results of genetic manipulation are evident for many as genetic gain can be achieved only by eliminating undesirable genotypes from the breeding population, but if the number of genotypes remaining become too little, the risk from narrowing the genetic base becomes unacceptable. The impact on productivity due to tree improvement is significant as even the most modest genetic improvement available raises it by about 10 per cent. If the best full-sibs or clones are planted, gains of 35 to 50 per cent are possible. (McKeand *et al.*, 2003).

According to Zobel and Talbert (1984), plus-tree selection is 'by far the most common method of first-generation selection'. In spite of the typically low heritabilities of growth traits, it has generally been presumed that the high selection intensities possible in plus-tree selection would nevertheless permit worthwhile gains to be made. As a result, and because of the importance almost universally attached to yield, individual-tree height, stem diameter or volume is generally the highest priority trait in plus-tree selection (Zobel and Talbert, 1984). The number of plus trees to be selected per region depends upon the overall breeding plan for a given species. If the plan anticipates selection and breeding over several generations, this number should be large. A large number of plus trees provides a broad genetic base that will avoid inbreeding and allows genetic gains to be made over several generations even if silvicultural systems change, new wood products are being sought and new diseases are introduced (Bingham *et al.*, 1971).

2.3 Pre sowing treatment and germination of seed

Seeds have different storage behaviour based on which they are generally classified into orthodox and recalcitrant seeds. Orthodox seeds are long-lived seeds and can be successfully dried to moisture contents as low as 5 per cent without injury and are able to tolerate freezing. Orthodox seeds, also termed as desiccation tolerant seeds can be prolonged with low moisture content and freezing temperatures. Recalcitrant seeds are remarkably short-lived which cannot be dried to moisture content below 20 - 30 per cent without injury and are unable to tolerate freezing. Recalcitrant seeds also termed as desiccation sensitive seeds are difficult to store and their ex-situ conservation is problematic (Chin and Roberts, 1980). The seed storage behaviour of jack tree is recalcitrant (Chandel *et al.*, 1995). The viability of jackfruit seeds lose very quickly. Even one or two weeks delay in planting will lead to poor germination and cannot survive more than few days or weeks in storage at ambient temperature.

There is a need of treatments in seeds of jack tree to improve seed germination and seedling growth. The work done by Padma and Reddy (1998), revealed that significant improvement of seedling growth was noticed in *Artocarpus heterophyllus* Lam. for different pre-sowing treatments. Seeds from fully ripened fruits were collected and thoroughly washed with water before imposing treatments. Solutions of gibberellic acid (GA_3) at 100 ppm and 200 ppm, Naphthalene Acetic Acid (NAA) at 25 ppm and 50 ppm and Potassium Nitrate (KNO_3) at 0.25 per cent and 0.5 per cent concentrations were prepared and used for soaking the seeds for 12 hours and 24 hours period of time along with soaking in distilled water. Seeds were sown in the polybags of size 7" x 4" (250 gauge) containing potting mixture (red earth, FYM and sand in the ratio of 2:1:1). The observations recorded on seedling height, seedling girth, absolute growth rate, leaf area and days taken for attaining graftable size in jack seedlings at 90th day after sowing showed significant differences among treatments. Soaking seeds in Gibberellic Acid (GA_3) at 200 ppm for 24 hours recorded tallest seedlings with more absolute growth rate and less number of days taken for attaining graftable size. The observations recorded on leaf area per seedling at 90th day after sowing showed significant differences among treatments. Soaking seed in Potassium Nitrate (KNO_3) at 0.5 per cent for 24 hours recorded maximum leaf area per seedling (2526 cm^2).

Parmar *et al.* (2018) studied the effect of organic compounds on seed germination and seedling growth of jack tree (*Artocarpus heterophyllus* Lam.) at the Regional Horticultural Research Station, Navsari Agricultural University Navsari. The experiment consisted of fourteen treatment combinations, comprising two levels of dipping hours (12 hours and 24 hours) and seven levels of organic treatments (cow dung slurry (T1), cow urine (T2), bijamrut (T3), amritpani (T4), banana pseudo stem sap (T5), panchagavya (T6), water soaking (T7) and control). Uniform sized and healthy seeds, stored for 15 days were used for the experiment. After treatment, seeds were sown in polythene bags of size of 20cm×15 cm and filled with potting mixture (soil, FYM and sand in the ratio of 2:1:1).The results revealed that among the different soaking hours and organic treatments, 12 hours and cow dung slurry were individually found to be most beneficial for minimized days for germination and improving germination percentage. Similar trend was observed on growth parameters such as height of plant, girth of plant, number of leaves, leaf area, number of roots, fresh weight and dry weight of plant, and survival percentage. The interaction between soaking hours and organic treatments for all parameters were found to be non-significant.

Jack trees usually bear fruit in two main seasons, although offseason fruiting is common. Seeds can be collected from fruits of trees with outstanding growth and fruit qualities. Each fruit contains 100–500 seeds; there is no correlation between fruit size and the number of seeds it contains. Large and heavy seeds have better emergence, seedling survival and growth than small seeds (Armstrong and Westoby, 1993). There are about 50–90 seeds/kg. The thin, slimy coating around the seed (perianth lobe) should be removed and the seeds should be thoroughly rinsed in water to remove any remaining pulp juice or sugary residue. Only the largest seeds should be used, as these will give the earliest and highest germination and produce the strongest seedlings (Singh, 1982).

The effect of seed size on the germination and vigour of *Artocarpus heterophyllus* was investigated by Silva *et al*. (2010), in an experiment carried out in a screen nursery at 50 per cent shading in Mossoro, Rio Grande do Norte, Brazil. The treatments were, small (2.66 g), medium (4.15 g), large (5.22 g) and extra-large (5.94 g) seeds. The leaf number per plant, length and dry matter of aerial parts and root system, total dry matter, germination percentage and index of emergency speed were evaluated. The germination was influenced by the size of the seeds; the small seeds presenting lower germination percentage of 70 per cent, differing significantly from the other treatments (medium, large and extra-large seeds had 88 per cent, 96 per cent and 98 per cent, respectively). The vigour of the seeds presented direct relationship with the size, justifying the adoption of size classes for the formation of seedlings. Therefore, selection and classification of seeds should be recommended in the production of seedlings of *Artocarpus heterophyllus*.

Khan (2004) studied the effect of seed mass on performance of seedlings of *Artocarpus heterophyllus*, a shade-tolerant tree species in three contrasting light conditions. Resprouting capacity of seedlings was also investigated. In jack tree, seed mass varies from 1.5g to 14g. He observed that germination differed significantly among three light regimes (50 per cent, 25 per cent and 3 per cent). The seedlings that emerged from large seeds survived better than those from small seeds under all light regimes. Survival of seedlings was maximum in 25 per cent light regime for all seed mass classes but did not differ significantly from that at 50 per cent light regime. Survival was significantly lower in 3 per cent light as compared to 50 per cent and 25 per cent light regimes. Seedling vigour (expressed in terms of seedling height, leaf area and dry weight) was also significantly affected by seed mass and light regimes. Seedlings that emerged from larger seeds and grew under 50 per cent light regime produced the heaviest seedlings, while those resulting from smaller seeds and grown under 3 per cent light regime produced the lightest seedlings.

2.4 Seedling growth

Light is an important factor in plant growth and development because of its role in photosynthesis, development of leaves and shoot, flower initiation and fruit setting. The study of light intensity on plant development is essential for a complete understanding of the processes of dry matter production and its partitioning (Akinyele, 2007).

Bolanle-Ojo *et al.* (2018) investigated the morphological and physiological response of *Artocarpus heterophyllus* under different light intensities and watering regimes. One hundred and sixty (160) *Artocarpus heterophyllus* seedlings were used for this study. The light intensities used were 100 per cent, 75 per cent, 50 per cent and 25 per cent, and the watering regimes were watering every day, once in 3 days, once in 5 days and once in 7 days. Data were collected on plant height, collar diameter, number of leaves, root length, leaf dry weight, stem dry weight, root dry weight, total dry weight, shoot to root ratio (SRR), relative turgidity (RT per cent) and, chlorophyll a and b. It was observed that there was no significant difference in seedling height, collar diameter, leaf production, leaf, stem and total dry weight, and root length but significantly affected the root dry weight. SRR increased with the age of the seedlings. Chlorophyll a and b content of the leaves of the seedlings were significantly affected by varying light intensities and watering regimes. The result from this study has shown that *Artocarpus heterophyllus* can be easily raised in the nursery under different light intensities and little moisture stress.

Hossain and Kamaluddin (2011) studied the effect of light conditions on growth and morphology of stock plants and rooting ability of cuttings for mass clonal propagation of jackfruit without application of rooting hormone. Forty five days-old containerized stock plants were placed under three different levels of light: full sun (Red to far red ratio 1.25), partial shade (R: FR 1; 60 per cent of full sun) and deep shade (R: FR 0.4; 3 per cent of full sun) for 45 days. Half of the stock plants growing in partial shade and deep shade were transferred to full sun for another 15 days and growth and morphology of shoots and rooting ability of cuttings were investigated. Growth and morphology of shoots and rooting ability of cuttings were significantly affected by the growth light conditions of stock plants. Internode number was significantly fewer, but internode length, leaf area and specific leaf area was higher in deep shade and deep shade to full sun regime. Leaf weight per unit area decreased gradually, when sun-grown stock plants were transferred to deep shade or partial shade and regained on returning them from shade to full sun. Highest rooting percentage (100 per cent), maximum number of root (6.3) and root dry weight (62 mg) per cutting was obtained from cuttings of deep shade to full sun regime followed by deep shade and the lowest was in full sun regime without application of any rooting hormone.

The success of any plantation is determined by the growth of seedling in the nursery. Seedling parameters show significant difference among different seed sources in the nursery. This is evident from the study by Liu *et al.* (2002), where he compared seedling parameters like height, number of leaves, total biomass, root biomass, and diameter growth of *Camptotheca acuminata*, seedlings in eighteen provenances in China. There were significant differences among the 18 provenances in their height and diameter. Provenance 14 achieved the greatest height growth (114 cm), whereas provenance two was the shortest (71 cm). Significant differences in biomass production were found among the 18 provenances in the provenance test. Provenance four and eight attained greatest whole-plant biomass. The two provenances that produced the greatest shoot biomass were four and eight, whereas the two smallest were two and three. Provenance eight produced the most leaves at an average of 19.3 g per seedling, whereas provenance 17 and provenance two produced the least leaf biomass of 8.3 g and 8.0 g, respectively. For root biomass production, provenance four and nine topped the list among the 18 provenances attaining an average of over 13 g per seedling, whereas provenance 15 and three produced only half of that amount.

2.5 Anatomical properties

Wood formation process is a result of the action of environmental and genetic factors which act in varying degrees and therefore same factors are responsible for the variation in anatomical properties in wood. Most of the anatomical parameters vary significantly from the pith to periphery in a tree. According to Bhat *et* al. (2001), wood anatomical properties show variation in the region of juvenile and mature wood.

According to Anoop *et al.* (2005), wood of jack tree has vessels which are solitary and in radial multiples of two to three. The individual vessel outline appear to be circular in shape. The vessel element length ranges from 300 μm – 530 μm with a mean of 400 μm. Tangential diameter of vessel element ranges from 160 μm -270 μm with a mean of 220 μm. Parenchyma arrangement in the wood of jack tree is paratracheal, with aliform or confluent nature. Rays are multiseriate with height ranging from 370 μm – 890 μm with a mean of 610 μm. Fibres are thin walled and non-septate.

Toong *et al.* (2014) studied the prediction of wood properties from anatomical characteristics in common commercial Malaysian timbers and concluded that anatomical characteristics of the wood, namely vessel diameter, vessel grouping, vessel per square millimetre, fiber thickness, ray width, ray height, and ray per millimetre, were the factors that determined the properties of the wood.

2.5.1 Vessel morphology

Vessels are vertical series of cells with open ends placed one above the other. These are multicellular conduits that vary in length both within and among species. Vessel dimension was one of the major parameters studied in wood anatomical investigations.

Ewers and Fisher (1989) reported that liana vessels are considered to be the longest and widest in the plant kingdom. Anatomical examination of certain tropical and subtropical lianas has shown that larger diameter stems tend to have longer as well as wider vessels (*Pithecodenium crucigerum*).

Fahn and Werker (1990) reported that large vessels are not obligatory in lianas and quite a significant number possess small vessels. For eg. *Carissa ovata* and *Quintinia fawkneri* have mean vessel diameters of 44μm and 60 μm, respectively. Such a reduction in vessel diameter in lianas is compensated by an increase in vessel frequency so that, the proportion of vessels remains higher on an average than in trees.

It is possible to keep high conductivity and mechanical resistance by combining large vessel diameter with fibres whose walls provide the resistance required of the tissue as a whole (Tyree *et al.*, 1994)

Idu and Ijomah (1996) reported that variations in vessel width are significant for identification purposes in closely related species. Vessels are of importance not only for their primary roles but also for impregnation of wood with chemicals for preservation and pulping. Vessel width showed significant variation along the stem vertical axis.

Vessel morphology is very much dependent on environmental factors; Varghese *et al.* (2000) studied the variation in growth and wood traits among nine populations of Teak in peninsular India and found a significant variation in the size of vessel elements of the sample collected from Kalakkad (Tamilnadu) and Allappally (Maharashtra).

Vessel size is expected to affect growth positively because the water transporting capacity of vessels increases with their diameter to the fourth power according to Hagen-Poiseuille's law (Hacke and Sperry, 2001).

Positive association between vessel diameter and climate is usually interpreted as reflecting a response to environmental conditions. Conductively efficient, wide vessels are seen as adaptations to moist conditions, with more cavitation resistant narrow vessels expected to be favored in drier areas (Carlquist, 2001; Tyree & Zimmermann, 2002). An important factor potentially interfering with ecological trend in vessel diameter is age (Corcuera *et al.*, 2004). To maintain a favourable water balance, when the tree is growing and increasing its leaf surface, trees usually produce longer and wider vessels in their stems with age (Cruiziat *et al.*, 2002).

Larger diameter vessels are more efficient, while the opposite is true for vessels with small diameter (Alves and Angyalossy, 2002). Vessel diameter should not be linked with sap transport only; since it is also related to the woods with higher or lower mechanical resistance. Therefore, large diameter vessels can lead to weaker woods when compared to woods with smaller diameter vessels.

In xeric environments, increase in mechanical strength can be guaranteed by the presence of vessels and imperforate tracheary elements with very thick walls and narrow lumen (Sperry, 2003)

Schmitz *et al.* (2006) studied vessel characters in relation to salinity in mangroves and concluded that environmental responsiveness of vessel diameter to soil water salinity was remarkably low in either rainy or dry season. However, average vessel diameter appears just as clearly predicted by water availability across habitats. Variation in the diameters of vessels, is thought to be of central to adaptive importance (Sperry *et al.*, 2006).

Vessel lumen diameter (VLD) is another property which is having significant importance in wood anatomical studies. Vessel lumen diameter generally shows radial variation from centre to bark region. Studies reported similar variation trend for vessel lumen diameter, i.e. the vessel lumen diameter increases from pith to outwards. Tsuchiya and Furukawa (2008, 2009) studied the relationship between radial variation in vessel lumen diameter and the stages of the radial growth in two species namely *Castanea crenata* and *Quercus serrata* and reported that vessel lumen diameter increased during the early and the middle stage and become stable in the later stage.

2.5.2 Ray morphology

Rays are groups or strips of horizontally aligned parenchyma cells running in a radial direction from pith or centre of a log to the bark or periphery and are meant mainly for radial conduction and storage. They are present in all woods and are visible on the end surface as numerous, fine, whitish, or light coloured parallel lines at right angles to the growth marks. On the tangential surface, they appear as spindle shaped bodies arranged with their long axis vertical (Rao and Juneja, 1971).

Chalk (1955) mentioned that wood samples with narrow rays (eg. Uniseriate rays) have a smaller proportion of wood devoted to ray tissue whereas samples with wider rays have higher proportion of wood present as ray tissue. Novruzova (1972) claims a higher percentage of ray tissue in xerophytic species when compared with those in mesic sites.

Abundant presence of protein droplets within xylem ray parenchyma cells indicated that the ray tissue in the secondary xylem of woody plants plays an important role in the translocation, storage, and mobilization of nutrients (Sauter, 1982).

Rays are often ignored by wood technologists and forest geneticists. Ray tissue constitutes on an average about 17 per cent of the hardwood xylem, it may reach more than 30 per cent (Haygreen and Bowyer, 1982). Chimelo and Mattos-Filho (1988) in a study on Brazilian woods found wider rays in Brazilian Cerrado and Caatinga vegetation (xeric conditions) species than in more mesic forest species. Carlquist (1988) mentioned that more studies comparing the frequency of rays with environmental condition are necessary.

Ray tissue in hardwoods account up to 18 per cent and upwards. It shows considerable variation in both size and number of the rays. Lev (1998) studied the relationship between ray density and ray height in early wood of *Pinus haplensis* and *Pinus pinea.* He found that all the trees of *Pinus* species showed gradual tendency for increase and decrease in ray number and ray height from pith to periphery. A similar study in *Terminalia ivorensis* by Urbinati *et al.* (2003), indicated that ray frequency, length of rays show well defined trend of variation along radial stem direction.

Ray width is considered as a useful character for wood identification of species groups of maple group (*Acer spp.)* (Dakak *et al.*, 1999). Ray height and ray width were greater than in normal wood in wound altered wood of *Aspidosperma quebracho-blanco* (Bravo, 2010).

A study of anatomical properties of *Leucaena leucocephala* wood: effect on oriented strand board by Nazri *et al.* (2012), revealed that the anatomical properties were affected by age except for the number of vessels. Ray width increased by 21 per cent as the age increased from eight year old to sixteen year old. The number of ray cells also exhibited significant differences.

Histochemical and anatomical studies of jack tree concluded that, ray parenchyma was multiseriate consisted with 2 - 4 layers of rays and ray parenchyma showed abundant starch content. The xylem ray parenchyma cells contained more protein than the wood fibers and phloem parenchyma cells (Islam and Begum, 2012).

Presence of perforated ray cells in uniseriate to multiseriate rays in the wood of *Heuchera sanguinea* is important. Such cells function as conducting elements and usually connect vessels located at opposite sides of the ray. These cells are known to occur in lianas (Angyalossy *et al*., 2009, 2012).

2.5.3 Fibre morphology

Fiber, the basic component material in paper making, comprises of elongated, dead and hollow stem cells, which are classified as plant fibers (Page *et al*., 1972). The function of fiber is to provide mechanical support to the plant and help to transport photosynthetic products and water to the other parts of the plant. They occur either as isolated cells, clusters or in large masses (tissues) depending upon the type of plant (Kocurek and Stevens, 1983). Paper industry utilizes these fibers for producing paper, which finds applications in almost all activities of human life.

In pulp manufacture, strength characteristics are determined in part by fibre length. Increased fibre length leads to the production of paper with increased strength. During the manufacturing process, increased fibre length increases the strength of wet webs enabling easier handling (Seth, 1995). However, long fibres are not desirable for all applications. In some cases, shorter fibres are preferable, such as in the production of smooth-surfaced papers. Fibre properties differ between species, and consequently particular species have been limited historically to particular applications. Fibres from hardwood species are generally much shorter than those from softwoods. This results in the production of pulp and paper with desirable surface characteristics such as smoothness and brightness, but with low strength characteristics. In practice, where a single species is providing fiber with appropriate combination of characteristics has not been available, the mixing of long and short fibre from different species is used. If a single source is available, possessing the desirable characteristics plus optimal fibre length, this would be of great benefit to the processor.

It is well documented by wood technologists that the dimensions of wood fibre of a species vary in different climatic conditions which have direct impact on wood quality. Temperature affects the relationship between fibre wall thickness and fibre lumen and the number and size distribution of xylem vessels in seedlings and mature trees (Thomas *et al.*, 2004).

Fibre walls tend to be thicker in drier environments (Luchi *et al.*, 2005) because a stronger wood is necessary to support negative xylem pressures which reflects that thicker cell wall make the wood less vulnerable to cavitation and collapse.

Xylem of affected trees are characterised by the presence of crystalliferous fibres developed in the latewood. Formation of such fibres was not found in normal trees. Considerable structural variations occurred in the xylem of affected trees (Rajput *et al.*, 2008).

Deviations from optimum conditions or stresses influence how the fibre develops to the characteristic length and wall thickness. Conditions which produce longest fibres produce highest yields. Stress affects the plant and through the effect on the plant, affects the fibre. Fibre is usually less affected by stresses than other parts of plant (Ramey, 1986).

Recently Maiti *et al.* (2015) reported large variation in fibre cell morphology and its dimensions among 30 species of woody plants in Northeastern Mexico and its possible relation to wood quality and its utility. It is expected that species having long fibres produce strong wood or strong paper pulp. Species having high wall thickness are expected to produce strong fibre through high lignification.

Materials and Methods

3. MATERIALS AND METHODS

The present study was aimed at the selection of plus trees of *Artocarpus heterophyllus* Lam. from different regions of Thrissur and Palakkad districts through seed collection, raising of seedlings and their evaluation in the nursery. It was also aimed at assessing the farmers' perceptions towards growing jack as a timber species in homesteads of the study area. The study was conducted in the department of Forest Products and Utilisation, College of Forestry, Kerala Agricultural University, Vellanikkara.

Species under the study

Species: *Artocarpus heterophyllus* Lam.

Family: Moraceae

Order: Rosales

Jack tree is a prominent multipurpose tree in homegardens and other mixed species systems of southern India. They occur either as scattered trees in the farm fields and /or as trees on farm boundaries (Kumar et al., 1994). Although wild jack has not been considered a promising species for monocultural woodlots (Jamaludheen, 1994), this species shows impressive growth in polycultural systems. The tree also occurs naturally in the evergreen forests of the Western Ghats (peninsular India).

3.1 MATERIALS

The experimental materials for the study consisted of forty *Artocarpus heterophyllus* plus trees from Thrissur and Palakkad districts. Nursery experiments was carried out at College of Forestry, Vellanikkara.

3.1.1 Location

The present work was carried out in Thrissur district (10.5276° N, 76.2144° E) and Palakkad district (10.7867° N, 76.6548° E).

Table 1. Details of seed sources (*varikka*) used in the study

Location	Trees	Height (m)	Girth at Breast Height (cm)
Madakkathara	FCV AH 1	24	152
	FCV AH 2	22	126
Thrikkur	FCV AH 3	21	115
	FCV AH 4	16	108
Avinissery	FCV AH 5	19	90
	FCV AH 6	20	112
Vadanappally	FCV AH 7	21	118
	FCV AH 8	17	123
Adat	FCV AH 9	20	103
	FCV AH 10	19	110
Nalleppally	FCV AH 11	18	164
	FCV AH 12	15	110
Nenmara	FCV AH 13	21	180
	FCV AH 14	22	145
Vaniyamkulam	FCV AH 15	17	115
	FCV AH 16	16	119
Ongallur	FCV AH 17	19	101
	FCV AH 18	21	120
Mathur	FCV AH 19	23	91
	FCV AH 20	21	151

Table 2. Details of seed sources (*koozha*) used in the study.

Location	Trees	Height (m)	Girth at Breast Height (cm)
Madakkathara	FCV AH 21	18	178
	FCV AH 22	19	154
Thrikkur	FCV AH 23	18	159
	FCV AH 24	17	134
Avinissery	FCV AH 25	18	132
	FCV AH 26	21	127
Vadanappally	FCV AH 27	18	97
	FCV AH 28	17	128
Adat	FCV AH 29	20	122
	FCV AH 30	22	115
Nalleppally	FCV AH 31	16	87
	FCV AH 32	20	158
Nenmara	FCV AH 33	17	117
	FCV AH 34	16	146
Vaniyamkulam	FCV AH 35	18	94
	FCV AH 36	21	112
Ongallur	FCV AH 37	17	110
	FCV AH 38	20	126
Mathur	FCV AH 39	17	133
	FCV AH 40	16	117

3.1.2 Sources of progeny

Candidate Plus Trees (CPT) were selected according to the comparison tree method based on subjective grading. Five panchayats each were selected from both districts. The Candidate Plus Trees were identified from **Madakkathara, Thrikkur, Avinissery, Vadanappally** and **Adat** panchayats of Thrissur district and **Nalleppally, Nenmara, Vaniyamkulam, Ongallur** and **Mathur** panchayats of Palakkad district. From each panchayat, two Plus Trees each of Varikka variety and Koozha variety was selected from the CPTs identified. The selected Plus Trees were assigned with accession number FCV AH.

3.2 METHODS

3.2.1 Collection of seeds

Seeds were collected from the ripened fruits of selected Plus Trees. Thirty seeds from each plus trees were obtained. The seeds were cleaned and dried in shade before it was sown.

3.2.2 Seedling growth

In order to study the seedling performance in the nursery, seeds were sown directly into polybags (6"×8") by dibbling method. Polybags were filled with potting mixture of coir pith, soil, and manure in the ratio of 1:2:1. The polybags were kept in shade net in nursery located in College of Forestry, Kerala Agricultural University, Vellanikara, Thrissur. They were frequently watered by means of mist. The experimental design was CRD.

3.2.2.1 Seedling biometric observations

Four seedlings were selected at random from each replication to record the following observations at 30, 60, 90, 120 and 150 DAP (Days After Planting). First leaves were plucked for leaf area determination, then the seedlings were taken out with the root systems intact, washed thoroughly in water and dried.

40

1.a

1. b

1. c

1. d

1. e

1. f

Plate 1. Selected Plus trees of *Artocarpus heterophyllus* Lam. from Thrissur and Palakkad Districts. a. Madakkathara panchayat- *koozha*. b. Avinissery panchayat- *koozha*. c. Ongallur Panchayat- *koozha*. d. Vadanappally panchayat- *varikka*. e. Nenmara panchayat- *varikka*. f. Nalleppally panchayat- *varikka*.

Plate 2. Collection of seeds from mature ripened fruits

Plate 3. Leaf area estimation using Leaf Area Meter (Model LI-Cor, Nebraska, USA)

Plate 4. Estimation of root fresh weight using Weighing balance

Plate 5. Collection of wood samples using Increment borer

a. Shoot height

The height of the seedlings was measured using a meter scale from the collar to the terminal bud and was expressed in centimetres.

b. Collar diameter

The collar diameter of the seedling was measured by averaging two diametrically opposite values using Vernier caliper having least count of 0.02 mm expressed in millimetres.

c. Number of leaves

Number of fully opened (functional leaves) were counted and recorded.

d. Leaf surface area

The leaves collected were used to measure the leaf surface area using a Leaf Area Meter (Model LI3100 LI-Cor, Nebraska, USA) and expressed in cm^2.

e. Fresh weight of shoot

The shoot of seedlings collected at various time intervals were used to find the fresh weight of the shoot using an electronic balance and were expressed in grams.

f. Dry weight of shoot

After finding out the fresh weight, the shoot portion was dried in a hot air oven at a temperature of $70^0C \pm 2^oC$ for 48 hours. The dry weight also was recorded using an electronic balance. Drying and weighing were continued till constant weights obtained. The dry weight was expressed in grams.

g. Fresh weight of leaves

The leaves of seedlings collected in time intervals were used to find the fresh weight of the leaves using an electronic balance and were expressed in grams.

h. Dry weight of leaves

After finding out the fresh weight, the leaves were dried in hot air oven at a temperature of $70^0C \pm 2^oC$ for 48 hours. The dry weight also was recorded using an electronic balance. Drying and weighing were continued till constant weights obtained. The dry weight was expressed in grams.

i. Tap root length

The length of taproot was recorded using a meter scale, from collar to the tip of the tap root in cm.

j. Fresh weight of root

The fresh weight of root was taken using an electronic balance and was recorded in grams.

k. Dry weight of root

After finding out the fresh weight, the root portion was dried in hot air oven at a temperature of $70^0C \pm 2^oC$ for 48 hours. The dry weight also was recorded using an electronic balance. Drying and weighing were continued till constant weights obtained. The dry weight was expressed in grams.

Plate 6. Seedlings at 60 days after planting in the nursery

Plate 7. Seedlings at 150 days after planting in the nursery

Plate 8. Seedlings at 120 days after planting in the nursery uprooted for morphometric measurement.

Plate 9. Variation in taproot length of seedlings at 120 days after planting.

3.2.2.2 PLANT GROWTH ANALYSIS

Growth analysis can be used to account for growth in terms of functional or structural significance.

a. Leaf Area Ratio

Leaf Area Ratio (LAR) is the photosynthetic surface area per unit dry weight of a plant. It is a measure of the efficiency with which a plant deploys its photosynthetic resources. The term, suggested by Radford (1967), expresses the ratio between the area of leaf lamina to the total plant biomass or the LAR reflects the leafiness of a plant or amount of leaf area formed per unit of biomass and expressed in cm^2g^{-1} of plant dry weight.

$$\text{Leaf area ratio } = \frac{\text{Leaf area per plant}}{\text{Plant dry weight}}$$

b. Specific leaf Area

Specific leaf Area is a measure of leaf area of the plant to leaf dry weight and expressed in cm^2g^{-1}

$$\text{Specific leaf Area} = \frac{\text{Leaf area}}{\text{Leaf weight}}$$

c. Absolute Growth Rate

Absolute growth rate is the total gain in weight or height by a plant within a specific time interval. It is expressed as cm/day.

$$\text{Absolute Growth Rate} = \frac{h2 - h1}{t2 - t1}$$

Where,

h_2 – Plant height at time (t_2)

h_1 – Plant height at time (t_1)

d. Relative Growth Rate

Relative Growth Rate (RGR) expresses the total plant dry weight increase in a time interval in relation to the initial weight or Dry matter increment per unit biomass per unit time or grams of dry weight increase per gram of dry weight and expressed as unit dry weight/ unit dry weight/ unit time ($g\ g^{-1}\ day^{-1}$) (Williams, 1946)

$$\text{Relative Growth Rate} = \frac{\log_e W2 - \log_e W1}{t2 - t1}$$

Where,

W_1 – whole plant dry weight at time t_1

W_2- whole plant dry weight at time t_2

e. Net Assimilation Rate

NAR is defined as dry matter increment per unit leaf area or per unit leaf dry weight per unit of time (Williams, 1946). The NAR is a measure of the average photosynthetic efficiency of leaves in a crop community. NAR is expressed as the grams of dry weight increase per unit dry weight or area per unit time ($g\ g^{-1} day^{-1}$).

$$\text{Net Assimilation Rate} = \frac{(W2 - W1)}{(t2 - t1)} \times \frac{(\log_e L2 - \log_e L1)}{(L2 - L1)}$$

Where,

W_1 and W_2 are dry weight of the whole plant at time t_1 and t_2 respectively

L_1 and L_2 are leaf weights or leaf area at t_1 and t_2 respectively

t_1 - t_2 are time interval in days

3.2.3 ANATOMICAL STUDIES

3.2.3.1 Sectioning and Staining

Thin microscopic sections were taken from the collar region of the six month old seedlings and core samples of mature trees from Jack Gene Sanctuary at ARS Mannuthy to study the anatomical properties. Sections were taken using a sliding microtome (Leica SM-2000 R). All sections were put into water in a glass petridish. The sections were stained using the procedure outlined by Johansen (1940). The sections were stained using safranin and later washed through a series of alcohol solutions at different concentrations (70 per cent, 90 per cent and 95 per cent) to ensure complete dehydration. They were subsequently dipped in acetone followed by xylene and finally mounted in DPX mountant to prepare permanent slides.

3.2.3.2 Image analysis

Permanent slides were examined using an image analyser (CatCam 500E series) which is provided with a microscope, digital camera and a personal computer. Images of the sections were captured and then measurements including length, diameter, thickness and proportions of fibre, vessel and rays were made using the software Catymage.

3.2.3.3 VESSEL MORPHOLOGY

a. Vessel diameter

Vessel diameter was measured from the image of cross section taken in image analyser. Images were taken in 10X. For measuring vessel diameter, two readings were taken using line tool and its average was noted as the vessel diameter. Vessel diameter was expressed in micrometers (μm).

b. Vessel area

Vessel area was taken from the image taken in an image analyser. Observations were taken using an area tool. It was expressed in micrometer square (μm^2). The images were taken in 10X.

c. Vessel frequency

Vessel frequency was measured from the images taken in 10X from five replications of the sample using the following formula. The mean of the values of replications were taken as vessel frequency.

$$Vessel\ frequency = \frac{Number\ of\ vessel}{Area\ in\ sq.microns} \times 10^6$$

d. Ray height

From the tangential section of six month old stem, ray height was measured with the help of analysis software, Catymage and was expressed in micrometers (μm). Mean value was expressed as ray height.

e. Ray width

Ray width was measured using the line tool of analysis software, Catymage. Mean value of observations was expressed as Ray width in micrometers (μm).

f. Ray frequency

Ray frequency was measured from the images taken in 10X from five replications of the sample using the following formula;

$$Ray\ frequency = \frac{number\ of\ rays}{Area\ in\ sq.microns} \times 10^6$$

3.2.3.4 FIBRE MORPHOLOGY

3.2.3.4.1 Maceration

Six month old stem samples of two varieties from each location were macerated for measuring fibre characteristics such as fibre length, fibre width, lumen diameter and wall thickness. Maceration of the sample was done by Jeffrey's method, using Jeffry's solution. Jeffrey's solution was prepared by mixing 10 g Potassium dichromate and 14 ml Nitric acid. Chips of stem shavings were taken from the sample material. These chips were boiled in the maceration fluid for 15-20 minutes so that individual fibres were separated. Then these test tubes were kept for 5-10 minutes so that the fibres settled at the bottom. The solution was discarded and the resultant material was thoroughly washed in distilled water until traces of acid were removed. The samples were stained using safranin and mounted on a temporary slide using glycerine as the mountant. Temporary slides were observed under the microscope. Measurement of fibre dimension was carried out using an image analyser (CatCam 500E series).

a. Fibre length

Fibres obtained from maceration were observed under an image analyser. The line tool was used to measure the fibre length. The images were taken in 10X. It was measured in micrometers (µm).

b. Fibre width

Fibre width was measured from the images of sample taken in 40X using an image analyser. It was measured in micrometers (µm).

c. Lumen diameter

Lumen diameter of a fibre was measured from the images taken in 40X using an image analyser in micrometers (µm).

Plate 10. Establishing a field trial plot near the International Hostel at KAU, Vellanikkara.

Plate 11. Seedlings at 30 days after field planting.

d. Wall thickness

Wall thickness was measured by using the following formula

$$\text{Wall thickness} = \frac{\text{fibre width} - \text{lumen diameter}}{2}$$

3.2.4 Field planting

The seedlings were out planted one year after nursery growth for establishing a field trial plot, which was located near the International hostel at KAU, Vellanikkara. Three replications of each plus trees were planted at a spacing of 3 m × 3 m. A total of 115 seedling were planted. Seedling height and Collar Diameter were recorded 30 days after planting.

3.2.4.1 Plant height (cm)

Plant height was measured from ground level to the tip of the stem and expressed in cm.

3.2.4.2 Basal Diameter (mm)

The basal diameter was measured at the base of the stem (near the ground level) and expressed in mm.

3.2.5 Questionnaire Survey

A detailed survey was conducted by using structured questionnaire (Appendix I) to assess the farmers' perceptions towards growing jack tree as a timber species in the homesteads of the study area. The responses to each questions were plotted on a five point Likert scale indicating preferences, i.e.; strongly agree, agree, neutral, disagree and strongly disagree and were assigned scores 5,4,3,2 and 1 respectively.

3.2.6 Statistical analysis

The data were subjected to analysis using the statistical package IBM SPSS version-21.0 for windows. The Duncan's Multiple Range Test (DMRT) was used to test the differences among the treatment means at 5 per cent significance level, wherever the F-values were found to be significant. A hierarchical Cluster analysis was also carried out based on the Euclidian squared distance to group plus trees into different clusters. Questionnaire survey was analysed using Mann-Whitney test, a non-parametric test.

54

Results

4. RESULTS

The results of the seedling evaluation in the nursery of forty plus trees from different panchayats of Thrissur and Palakkad district along with anatomical studies are described in this chapter. The results of the questionnaire survey to analyse the farmers' perception towards growing jack tree as a timber species in homegardens will also be discussed here.

4.1 SEEDLING EVALUATION

4.1.1 Shoot Height

Shoot height was analysed for significant differences among the seedlings from different seed sources. Significant variations were found for shoot height at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 3). At 30 DAP, the mean height of all the seedlings was 27.32 cm. The highest value (35.55 cm) was recorded for seedlings from FCV AH 22 seed source and the lowest value (19.65 cm) for FCV AH 25. At 60 DAP, average height of seedlings from all seed sources was 45.33 cm. The highest (57.50 cm) value was observed in FCV AH 22 and the lowest (31.80 cm) in FCV AH 25. At 90 DAP, the overall mean height of the seedlings was 62.66 cm. FCV AH 23 was the tallest (79.50 cm) among the progenies and FCV AH 10 was having the shortest (46.85 cm). At 120 DAP, FCV AH 23 (96.85 cm) was having the highest and FCV AH 1 (61.10 cm) the lowest shoot height. The overall mean for shoot height at 120 DAP was 77.12 cm. The mean shoot height at 150 DAP was 90.02 cm with FCV AH 22 (123.10 cm) being the longest and FCV AH 1 (68.35 cm) the shortest.

4.1.2 Collar diameter

Analysis of variance was used to test the significant differences among the seedlings from different seed sources for collar diameter (Table 4). Significant variations were found for collar diameter at 30 DAP. The mean collar diameter at 30 DAP was 4.34 mm with the highest value for FCV AH 13 (5.94 mm) and the lowest one for FCV AH 34 at 3.25 mm. At 60 DAP, collar diameter showed significant difference among the progenies of different seed sources. The overall

Table 3. Variation in height (cm) of seedlings from different seed sources.

Seed Source	Seedling Height (cm)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AH 1	26.90^{fgh}	38.60^{nop}	49.45^{n}	61.10^{r}	68.35^{s}
FCV AH 2	29.00^{cdef}	53.25^{cd}	65.05^{ghi}	77.50^{hi}	82.55^{mno}
FCV AH 3	32.15^{abc}	56.20^{abc}	71.50^{de}	87.00^{cd}	97.95^{def}
FCV AH 4	26.10^{fghi}	46.85^{fgh}	64.65^{ghi}	73.50^{jk}	96.80^{def}
FCV AH 5	25.25^{fghi}	41.85^{jklmn}	56.10^{lm}	61.45^{qr}	73.25^{qr}
FCV AH 6	22.20^{ijk}	37.65^{op}	54.45^{m}	67.40^{mn}	86.95^{jklm}
FCV AH 7	25.50^{fghi}	39.45^{mnop}	56.80^{lm}	73.50^{jk}	91.35^{ghij}
FCV AH 8	24.35^{ghij}	50.95^{de}	70.35^{ef}	85.00^{de}	100.50^{cd}
FCV AH 9	27.60^{efg}	43.45^{hijkl}	64.95^{ghi}	81.50^{efg}	109.50^{b}
FCV AH 10	22.25^{ijk}	34.05^{qr}	46.85^{n}	62.70^{pqr}	73.45^{qr}
FCV AH 11	26.65^{fgh}	40.50^{lmnop}	54.85^{m}	63.55^{opqr}	70.70^{rs}
FCV AH 12	28.15^{defg}	46.00^{fghi}	62.00^{ijk}	73.05^{jk}	83.25^{lmn}
FCV AH 13	25.40^{fghi}	38.30^{nop}	56.05^{lm}	78.20^{ghi}	97.45^{def}
FCV AH 14	23.50^{hij}	42.85^{ijklm}	66.35^{gh}	85.15^{de}	94.75^{efgh}
FCV AH 15	34.30^{ab}	55.70^{abc}	73.10^{cde}	90.30^{bc}	102.95^{c}
FCV AH 16	26.90^{fgh}	46.90^{fgh}	59.50^{jkl}	78.75^{fghi}	89.95^{hijk}
FCV AH 17	31.50^{bcd}	54.40^{abcd}	74.50^{bcd}	86.80^{cd}	99.05^{cde}
FCV AH 18	24.50^{ghij}	45.30^{ghij}	64.20^{ghi}	78.85^{fghi}	85.90^{klm}
FCV AH 19	33.25^{ab}	56.30^{abc}	75.05^{bcd}	90.95^{b}	103.75^{c}
FCV AH 20	27.70^{defg}	49.45^{ef}	71.30^{de}	86.95^{cd}	95.65^{defg}
FCV AH 21	32.25^{abc}	45.05^{ghij}	56.70^{lm}	86.80^{cd}	111.45^{b}
FCV AH 22	35.55^{a}	57.50^{a}	77.95^{ab}	95.00^{a}	123.10^{a}
FCV AH 23	27.75^{defg}	56.95^{ab}	79.50^{a}	96.85^{a}	120.15^{a}
FCV AH 24	27.7^{defg}	38.25^{nop}	56.55^{lm}	82.50^{ef}	93.60^{fghi}
FCV AH 25	19.65^{k}	31.80^{r}	54.45^{m}	64.05^{nopqr}	75.95^{pq}
FCV AH 26	25.00^{ghi}	44.00^{hijkl}	74.30^{bcde}	81.40^{efg}	92.95^{fghi}
FCV AH 27	24.50^{ghij}	39.60^{mnop}	58.05^{lm}	75.00^{ijk}	87.90^{jkl}
FCV AH 28	25.35^{fghi}	40.50^{lmnop}	54.40^{m}	66.80^{mno}	76.50^{pq}
FCV AH 29	34.75^{ab}	51.30^{de}	76.65^{abc}	84.15^{de}	93.25^{fghi}
FCV AH 30	27.75^{defg}	41.00^{klmno}	57.05^{lm}	78.75^{fghi}	87.05^{jklm}
FCV AH 31	25.75^{fghi}	44.40^{ghijk}	57.55^{lm}	65.05^{nopq}	73.90^{qr}
FCV AH 32	25.70^{fghi}	40.75^{klmnop}	65.50^{ghi}	77.75^{ghi}	86.30^{jklm}
FCV AH 33	32.00^{abc}	51.50^{de}	67.05^{fg}	83.40^{de}	96.75^{def}
FCV AH 34	23.10^{hijk}	40.80^{klmnop}	58.50^{klm}	71.40^{kl}	80.95^{nop}
FCV AH 35	31.30^{bcde}	43.75^{hijkl}	56.90^{lm}	65.95^{mnop}	76.20^{pq}
FCV AH 36	33.10^{ab}	43.65^{hijkl}	56.50^{lm}	69.30^{lm}	80.50^{nop}
FCV AH 37	25.05^{fghi}	48.05^{efg}	54.2^{m}	67.50^{mn}	77.65^{opq}
FCV AH 38	20.75^{jk}	53.60^{bcd}	62.50^{hij}	72.35^{kl}	79.35^{nop}
FCV AH 39	24.95^{ghi}	37.10^{pq}	57.55^{lm}	76.30^{ij}	89.45^{ijk}
FCV AH 40	27.70^{defg}	45.65^{ghi}	67.50^{fg}	81.30^{efgh}	93.95^{efghi}
Mean	27.32	45.33	62.66	77.12	90.02
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

Table 4. Variation in collar diameter (mm) of seedlings from different seed sources.

Seed Source	Collar Diameter (mm)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	5.54^{ab}	5.40^{i}	6.81^{lm}	8.70^{kl}	11.19^{fghij}
FCV AH 2	3.96^{ijklmno}	6.34^{efgh}	7.02^{jkl}	8.80^{ijkl}	10.15^{klmn}
FCV AH 3	4.66^{efgh}	5.52^{i}	7.24^{jkl}	9.27^{fgh}	13.51^{b}
FCV AH 4	5.13^{bcdef}	5.51^{i}	8.09^{def}	10.00^{cd}	12.64^{c}
FCV AH 5	4.20^{ghijkl}	5.53^{i}	6.56^{mn}	9.77^{de}	11.83^{def}
FCV AH 6	3.45^{op}	7.16^{bc}	8.30^{cd}	9.42^{efgh}	10.71^{hijk}
FCV AH 7	3.35^{op}	3.89^{k}	4.75^{q}	5.88^{p}	7.18^{r}
FCV AH 8	4.81^{cdefg}	6.31^{efgh}	7.09^{jkl}	9.50^{efgh}	14.39^{a}
FCV AH 9	4.43^{ghij}	6.66^{def}	7.27^{ijk}	8.65^{l}	10.86^{ghijk}
FCV AH 10	3.70^{klmnop}	4.58^{j}	5.76^{n}	6.69^{o}	9.82^{lmno}
FCV AH 11	4.49^{fghi}	6.25^{fgh}	7.71^{fgh}	8.75^{jkl}	10.42^{jklm}
FCV AH 12	4.38^{ghij}	7.27^{b}	8.27^{cd}	9.59^{defgh}	10.45^{jklm}
FCV AH 13	5.94^{a}	6.91^{bcd}	8.53^{c}	10.35^{bc}	12.53^{cd}
FCV AH 14	4.42^{ghij}	6.75^{cde}	7.76^{efg}	8.39^{lm}	9.69^{mno}
FCV AH 15	4.44^{ghi}	5.61^{i}	6.83^{lm}	7.20^{n}	9.53^{no}
FCV AH 16	4.45^{ghi}	6.33^{efgh}	7.31^{hij}	8.46^{l}	9.08^{op}
FCV AH 17	4.68^{defgh}	5.34^{i}	6.22^{n}	8.52^{l}	10.35^{jklmn}
FCV AH 18	3.54^{mnop}	4.45^{j}	5.71^{n}	7.44^{n}	8.56^{pq}
FCV AH 19	4.41^{ghij}	6.49^{defgh}	7.65^{ghi}	9.38^{efgh}	10.29^{klmn}
FCV AH 20	4.51^{fghi}	6.08^{h}	7.81^{efg}	9.29^{efgh}	11.70^{efg}
FCV AH 21	4.24^{ghijkl}	6.27^{efgh}	8.52^{cd}	9.15^{hijk}	11.34^{fghi}
FCV AH 22	5.41^{abc}	6.64^{def}	9.29^{ab}	10.37^{bc}	13.61^{ab}
FCV AH 23	3.66^{lmnop}	6.53^{defgh}	7.21^{jkl}	9.19^{ghij}	10.90^{ghijk}
FCV AH 24	4.13^{hijklm}	5.53^{i}	7.20^{jkl}	9.37^{efgh}	13.40^{b}
FCV AH 25	3.45^{op}	4.51^{j}	5.34^{p}	6.40^{o}	7.86^{qr}
FCV AH 26	3.47^{nop}	5.38^{i}	6.28^{n}	7.18^{n}	8.55^{pq}
FCV AH 27	4.11^{hijklmn}	5.41^{i}	6.85^{klm}	9.26^{fghi}	11.65^{efg}
FCV AH 28	3.35^{op}	4.47^{j}	7.22^{jkl}	7.98^{m}	9.25^{op}
FCV AH 29	4.67^{efgh}	6.16^{gh}	7.21^{jkl}	9.18^{ghij}	14.35^{a}
FCV AH 30	4.24^{ghijkl}	6.32^{efgh}	8.32^{cd}	9.40^{efgh}	10.36^{jklmn}
FCV AH 31	5.20^{bcde}	6.36^{efgh}	8.35^{cd}	9.72^{def}	10.34^{jklmn}
FCV AH 32	4.31^{ghijkl}	5.34^{i}	7.65^{ghi}	9.57^{defgh}	11.44^{fgh}
FCV AH 33	4.26^{ghijkl}	7.15^{bc}	9.26^{ab}	10.47^{b}	11.67^{efg}
FCV AH 34	3.25^{p}	6.57^{defg}	8.44^{cd}	9.72^{def}	11.16^{fghij}
FCV AH 35	4.71^{defgh}	6.70^{def}	8.37^{cd}	9.66^{defg}	10.34^{jklmn}
FCV AH 36	4.54^{fghi}	6.44^{defgh}	7.70^{fgh}	9.46^{efgh}	10.57^{ijkl}
FCV AH 37	5.32^{bcd}	6.50^{defgh}	8.14^{cde}	9.48^{efgh}	11.67^{efg}
FCV AH 38	3.76^{jklmnop}	6.65^{def}	9.60^{a}	11.70^{a}	13.67^{ab}
FCV AH 39	4.34^{ghijk}	6.59^{defg}	9.17^{b}	10.35^{bc}	12.35^{cde}
FCV AH 40	4.71^{defgh}	8.62^{a}	9.10^{b}	10.65^{b}	12.51^{cd}
Mean	4.34	6.06	7.55	9.06	11.05
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

mean collar diameter was 6.06 mm with FCV AH 40 (8.62 mm) having the highest and FCV AH 7 (3.89 mm) having the lowest collar diameter. At 90 DAP, significant variation was found between the collar diameter of *Artocarpus heterophyllus* seedlings. The highest value was for FCV AH 38 (9.60 mm) and the lowest was for FCV AH 7 (4.75 mm). The mean collar diameter at 90 DAP was 7.55 mm. There was significant difference in the collar diameter measurements taken at 120 DAP. The overall mean value for collar diameter was 9.06 mm with FCV AH 38 (11.70 mm) having the highest and FCV AH 7 (5.88 mm) having the lowest. At 150 DAP, there was significant difference between the collar diameters of seedlings from the different seed sources. The highest value for collar diameter was for FCV AH 8 (14.39 mm) and the lowest for FCV AH 7 (7.18 mm). The mean collar diameter at 150 DAP was 11.05 mm.

4.1.3 Taproot length

Taproot length of *Artocarpus heterophyllus* seedlings were analysed for variation among the different seed sources. The results revealed significant difference over time (Table 5). Variations in taproot length for the different seed sources were significant at 30 DAP, 60 DAP and 90 DAP but did not show any significant difference at 120 DAP and 150 DAP. At 30 DAP, the mean taproot length of all the seedlings was 16.09 cm. The highest value (21.50 cm) was recorded for seedlings from FCV AH 29 seed source and the lowest (11.90 cm) for FCV AH 25. At 60 DAP, the average length of taproot from all the sources was 24.64 cm. The longest (28.80 cm) taproot length was observed in FCV AH 7 and shortest (19.75 cm) in FCV AH 17. At 90 DAP, the mean taproot length of the seedlings was 30.49 cm. FCV AH 5 had the longest (37.00 cm) among the progenies and FCV AH 31 (26.25 cm) was having the shortest taproot length at 90 DAP. At 120 DAP, FCV AH 3 (40.00 cm) was having the highest value and FCV AH 13 (28.30 cm) the lowest value for taproot length. The overall mean for taproot length at 120 DAP was 34.46 cm. The mean taproot length at 150 DAP was 38.39 cm with FCV AH 2 (48.85 cm) being the longest and FCV AH 14 (30.45 cm) the shortest.

59

Table 5. Variation in taproot length (cm) of seedlings from different seed sources.

Seed Source	Taproot Length (cm)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AH 1	$18.05^{bcdefgh}$	25.15^{abcdef}	32.75^{abcde}	34.60	42.65
FCV AH 2	$17.00^{cdefghi}$	25.85^{abcdef}	33.90^{abcd}	39.55	48.85
FCV AH 3	$15.50^{ghijklmn}$	$24.35^{abcdefg}$	35.55^{ab}	40.00	39.95
FCV AH 4	$16.25^{efghijkl}$	23.55^{bcdefg}	30.45^{abcde}	36.60	38.20
FCV AH 5	12.65^{no}	25.35^{abcdef}	37.00^{a}	29.90	38.90
FCV AH 6	$14.35^{ijklmno}$	27.90^{abc}	32.50^{abcde}	39.80	40.85
FCV AH 7	13.05^{mno}	28.80^{a}	31.05^{abcde}	35.00	39.75
FCV AH 8	$15.80^{fghijklm}$	$24.90^{abcdefg}$	29.95^{abcde}	37.10	33.60
FCV AH 9	19.15^{abcde}	25.05^{abcdef}	28.35^{cde}	29.05	35.55
FCV AH 10	$14.05^{ijklmno}$	26.30^{abcdef}	30.40^{abcde}	31.72	39.95
FCV AH 11	$17.75^{bcdefgh}$	$24.70^{abcdefg}$	26.25^{e}	35.70	37.25
FCV AH 12	21.05^{a}	21.70^{fg}	28.85^{bcde}	31.85	35.10
FCV AH 13	$16.15^{efghijkl}$	22.55^{defg}	35.90^{ab}	28.30	36.00
FCV AH 14	20.25^{ab}	23.10^{cdefg}	28.15^{cde}	33.05	30.45
FCV AH 15	$14.00^{ijklmno}$	27.05^{abcde}	27.1^{de}	34.50	38.35
FCV AH 16	13.85^{jklmno}	27.25^{abcde}	26.95^{de}	30.15	40.70
FCV AH 17	18.85^{abcdef}	19.75^{g}	29.70^{bcde}	32.50	33.75
FCV AH 18	$15.00^{hijklmn}$	23.30^{cdefg}	30.40^{abcde}	33.65	35.55
FCV AH 19	19.75^{abc}	$24.35^{abcdefg}$	33.85^{abcd}	35.95	37.65
FCV AH 20	$17.01^{cdefghi}$	$24.25^{abcdefg}$	29.20^{bcde}	33.35	42.20
FCV AH 21	18.10^{bcdefg}	$24.90^{abcdefg}$	28.35^{cde}	31.40	39.60
FCV AH 22	$17.70^{bcdefgh}$	19.8^{g}	30.90^{abcde}	33.30	39.00
FCV AH 23	$14.05^{ijklmno}$	$24.75^{abcdefg}$	31.20^{abcde}	35.70	34.05
FCV AH 24	$15.05^{ghijklmn}$	23.55^{bcdefg}	33.75^{abcd}	38.10	38.50
FCV AH 25	11.90^{o}	25.50^{abcdef}	33.30^{abcde}	36.12	42.00
FCV AH 26	13.55^{klmno}	25.85^{abcdef}	32.45^{abcde}	36.10	38.50
FCV AH 27	13.50^{lmno}	$24.55^{abcdefg}$	31.05^{abcde}	37.00	37.45
FCV AH 28	$15.05^{ghijklmn}$	$24.85^{abcdefg}$	29.95^{abcde}	35.85	36.90
FCV AH 29	21.50^{a}	28.65^{ab}	28.35^{cde}	36.45	37.45
FCV AH 30	18.85^{abcdef}	22.20^{efg}	30.40^{abcde}	31.20	36.95
FCV AH 31	13.70^{jklmno}	22.55^{defg}	26.25^{e}	35.00	38.90
FCV AH 32	11.95^{o}	22.75^{cdefg}	28.85^{bcde}	37.30	40.85
FCV AH 33	$16.65^{defghij}$	$24.25^{abcdefg}$	27.05^{de}	36.05	39.75
FCV AH 34	13.65^{jklmno}	$23.85^{abcdefg}$	28.95^{bcde}	32.60	33.60
FCV AH 35	$15.10^{ghijklmn}$	$24.30^{abcdefg}$	28.90^{bcde}	32.95	35.55
FCV AH 36	$16.60^{efghijk}$	27.55^{abcd}	29.30^{bcde}	34.90	40.25
FCV AH 37	$16.50^{efghijkl}$	26.40^{abcdef}	28.35^{cde}	35.70	41.25
FCV AH 38	$15.35^{ghijklmn}$	25.80^{abcdef}	34.90^{abc}	34.30	39.50
FCV AH 39	19.65^{abcd}	$24.50^{abcdefg}$	30.00^{abcde}	33.85	38.95
FCV AH 40	$15.90^{fghijklm}$	$23.75^{abcdefg}$	29.05^{bcde}	32.05	41.50
Mean	16.09	24.64	30.49	34.46	38.39
P	<0.001**	0.030*	0.040*	0.077^{ns}	0.353^{ns}

**Significant at 5 per cent level, ** significant at 1 per cent level and 'ns' indicate non-significant*

Values with the same superscript along the column are homogenous

4.1.4 Fresh weight of stem

The fresh weight of stem showed significant variations in *Artocarpus heterophyllus* seedlings from different seed sources at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 6). At 30 DAP, the mean fresh weight of stem of all the seedlings was 2.63 g. The highest value (3.40 g) was recorded for seedlings from FCV AH 37 seed source and the lowest (1.69 g) for FCV AH 14. At 60 DAP, the average fresh weight of stem from all the sources was 6.93 g. The highest (8.95 g) fresh weight of stem was observed in FCV AH 9 and lowest (5.02 g) in FCV AH 19. At 90 DAP, the mean fresh weight of stem of the seedlings was 14.73 g. FCV AH 15 had the highest (18.35 g) stem fresh weight among the progenies and FCV AH 1 (7.64 g) was having the lowest fresh weight of stem at 90 DAP. At 120 DAP, FCV AH 27 (26.65 g) was having the highest and FCV AH 1 (12.34 g) the lowest fresh weight of stem. The overall mean for fresh weight of stem at 120 DAP was 21.05 g. The mean fresh weight of stem at 150 DAP was 25.85 g with FCV AH 4 (33.88 g) being the highest and FCV AH 1 (17.84 g) the lowest.

4.1.5 Fresh weight of leaves

The fresh weight of leaves was analysed for variation between the different seed sources. The results revealed significant difference in fresh weight of leaves due to different seed sources over time (Table 7). Significant variations were found at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP. At 30 DAP, the mean fresh weight of leaves of all the seedlings was 1.7 g. The highest value (3.41 g) was recorded for seedlings from FCV AH 22 seed source and the lowest (0.70 g) for FCV AH 25. At 60 DAP, the average fresh weight of leaves from all the sources was 6.65 g. The highest (9.55 g) fresh weight of leaves was observed in FCV AH 4 and lowest (4.34 g) in FCV AH 25. At 90 DAP, the mean fresh weight of leaves of the seedlings was 11.17 g. FCV AH 27 was the highest (13.56 g) among the progenies and FCV AH 15 (8.90 g) was having the lowest fresh weight of leaves at 90 DAP. At 120 DAP, FCV AH 27 (17.83 g) was having the highest and FCV AH 25 (11.32 g) the lowest fresh weight of leaves. The overall mean for fresh

Table 6. Variation in stem fresh weight (g) of seedlings from different seed sources

Seed source	**Fresh Weight of Stem (g)**				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	3.39^{ab}	5.83^{klmn}	7.64^{s}	12.34^{p}	17.84^{p}
FCV AH 2	2.49^{efghi}	7.89^{cdef}	10.59^{q}	16.63^{mno}	21.33^{no}
FCV AH 3	2.59^{defghi}	6.23^{jklm}	15.07^{hij}	25.62^{ab}	29.76^{cde}
FCV AH 4	2.58^{defghi}	6.69^{ghij}	16.12^{defgh}	26.52^{a}	33.88^{a}
FCV AH 5	2.41^{fghij}	7.39^{efgh}	12.86^{mnop}	17.10^{lmno}	21.25^{no}
FCV AH 6	2.43^{fghij}	6.52^{ijk}	16.15^{defgh}	24.65^{abcd}	28.36^{def}
FCV AH 7	$2.65^{cdefghi}$	7.28^{efghi}	12.04^{p}	17.92^{lm}	23.13^{lmn}
FCV AH 8	3.24^{abcd}	7.77^{cdef}	14.45^{ijk}	22.02^{fghi}	29.09^{cde}
FCV AH 9	2.38^{fghij}	8.95^{a}	18.22^{a}	25.84^{ab}	32.31^{ab}
FCV AH 10	1.80^{jk}	8.04^{bcde}	15.68^{efgh}	17.83^{lm}	21.01^{no}
FCV AH 11	$2.65^{cdefghi}$	7.91^{cdef}	12.21^{op}	15.64^{no}	17.68^{p}
FCV AH 12	$2.79^{abcdefghi}$	5.54^{lmno}	13.84^{klmn}	18.55^{klm}	21.23^{no}
FCV AH 13	2.50^{efghi}	6.24^{jklm}	17.98^{ab}	26.05^{ab}	29.63^{cde}
FCV AH 14	1.69^{k}	5.50^{mno}	12.69^{nop}	18.31^{lm}	22.39^{mno}
FCV AH 15	2.37^{fghij}	8.78^{ab}	18.35^{a}	26.36^{a}	33.24^{a}
FCV AH 16	2.19^{ijk}	8.06^{bcde}	16.33^{defg}	17.88^{lm}	20.86^{o}
FCV AH 17	$2.71^{cdefghi}$	6.01^{jklmn}	9.41^{r}	15.69^{no}	25.09^{ijkl}
FCV AH 18	2.18^{ijk}	5.34^{no}	9.49^{r}	15.17^{o}	24.91^{ijkl}
FCV AH 19	$2.84^{abcdefghi}$	5.02^{o}	12.77^{mnop}	17.56^{lmn}	22.29^{mno}
FCV AH 20	2.61^{defghi}	6.61^{hijk}	12.71^{nop}	17.95^{lm}	24.21^{jklm}
FCV AH 21	$2.94^{abcdefgh}$	5.39^{no}	17.32^{abcd}	21.99^{fghi}	25.95^{ghij}
FCV AH 22	3.32^{abc}	7.39^{efgh}	16.85^{bcde}	24.50^{abcde}	27.73^{efgh}
FCV AH 23	2.56^{efghi}	6.29^{jkl}	12.19^{op}	17.34^{lmn}	23.15^{lmn}
FCV AH 24	$2.74^{abcdefghi}$	7.12^{fghi}	15.29^{fghi}	17.93^{lm}	24.93^{ijkl}
FCV AH 25	2.36^{ghij}	5.345^{no}	16.49^{def}	18.67^{klm}	24.77^{ijkl}
FCV AH 26	$2.99^{abcdefg}$	7.76^{cdef}	17.9^{abc}	22.02^{fghi}	26.31^{fghij}
FCV AH 27	3.17^{abcde}	6.28^{jklm}	16.58^{de}	26.65^{a}	26.60^{fghi}
FCV AH 28	2.63^{defghi}	7.58^{def}	13.111^{mnop}	20.50^{ijk}	25.84^{ghijk}
FCV AH 29	2.53^{efghi}	6.31^{jkl}	15.64^{efgh}	23.51^{cdefg}	28.96^{de}
FCV AH 30	1.80^{jk}	6.31^{jkl}	14.13^{jkl}	26.15^{a}	31.18^{bc}
FCV AH 31	$2.72^{bcdefghi}$	6.56^{ijk}	15.22^{ghij}	23.94^{bcdef}	27.94^{efg}
FCV AH 32	3.05^{abcdef}	7.62^{def}	16.33^{defg}	25.38^{abc}	28.42^{def}
FCV AH 33	$2.81^{abcdefghi}$	8.24^{abcd}	17.78^{abc}	25.90^{ab}	30.31^{bcd}
FCV AH 34	2.44^{fghij}	7.40^{efgh}	16.19^{defgh}	20.91^{hij}	25.94^{ghij}
FCV AH 35	$2.94^{abcdefgh}$	7.59^{def}	15.90^{efgh}	23.97^{bcdef}	26.44^{fghij}
FCV AH 36	2.60^{defghi}	6.75^{ghij}	13.36^{klmno}	21.67^{ghi}	26.74^{fghi}
FCV AH 37	3.40^{a}	7.45^{defg}	13.89^{klm}	19.17^{jkl}	23.65^{klm}
FCV AH 38	2.33^{ghijk}	8.50^{abc}	16.77^{cde}	22.73^{defgh}	27.53^{efgh}
FCV AH 39	2.30^{hijk}	7.17^{fghi}	17.93^{ab}	22.48^{efghi}	26.50^{fghij}
FCV AH 40	$2.84^{abcdefghi}$	6.49^{ijk}	15.77^{efgh}	20.98^{hij}	25.64^{hijk}
Mean	2.63	6.93	14.73	21.05	25.85
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

Table 7. Variation in leaf fresh weight (g) of seedlings from different seed sources.

Seed source	Fresh Weight of Leaf (g)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	$1.60^{bcdefghi}$	5.23^{ghij}	12.97^{abcd}	14.19^{bcdefg}	15.36^{defgh}
FCV AH 2	0.99^{ghi}	$6.98^{bcdefgh}$	9.69^{ghi}	13.30^{efgh}	16.56^{cdefgh}
FCV AH 3	$1.83^{bcdefghi}$	6.48^{cdefgh}	10.13^{efghi}	14.19^{bcdefg}	19.53^{bcde}
FCV AH 4	$1.91^{bcdefghi}$	9.55^{a}	$11.57^{abcdefghi}$	14.49^{bcdefg}	18.32^{bcdefg}
FCV AH 5	$2.045^{bcdefgh}$	7.81^{abcd}	9.82^{efghi}	12.96^{gh}	15.08^{efgh}
FCV AH 6	$1.56^{bcdefghi}$	$6.11^{defghij}$	$11.90^{abcdefgh}$	13.83^{defgh}	18.73^{bcdefg}
FCV AH 7	1.19^{defghi}	$6.22^{defghij}$	9.83^{efghi}	12.90^{gh}	14.66^{efghi}
FCV AH 8	2.67^{abc}	9.39^{a}	13.095^{abcd}	16.20^{abcde}	22.04^{ab}
FCV AH 9	2.46^{abcd}	6.55^{cdefgh}	$9.80f^{ghi}$	13.01^{gh}	16.60^{cdefgh}
FCV AH 10	$1.59^{bcdefghi}$	7.33^{bcdef}	$11.77^{abcdefgh}$	$15.32^{abcdefg}$	19.33^{bcdef}
FCV AH 11	$2.20^{abcdefg}$	5.31^{fghij}	9.71^{ghi}	12.93^{gh}	10.08^{ij}
FCV AH 12	$1.90^{bcdefghi}$	7.34^{bcde}	13.51^{ab}	16.87^{abc}	20.88^{abc}
FCV AH 13	1.23^{defghi}	$7.01^{bcdefgh}$	$12.00^{abcdefgh}$	16.48^{abcd}	16.56^{cdefgh}
FCV AH 14	1.01^{ghi}	$6.90^{bcdefgh}$	10.05^{efghi}	13.45^{efgh}	14.64^{efghi}
FCV AH 15	1.18^{defghi}	5.69^{efghij}	8.90^{i}	14.49^{bcdefg}	20.34^{bcd}
FCV AH 16	1.16^{efghi}	5.73^{efghij}	10.09^{efghi}	14.37^{bcdefg}	15.39^{defgh}
FCV AH 17	$2.10^{bcdefgh}$	7.15^{bcdefg}	$10.80^{bcdefghi}$	$15.26^{abcdefg}$	19.60^{bcde}
FCV AH 18	1.27^{defghi}	7.10^{bcdefg}	$11.10^{abcdefghi}$	16.15^{abcde}	16.92^{cdefgh}
FCV AH 19	2.70^{ab}	8.27^{abc}	12.54^{abcde}	16.16^{abcde}	16.61^{cdefgh}
FCV AH 20	$1.60^{bcdefghi}$	$7.02^{bcdefgh}$	$11.10^{abcdefghi}$	$15.63^{abcdefg}$	$17.77^{bcdefgh}$
FCV AH 21	$1.84^{bcdefghi}$	$6.85^{bcdefgh}$	$11.92^{abcdefgh}$	$15.57^{abcdefg}$	16.95^{cdefgh}
FCV AH 22	3.41^{a}	$6.87^{bcdefgh}$	$10.94^{abcdefghi}$	16.04^{abcde}	25.11^{a}
FCV AH 23	$1.76^{bcdefghi}$	7.44^{bcde}	10.71^{defghi}	16.14^{abcde}	16.49^{cdefgh}
FCV AH 24	0.91^{hi}	$6.88^{bcdefgh}$	8.91^{i}	13.33^{efgh}	18.96^{bcdefg}
FCV AH 25	0.70^{i}	4.34^{j}	9.98^{efghi}	11.32^{h}	9.02^{j}
FCV AH 26	1.17^{efghi}	4.54^{ij}	9.37^{hi}	13.32^{efgh}	13.31^{hij}
FCV AH 27	1.14^{fghi}	$6.67^{bcdefgh}$	13.56^{a}	17.83^{a}	18.82^{bcdefg}
FCV AH 28	$2.20^{abcdefg}$	7.26^{bcdef}	$11.93^{abcdefgh}$	16.91^{abc}	17.08^{cdefgh}
FCV AH 29	$1.65^{bcdefghi}$	7.47^{bcde}	12.96^{abcd}	17.61^{a}	16.54^{cdefgh}
FCV AH 30	2.41^{abcdef}	8.60^{ab}	12.53^{abcdef}	16.44^{abcd}	16.43^{cdefgh}
FCV AH 31	$1.40^{cdefghi}$	5.04^{hij}	13.44^{abc}	15.93^{abcdef}	19.42^{bcdef}
FCV AH 32	$1.63^{bcdefghi}$	4.43^{j}	$10.75^{cdefghi}$	13.08^{fgh}	14.49^{fghi}
FCV AH 33	$2.06^{bcdefgh}$	4.53^{ij}	$11.58^{abcdefghi}$	16.98^{ab}	19.48^{bcdef}
FCV AH 34	0.94^{ghi}	5.69^{efghij}	$11.76^{abcdefgh}$	$15.73^{abcdefg}$	16.68^{cdefgh}
FCV AH 35	2.44^{abcde}	$6.71^{bcdefgh}$	$11.69^{abcdefgh}$	16.95^{abc}	20.44^{bc}
FCV AH 36	$1.87^{bcdefghi}$	$6.07^{defghij}$	9.41^{hi}	14.06^{cdefgh}	17.04^{cdefgh}
FCV AH 37	0.72^{i}	7.12^{bcdefg}	$10.72^{cdefghi}$	$15.12^{abcdefg}$	16.61^{cdefgh}
FCV AH 38	1.02^{ghi}	$6.82^{bcdefgh}$	$12.18^{abcdefg}$	16.04^{abcde}	22.19^{ab}
FCV AH 39	$1.66^{bcdefghi}$	$6.07^{defghij}$	10.13^{efghi}	14.24^{bcdefg}	14.20^{ghi}
FCV AH 40	2.81^{ab}	7.17^{bcdefg}	$11.97^{abcdefgh}$	$15.76^{abcdefg}$	16.74^{cdefgh}
Mean	1.7	6.65	11.17	15.02	17.28
P	0.001**	<0.001**	0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

weight of leaves at 120 DAP was 15.02 g. The mean fresh weight of leaves at 150 DAP was 17.28 g with FCV AH 22 (25.22 g) being the highest and FCV AH 25 (9.02 g) the lowest.

4.1.6 Fresh weight of root

Analysis of variance revealed significant difference in fresh weight of root at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 8). At 30 DAP, the mean fresh weight of root of all the seedlings was 1.01 g. The highest value (1.70 g) was recorded for seedlings from FCV AH 1 seed source and the lowest (0.25 g) for FCV AH 14. At 60 DAP, the average fresh weight of root from all the sources was 3.35 g. The highest (5.23 g) fresh weight of root was observed in FCV AH 29 and lowest (1.53 g) in FCV AH 32. At 90 DAP, the mean fresh weight of root of the seedlings was 5.57 g. FCV AH 29 was having the highest value (7.19 g) among the progenies and FCV AH 1 (4.12 g) was having the lowest fresh weight of root at 90 DAP. At 120 DAP, FCV AH 22 (17.19 g) was having the highest and FCV AH 25 (6.06 g) the lowest fresh weight of root. The overall mean for fresh weight of root at 120 DAP was 11.89 g. The mean fresh weight of root at 150 DAP was 16.67 g with FCV AH 15 (25.25 g) being the highest and FCV AH 25 (7.42 g) the lowest.

4.1.7 Dry weight of stem

Significant difference in dry weight of stem was found during the analysis at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 9).). At 30 DAP, the mean dry weight of stem of all the seedlings was 0.39 g. The highest value (0.57 g) was recorded for seedlings from FCV AH 11 seed source and the lowest (0.22 g) for FCV AH 6. At 60 DAP, the average dry weight of stem from all the sources was 1.81 g. The highest (2.61 g) dry weight of stem was observed in FCV AH 15 and lowest (1.01 g) in FCV AH 19. At 90 DAP, the mean dry weight of stem of the seedlings was 4.95 g. FCV AH 32 was the highest (7.58 g) among the progenies and FCV AH 20 (3.13 g) was having the lowest dry weight of stem at 90 DAP. At 120 DAP, FCV AH 4 (10.46 g) was having the highest and FCV AH 1 (4.56 g) the

64

Table 8. Variation in root fresh weight (g) of seedlings from different seed sources.

Seed source	Fresh Weight of Root (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AH 1	1.70^{a}	2.56^{ghij}	4.12^{l}	11.63^{ijkl}	16.22^{ghijkl}
FCV AH 2	$1.10^{bcdefghi}$	3.45^{cdefg}	$5.55^{defghijk}$	11.15^{lm}	14.33^{mnop}
FCV AH 3	1.60^{ab}	2.61^{efghi}	$5.40^{defghijk}$	9.30^{p}	13.91^{nopq}
FCV AH 4	$0.91^{efghijkl}$	3.72^{bcdef}	4.89^{hijkl}	15.07^{c}	23.71^{ab}
FCV AH 5	$1.16^{abcdefghi}$	3.75^{bcde}	$5.23^{efghijk}$	13.11^{efg}	16.81^{fghi}
FCV AH 6	0.61^{ijklmn}	2.98^{efghi}	$5.24^{efghijk}$	13.11^{efg}	24.78^{ab}
FCV AH 7	$0.70^{ghijklmn}$	3.65^{bcdefg}	$5.68^{defghij}$	11.52^{jklm}	18.85^{de}
FCV AH 8	1.39^{abcdef}	4.39^{abc}	6.14^{bcdef}	14.70^{c}	16.95^{fghi}
FCV AH 9	$0.79^{ghijklmn}$	3.48^{cdefg}	$5.34^{defghijk}$	13.52^{de}	18.69^{de}
FCV AH 10	$0.97^{cdefghijk}$	4.43^{abc}	$5.92^{bcdefgh}$	12.65^{fgh}	17.13^{efghi}
FCV AH 11	1.69^{a}	3.41^{cdefg}	$5.27^{defghijk}$	11.55^{jklm}	16.24^{ghijkl}
FCV AH 12	1.50^{abc}	3.39^{cdefg}	6.25^{abcde}	12.34^{ghi}	14.70^{lmno}
FCV AH 13	$0.84^{fghijklm}$	3.22^{defgh}	$5.71^{defghij}$	16.43^{b}	24.59^{ab}
FCV AH 14	0.25^{n}	3.67^{bcdefg}	$5.74^{defghij}$	8.24^{q}	11.07^{rs}
FCV AH 15	$0.69^{hijklmn}$	2.81^{efghi}	4.98^{ghijkl}	15.04^{c}	25.25^{a}
FCV AH 16	$0.81^{ghijklmn}$	2.56^{ghij}	4.82^{ijkl}	10.18^{no}	16.88^{fghi}
FCV AH 17	$1.19^{abcdefgh}$	3.47^{cdefg}	$5.66^{defghij}$	11.45^{klm}	18.18^{def}
FCV AH 18	$0.92^{defghijkl}$	3.30^{cdefgh}	5.01^{ghijkl}	9.76^{op}	12.53^{qr}
FCV AH 19	$1.21^{abcdefgh}$	3.05^{efghi}	$5.39^{defghijk}$	7.99^{q}	10.08^{s}
FCV AH 20	$0.85^{fghijklm}$	2.90^{efghi}	4.82^{ijkl}	8.37^{q}	12.89^{pq}
FCV AH 21	1.43^{abcde}	4.35^{abcd}	6.31^{abcd}	13.87^{d}	20.70^{c}
FCV AH 22	1.41^{abcde}	2.79^{efghi}	$5.85^{cdefghi}$	17.19^{a}	23.57^{b}
FCV AH 23	0.49^{jklmn}	4.67^{ab}	6.88^{ab}	10.82^{mn}	13.78^{nopq}
FCV AH 24	$1.22^{abcdefgh}$	2.85^{efghi}	5.04^{ghijkl}	12.41^{gh}	15.47^{ijklmn}
FCV AH 25	0.29^{mn}	3.09^{efghi}	$5.09^{fghijkl}$	6.06^{s}	7.42^{t}
FCV AH 26	0.45^{klmn}	3.59^{bcdefg}	$5.70^{defghij}$	7.28^{r}	9.57^{s}
FCV AH 27	$0.84^{fghijklm}$	4.27^{abcd}	5.98^{bcdefg}	12.19^{hijk}	15.76^{hijklm}
FCV AH 28	$1.26^{abcdefg}$	4.64^{ab}	6.83^{abc}	14.62^{c}	19.13^{d}
FCV AH 29	1.47^{abcd}	5.23^{a}	7.19^{a}	11.41^{lm}	14.77^{klmno}
FCV AH 30	$0.80^{ghijklmn}$	3.42^{cdefg}	6.28^{abcde}	12.25^{hij}	16.51^{fghijk}
FCV AH 31	1.40^{abcdef}	2.96^{efghi}	$5.39^{defghijk}$	12.96^{efgh}	15.33^{jklmn}
FCV AH 32	$0.99^{cdefghijk}$	1.53^{j}	4.57^{kl}	10.08^{o}	$16.41^{fghijkl}$
FCV AH 33	$1.12^{bcdefghi}$	2.03^{ij}	$5.32^{defghijk}$	12.55^{gh}	17.28^{efgh}
FCV AH 34	0.39^{lmn}	2.79^{efghi}	$5.76^{defghij}$	13.32^{def}	17.86^{defg}
FCV AH 35	$1.19^{abcdefgh}$	3.43^{cdefg}	6.22^{abcde}	12.54^{gh}	$16.41^{fghijkl}$
FCV AH 36	$1.05^{bcdefghij}$	3.59^{bcdefg}	$5.47^{defghijk}$	11.33^{lm}	13.42^{opq}
FCV AH 37	$0.74^{ghijklmn}$	2.21^{hij}	4.75^{jkl}	11.00^{lm}	17.13^{efghi}
FCV AH 38	$0.78^{ghijklmn}$	2.59^{fghij}	$5.78^{defghij}$	10.05^{o}	13.40^{opq}
FCV AH 39	$0.68^{hijklmn}$	2.97^{efghi}	4.91^{hijkl}	11.30^{lm}	17.21^{efghi}
FCV AH 40	1.48^{abcd}	4.26^{abcd}	6.16^{bcde}	15.01^{c}	21.97^{c}
Mean	1.01	3.35	5.57	11.89	16.67
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

65

Table 9. Variation in stem dry weight (g) of seedlings from different seed sources.

Seed source	Dry Weight of Stem (g)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	0.60^{a}	1.22^{opqrs}	3.65^{nop}	4.56^{p}	9.05^{lmn}
FCV AH 2	0.47^{cd}	2.22^{defg}	4.41^{hijk}	6.61^{lmn}	11.10^{ghij}
FCV AH 3	0.42^{defg}	1.27^{opqrs}	4.81^{fgh}	10.36^{ab}	14.16^{bcd}
FCV AH 4	0.39^{ghi}	1.25^{opqrs}	4.70^{ghi}	10.46^{a}	16.41^{a}
FCV AH 5	0.51^{b}	2.59^{a}	3.82^{mno}	5.70^{o}	11.09^{ghij}
FCV AH 6	0.22^{q}	1.36^{nopq}	4.59^{hij}	9.54^{bcde}	13.27^{def}
FCV AH 7	0.29^{mno}	1.45^{mno}	3.65^{nop}	5.76^{o}	12.15^{fg}
FCV AH 8	0.32^{klm}	1.58^{lmn}	4.21^{jklm}	6.71^{klmn}	14.36^{bcd}
FCV AH 9	0.53^{b}	1.71^{kl}	7.46^{a}	9.99^{abcd}	15.19^{b}
FCV AH 10	0.25^{opq}	2.31^{bcde}	4.27^{ijkl}	6.39^{no}	8.39^{n}
FCV AH 11	0.57^{a}	2.24^{cdef}	4.81^{fgh}	6.00^{no}	9.01^{lmn}
FCV AH 12	0.41^{efgh}	2.53^{ab}	4.80^{fgh}	6.01^{no}	8.42^{n}
FCV AH 13	0.36^{ijk}	1.81^{ijkl}	7.32^{a}	10.31^{ab}	13.16^{def}
FCV AH 14	0.26^{opq}	1.97^{ghij}	5.12^{efg}	7.49^{hijk}	9.49^{klmn}
FCV AH 15	0.34^{jkl}	2.61^{a}	7.40^{a}	10.09^{abc}	15.12^{b}
FCV AH 16	0.46^{cd}	1.02^{s}	6.14^{bcdef}	7.28^{jklm}	9.29^{klmn}
FCV AH 17	0.36^{ijkl}	1.33^{nopq}	3.28^{pq}	6.82^{jklmn}	9.68^{klmn}
FCV AH 18	0.46^{de}	1.15^{qrs}	3.38^{opq}	8.21^{fghi}	10.23^{ijkl}
FCV AH 19	0.58^{a}	1.01^{s}	3.59^{nop}	6.48^{mno}	10.03^{jklm}
FCV AH 20	0.44^{def}	1.72^{jkl}	3.13^{q}	7.34^{jkl}	8.71^{mn}
FCV AH 21	0.29^{mno}	1.32^{nopqr}	4.53^{hijk}	6.30^{no}	11.12^{ghij}
FCV AH 22	0.26^{opq}	1.97^{ghij}	5.28^{e}	7.20^{jklm}	12.50^{efg}
FCV AH 23	0.33^{jklm}	2.51^{ab}	4.39^{hijk}	8.15^{fghi}	9.12^{lmn}
FCV AH 24	0.23^{pq}	2.49^{abc}	5.45^{de}	9.39^{cde}	11.11^{ghij}
FCV AH 25	0.31^{lmn}	2.56^{ab}	3.91^{lmn}	8.34^{fg}	12.14^{fg}
FCV AH 26	0.27^{nop}	2.42^{abcd}	4.15^{jklm}	7.55^{ghij}	10.1^{ijkl}
FCV AH 27	0.37^{hij}	1.07^{rs}	3.60^{nop}	9.20^{de}	11.16^{ghij}
FCV AH 28	0.33^{jklm}	1.62^{lm}	6.22^{bc}	8.21^{fghi}	11.48^{ghi}
FCV AH 29	0.26^{opq}	2.05^{fghi}	4.44^{hijk}	9.27^{de}	13.63^{cde}
FCV AH 30	0.27^{opq}	2.00^{fghi}	5.51^{de}	10.22^{ab}	14.65^{bc}
FCV AH 31	0.43^{defg}	1.18^{pqrs}	5.49^{de}	8.98^{ef}	12.10^{fg}
FCV AH 32	0.40^{fghi}	2.01^{fghi}	7.58^{a}	10.21^{ab}	14.05^{bcd}
FCV AH 33	0.53^{b}	2.26^{cdef}	4.10^{klm}	9.22^{de}	14.29^{bcd}
FCV AH 34	0.45^{de}	1.82^{hijkl}	5.86^{cd}	8.40^{f}	11.50^{ghi}
FCV AH 35	0.59^{a}	1.42^{mnop}	5.23^{ef}	9.17^{e}	10.26^{ijkl}
FCV AH 36	0.50^{bc}	1.90^{hijk}	6.40^{b}	8.32^{fg}	10.67^{hijk}
FCV AH 37	0.40^{fghi}	2.08^{efgh}	5.32^{e}	7.34^{jkl}	11.97^{fgh}
FCV AH 38	0.35^{jkl}	2.06^{efghi}	6.10^{bc}	8.26^{fgh}	12.11^{fg}
FCV AH 39	0.27^{opq}	1.92^{hijk}	4.44^{hijk}	7.44^{ijk}	10.28^{ijkl}
FCV AH 40	0.41^{efgh}	1.27^{opqrs}	5.24^{ef}	8.33^{fg}	10.28^{ijkl}
Mean	0.39	1.81	4.95	8.04	11.57
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

lowest dry weight of stem. The overall mean for dry weight of stem at 120 DAP was 8.04 g. The mean dry weight of stem at 150 DAP was 11.57 g with FCV AH 4 (16.41 g) being the highest and FCV AH 10 (8.39 g) the lowest.

4.1.8 Dry weight of leaves

Analysis of variance revealed significant difference in dry weight of leaves at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 10). At 30 DAP, the mean dry weight of leaves of all the seedlings was 0.39 g. The highest value (0.73 g) was recorded for seedlings from FCV AH 30 seed source and the lowest (0.15 g) for FCV AH 25. At 60 DAP, the average dry weight of leaves from all the sources was 1.65 g. The highest (2.60 g) dry weight of leaves was observed in FCV AH 30 and lowest (1.04 g) in FCV AH 25. At 90 DAP, the mean dry weight of leaves of the seedlings was 3.34 g. FCV AH 31 was the highest (4.15 g) among the progenies and FCV AH 15 (2.66 g) was having the lowest dry weight of leaves at 90 DAP. At 120 DAP, FCV AH 22 (5.56 g) was having the highest and FCV AH 25 (3.26 g) the lowest dry weight of leaves. The overall mean for dry weight of leaves at 120 DAP was 4.27 g. The mean dry weight of leaves at 150 DAP was 5.35 g with FCV AH 22 (8.26 g) being the highest and FCV AH 25 (3.38 g) the lowest.

4.1.9 Dry weight of root

Analysis of variance revealed significant difference in dry weight of root at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 11). At 30 DAP, the mean dry weight of root of all the seedlings was 0.23 g. The highest value (0.67 g) was recorded for seedlings from FCV AH 28 seed source and the lowest (0.05 g) for FCV AH 25. At 60 DAP, the average dry weight of root from all the sources was 1.10 g. The highest (2.08 g) dry weight of root was observed in FCV AH 28 and lowest (0.40 g) in FCV AH 15. At 90 DAP, the mean dry weight of root of the seedlings was 1.99 g. FCV AH 23 was the highest (2.91 g) among the progenies and FCV AH 24 (1.22 g) was having the lowest dry weight of root at 90 DAP. At 20 DAP, FCV AH 40 (5.58 g) was having the highest and FCV AH 26 (2.59 g) the

Table 10. Variation in leaf dry weight (g) of seedlings from different seed sources.

Seed source	Dry Weight of Leaf (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AH 1	$0.42^{abcdefgh}$	1.23^{hijkl}	3.34^{bcdefg}	$4.11^{efghijk}$	4.60^{ghijkl}
FCV AH 2	0.19^{efgh}	$1.64^{cdefghij}$	3.22^{bcdefg}	$4.13^{efghijk}$	$5.26^{defghij}$
FCV AH 3	$0.35^{bcdefgh}$	$1.74^{cdefghi}$	3.25^{bcdefg}	$4.21^{defghijk}$	6.23^{cdef}
FCV AH 4	$0.40^{abcdefgh}$	2.05^{bcd}	3.47^{abcde}	3.94^{ghijkl}	5.99^{cdefg}
FCV AH 5	$0.37^{bcdefgh}$	1.95^{bcde}	3.20^{bcdefg}	3.91^{ghijkl}	4.59^{ghijkl}
FCV AH 6	0.33^{cdefgh}	$1.66^{cdefghij}$	3.47^{abcde}	$4.25^{defghijk}$	5.76^{cdefgh}
FCV AH 7	0.34^{cdefgh}	$1.61^{defghijk}$	3.26^{bcdefg}	3.95^{ghijkl}	4.66^{ghijkl}
FCV AH 8	0.60^{abcd}	2.18^{abc}	3.72^{abcd}	4.66^{bcdefg}	7.95^{ab}
FCV AH 9	0.66^{abc}	$1.75^{cdefghi}$	3.04^{defg}	3.74^{hijkl}	$4.70^{fghijkl}$
FCV AH 10	$0.42^{abcdefgh}$	$1.78^{bcdefgh}$	3.35^{bcdefg}	4.50^{cdefgh}	5.84^{cdefgh}
FCV AH 11	$0.47^{abcdefgh}$	$1.43^{efghijkl}$	2.78^{efg}	3.81^{hijkl}	3.44^{kl}
FCV AH 12	$0.47^{abcdefgh}$	1.81^{bcdefg}	3.88^{ab}	4.44^{defghi}	6.59^{cd}
FCV AH 13	0.24^{defgh}	$1.68^{cdefghij}$	3.52^{abcd}	4.92^{abcde}	$5.26^{defghij}$
FCV AH 14	0.18^{fgh}	1.87^{bcdef}	3.26^{bcdefg}	$4.08^{fghijkl}$	4.37^{hijkl}
FCV AH 15	0.25^{defgh}	1.30^{ghijkl}	2.66^{g}	3.49^{kl}	6.85^{bc}
FCV AH 16	0.24^{defgh}	$1.59^{defghijk}$	3.29^{bcdefg}	$4.08^{fghijkl}$	$4.95^{efghijk}$
FCV AH 17	0.51^{abcdef}	$1.70^{cdefghij}$	3.29^{bcdefg}	5.30^{ab}	6.33^{cde}
FCV AH 18	$0.48^{abcdefgh}$	$1.67^{cdefghij}$	3.42^{bcdef}	$4.26^{defghijk}$	$5.35^{cdefghij}$
FCV AH 19	$0.47^{abcdefgh}$	2.28^{ab}	3.75^{abcd}	$4.41^{defghij}$	$5.37^{cdefghij}$
FCV AH 20	$0.37^{bcdefgh}$	$1.60^{defghijk}$	$3.34b^{cdefg}$	$4.17^{defghijk}$	$5.41^{cdefghi}$
FCV AH 21	$0.40^{abcdefgh}$	$1.60^{defghijk}$	3.77^{abc}	4.84^{abcdef}	$5.63^{cdefghi}$
FCV AH 22	0.68^{abc}	$1.62^{defghijk}$	3.19^{bcdefg}	5.56^{a}	8.26^{a}
FCV AH 23	$0.37^{bcdefgh}$	1.83^{bcdefg}	3.12^{cdefg}	3.75^{hijkl}	4.19^{ijkl}
FCV AH 24	0.18^{fgh}	$1.49^{efghijkl}$	2.80^{efg}	$4.22^{defghijk}$	$5.62^{cdefghi}$
FCV AH 25	0.15^{h}	1.04^{l}	3.53^{abcd}	3.26^{l}	3.38^{l}
FCV AH 26	0.25^{defgh}	1.29^{ghijkl}	3.33^{bcdefg}	3.75^{hijkl}	3.84^{jkl}
FCV AH 27	0.29^{defgh}	$1.51^{defghijkl}$	3.75^{abc}	5.25^{abc}	6.07^{cdefg}
FCV AH 28	0.58^{abcd}	$1.76^{bcdefgh}$	3.39^{bcdef}	4.96^{abcd}	$5.22^{defghij}$
FCV AH 29	$0.44^{abcdefgh}$	1.97^{bcde}	3.61^{abcd}	4.49^{cdefgh}	4.16^{ijkl}
FCV AH 30	0.73^{a}	2.60^{a}	3.62^{abcd}	4.50^{cdefgh}	4.59^{ghijkl}
FCV AH 31	0.28^{defgh}	1.20^{ijkl}	4.15^{a}	5.49^{a}	6.40^{cde}
FCV AH 32	$0.36^{bcdefgh}$	1.09^{kl}	3.21^{bcdefg}	3.59^{jkl}	4.13^{ijkl}
FCV AH 33	0.55^{abcde}	1.15^{jkl}	3.15^{cdefg}	$4.45^{cdefghi}$	6.11^{cdefg}
FCV AH 34	0.195^{efgh}	$1.59^{defghijk}$	3.58^{abcd}	$4.27^{defghijk}$	$5.16^{defghij}$
FCV AH 35	0.53^{abcdef}	$1.67^{cdefghij}$	3.62^{abcd}	4.44^{defghi}	5.83^{cdefgh}
FCV AH 36	$0.46^{abcdefgh}$	$1.34^{fghijkl}$	2.72^{fg}	3.66^{ijkl}	$5.56^{cdefghi}$
FCV AH 37	0.16^{gh}	$1.74^{cdefghi}$	3.09^{cdefg}	$4.05^{fghijkl}$	$4.95^{efghijk}$
FCV AH 38	0.19^{efgh}	$1.61^{defghijk}$	3.21^{bcdefg}	4.67^{bcdefg}	6.27^{cde}
FCV AH 39	$0.36^{bcdefgh}$	$1.57^{defghijkl}$	2.78^{efg}	3.61^{jkl}	4.56^{ghijkl}
FCV AH 40	0.71^{ab}	$1.66^{cdefghij}$	3.24^{bcdefg}	3.53^{kl}	4.37^{hijkl}
Mean	0.39	1.65	3.34	4.27	5.35
P	0.004**	<0.001**	0.002**.	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

Table 11. Variation in root dry weight (g) of seedlings from different seed sources.

Seed source	Dry Weight of Root (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AH 1	$0.26^{bcdefghij}$	0.42^{n}	1.34^{mno}	4.16^{ghijkl}	5.12^{klmn}
FCV AH 2	0.14^{ghijk}	1.15^{efghi}	1.86^{ghijkl}	4.38^{efghi}	4.90^{mn}
FCV AH 3	$0.26^{bcdefghi}$	$0.89^{ghijklmn}$	2.13^{efg}	3.86^{ijkl}	5.86^{ghi}
FCV AH 4	$0.18^{defghijk}$	0.69^{ijklmn}	1.64^{jklmno}	4.72^{def}	8.07^{a}
FCV AH 5	0.33^{bcdef}	1.08^{fghijk}	1.92^{fghijk}	4.45^{defgh}	5.58^{hijkl}
FCV AH 6	0.12^{hijk}	$0.75^{hijklmn}$	1.45^{lmno}	5.24^{abc}	8.36^{a}
FCV AH 7	0.07^{k}	1.16^{efghi}	2.08^{efghi}	4.77^{cde}	7.02^{bc}
FCV AH 8	0.43^{b}	2.17^{a}	2.25^{cdefg}	4.48^{defgh}	5.61^{hijkl}
FCV AH 9	0.14^{ghijk}	$0.78^{ghijklmn}$	1.87^{ghijk}	5.29^{ab}	6.56^{cdef}
FCV AH 10	$0.21^{cdefghijk}$	1.90^{abc}	2.42^{bcde}	4.57^{defgh}	5.42^{ijklm}
FCV AH 11	$0.35b^{cde}$	$1.05^{fghijkl}$	1.23^{o}	4.67^{defgh}	6.10^{fgh}
FCV AH 12	0.42^{b}	1.24^{efgh}	2.32^{cdef}	4.58^{defgh}	5.28^{ijklmn}
FCV AH 13	$0.17^{defghijk}$	1.22^{efgh}	1.66^{ijklmn}	5.52^{a}	8.39^{a}
FCV AH 14	0.11^{ijk}	1.14^{efghij}	2.10^{efgh}	4.15^{hijkl}	5.31^{ijklmn}
FCV AH 15	0.10^{ijk}	0.40^{n}	1.45^{lmno}	5.43^{ab}	8.54^{a}
FCV AH 16	0.13^{hijk}	0.64^{jklmn}	1.38^{mno}	$4.28^{efghijk}$	5.76^{ghijk}
FCV AH 17	$0.27^{bcdefgh}i$	1.44^{cdef}	$2.02^{efghijk}$	4.59^{defgh}	6.52^{cdef}
FCV AH 18	0.16^{fghijk}	$0.75^{hijklmn}$	1.59^{klmno}	4.22^{fghijk}	5.75^{ghijk}
FCV AH 19	0.35^{bcd}	1.26^{efg}	2.06^{efghij}	3.83^{jklm}	4.97^{lmn}
FCV AH 20	$0.20^{cdefghijk}$	$0.85^{ghijklmn}$	1.25^{no}	3.80^{klm}	5.71^{ghijk}
FCV AH 21	0.38^{bc}	2.13^{a}	2.32^{cdef}	4.93^{bcd}	7.45^{b}
FCV AH 22	0.35^{bcd}	0.50^{n}	$2.00^{efghijk}$	5.42^{ab}	6.67^{cdef}
FCV AH 23	$0.17^{efghijk}$	2.22^{a}	2.91^{a}	4.36^{efghij}	5.41^{ijklm}
FCV AH 24	$0.21^{cdefghijk}$	0.51^{n}	1.22^{o}	5.27^{ab}	6.16^{efgh}
FCV AH 25	0.05^{k}	0.51^{n}	1.27^{mno}	2.66^{n}	3.76^{o}
FCV AH 26	0.08^{jk}	1.40^{def}	1.91^{fghijk}	2.59^{n}	3.69^{o}
FCV AH 27	0.16^{fghijk}	1.86^{abcd}	2.21^{defg}	4.66^{defgh}	5.25^{ijklmn}
FCV AH 28	0.67^{a}	2.08^{a}	2.56^{abcd}	5.41^{ab}	6.30^{defg}
FCV AH 29	0.32^{bcdefg}	1.59^{bcde}	2.76^{ab}	4.36^{efghij}	5.17^{jklmn}
FCV AH 30	$0.19^{defghijk}$	1.75^{abcd}	2.65^{abc}	4.33^{efghij}	5.27^{ijklmn}
FCV AH 31	$0.23^{cdefghijk}$	0.61^{klmn}	2.56^{abcd}	4.18^{ghijk}	5.82^{ghij}
FCV AH 32	$0.17^{efghijk}$	0.40^{n}	2.16^{defg}	3.36^{m}	5.28^{ijklmn}
FCV AH 33	$0.30^{bcdefgh}$	0.61^{klmn}	1.87^{ghijkl}	4.70^{defg}	6.54^{cdef}
FCV AH 34	0.09^{ijk}	$0.78^{ghijklmn}$	2.26^{cdefg}	4.95^{bcd}	6.53^{cdef}
FCV AH 35	0.35^{bcde}	$1.02^{fghijklm}$	2.75^{ab}	$4.25^{efghijk}$	5.88^{ghi}
FCV AH 36	$0.30^{bcdefgh}$	1.24^{efgh}	2.58^{abcd}	3.91^{ijkl}	4.71^{n}
FCV AH 37	0.14^{ghijk}	0.57^{lmn}	1.68^{hijklm}	$4.28^{efghijk}$	6.78^{cde}
FCV AH 38	0.13^{hijk}	$0.83^{ghijklmn}$	1.88^{ghijk}	3.66^{lm}	5.78^{ghijk}
FCV AH 39	$0.18^{defghijk}$	0.55^{mn}	1.68^{hijklm}	$4.29^{efghijk}$	6.87^{bcd}
FCV AH 40	0.35^{bcde}	1.92^{ab}	2.13^{efg}	5.58^{a}	8.21^{a}
Mean	0.23	1.1	1.99	4.46	6.06
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

lowest dry weight of root. The overall mean for dry weight of root at 120 DAP was 4.46 g. The mean dry weight of root at 150 DAP was 6.06 g with FCV AH 15 (8.54 g) being the highest and FCV AH 26 (3.69 g) the lowest.

4.1.10 Number of leaves

Analysis of variance revealed significant difference in number of leaves due to different seed sources at 30 DAP and 150 DAP while there were no significant variations in number of leaves in 60 DAP, 90 DAP and 120 DAP (Table 12). At 30 DAP, the mean number of leaves of all the seedlings was 2.85. The highest value (3.75) was recorded for seedlings from FCV AH 14 seed source and the lowest (2.00) for FCV AH 38. At 60 DAP, the average number of leaves from all the sources was 5.54. The highest (7.00) number of leaves was observed in FCV AH 3 and lowest (4.00) in FCV AH 26. At 90 DAP, the mean number of leaves of the seedlings was 7.31. FCV AH 4 was having the highest (8.50) among the progenies and FCV AH 37 (6.00) was having the lowest number of leaves at 90 DAP. At 120 DAP, FCV AH 12 (10.50) was having the highest and FCV AH 2 (7.50) the lowest number of leaves. The overall mean for number of leaves at 120 DAP was 9.09. The mean number of leaves at 150 DAP was 9.51 with FCV AH 15 (12.00) being the highest and FCV AH 25 (7.00) the lowest.

4.1.11 Leaf area

Analysis of variance revealed significant difference in leaf area at 30 DAP, 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 13). At 30 DAP, the mean leaf area of all the seedlings was 28.42 cm^2. The highest value (52.75 cm^2) was recorded for seedlings from FCV AH 17 seed source and the lowest (15.20 cm^2) for FCV AH 26. At 60 DAP, the average leaf area from all the sources was 54.56 cm^2. The highest value (87.34 cm^2) for leaf area was observed in FCV AH 4 and lowest (31.67 cm^2) in FCV AH 26. At 90 DAP, the mean leaf area of the seedlings was 78.14 cm^2. FCV AH 4 was the highest (116.27 cm^2) among the progenies and FCV AH 30 (55.21 cm^2) was having the lowest leaf area at 90 DAP. At 120 DAP, FCV AH 4 (128.99 cm^2) was having the highest and FCV AH 9 (72.44 cm^2) the lowest

Table 12. Variation in number of leaves of seedlings from different seed sources.

Seed Source	Number of Leaves				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	3.00^{ab}	5.50	8.00	9.50	8.00^{cd}
FCV AH 2	2.00^{b}	5.00	6.50	7.50	8.00^{cd}
FCV AH 3	3.50^{a}	7.00	6.50	8.50	11.00^{ab}
FCV AH 4	3.50^{a}	6.00	8.50	9.50	11.00^{ab}
FCV AH 5	3.50^{a}	6.50	7.50	8.50	9.00^{bcd}
FCV AH 6	2.00^{b}	5.50	8.00	9.50	9.50^{abcd}
FCV AH 7	2.50^{ab}	5.00	7.00	8.50	9.50^{abcd}
FCV AH 8	3.00^{ab}	6.50	7.50	9.50	10.00^{abcd}
FCV AH 9	3.50^{a}	5.50	7.00	8.50	10.00^{abcd}
FCV AH 10	2.50^{ab}	5.50	7.50	9.50	10.50^{abc}
FCV AH 11	3.00^{ab}	5.50	7.50	9.00	7.50^{d}
FCV AH 12	2.50^{ab}	5.50	8.00	10.50	10.50^{abc}
FCV AH 13	2.00^{b}	5.00	7.50	9.50	9.00^{bcd}
FCV AH 14	3.75^{a}	6.00	7.50	9.00	8.50^{bcd}
FCV AH 15	3.00^{ab}	5.50	7.00	9.50	12.00^{a}
FCV AH 16	3.00^{ab}	5.50	7.50	9.50	9.00^{bcd}
FCV AH 17	2.50^{ab}	5.00	6.50	8.50	10.00^{abcd}
FCV AH 18	3.00^{ab}	5.50	7.50	9.50	9.00^{bcd}
FCV AH 19	3.50^{a}	6.00	8.00	9.50	9.50^{abcd}
FCV AH 20	3.50^{a}	6.00	7.50	9.50	9.50^{abcd}
FCV AH 21	3.50^{a}	6.50	7.50	10.00	9.50^{abcd}
FCV AH 22	3.50^{a}	6.00	7.50	9.50	11.00^{ab}
FCV AH 23	3.00^{ab}	5.50	7.50	9.50	9.00^{bcd}
FCV AH 24	2.00^{b}	5.00	6.50	8.50	10.00^{abcd}
FCV AH 25	2.00^{b}	5.00	7.50	8.50	7.00^{d}
FCV AH 26	2.50^{ab}	4.00	7.00	9.00	9.00^{bcd}
FCV AH 27	3.00^{ab}	6.50	8.00	9.50	10.50^{abc}
FCV AH 28	3.50^{a}	5.50	7.50	9.50	8.50^{bcd}
FCV AH 29	2.50^{ab}	5.00	7.50	9.50	9.50^{abcd}
FCV AH 30	3.50^{a}	6.50	8.00	9.50	9.00^{bcd}
FCV AH 31	2.00^{b}	5.50	7.00	9.00	10.50^{abc}
FCV AH 32	2.50^{ab}	5.00	6.50	8.00	8.00^{cd}
FCV AH 33	3.50^{a}	6.00	7.00	9.00	10.50^{abc}
FCV AH 34	2.50^{ab}	4.50	6.50	8.50	9.00^{bcd}
FCV AH 35	3.50^{a}	5.50	7.50	9.50	10.00^{abcd}
FCV AH 36	2.50^{ab}	5.00	6.50	8.50	9.50^{abcd}
FCV AH 37	2.00^{b}	4.50	6.00	8.00	8.00^{cd}
FCV AH 38	2.00^{b}	5.50	8.00	10.00	10.50^{abc}
FCV AH 39	2.50^{ab}	5.00	6.50	8.50	9.50^{abcd}
FCV AH 40	3.50^{a}	5.50	7.50	9.00	10.50^{abc}
Mean	2.85	5.54	7.31	9.09	9.51
P	0.006**	0.057^{ns}	0.12^{ns}	0.227^{ns}	0.041*

**Significant at 5 per cent level, ** significant at 1 per cent level and superscript 'ns' indicate non-significant*

Values with the same superscript along the column are homogenous

Table 13. Variation in leaf area (cm^2) of seedlings from different seed sources.

Seed source	Leaf Area (cm^2)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	21.27^{jklmn}	39.15^{jklm}	64.57^{hij}	88.16^{defgh}	109.05^{abcd}
FCV AH 2	20.91^{jklmn}	44.40^{hijklm}	75.41^{bcdefghi}	89.38^{cdefgh}	109.89^{abcd}
FCV AH 3	22.87^{ijklmn}	47.32^{ghijklm}	82.43^{bcdefg}	94.47^{bcdefgh}	92.20^{defghij}
FCV AH 4	31.87^{cdefghij}	87.34^{a}	116.27^{a}	128.99^{a}	108.17^{abcde}
FCV AH 5	31.40^{defghijk}	50.22^{efghijklm}	69.84^{efghij}	86.10^{fghi}	98.75^{bcdefghij}
FCV AH 6	39.74^{bcdef}	60.14^{bcdefgh}	75.71^{bcdefghi}	88.84^{cdefgh}	94.90^{bcdefghij}
FCV AH 7	28.44^{efghijkl}	51.87^{cdefghijkl}	68.37^{efghij}	84.99^{ghi}	96.44^{bcdefghij}
FCV AH 8	26.98^{ghijklmn}	59.66^{bcdefgh}	79.28^{bcdefgh}	90.94^{cdefgh}	109.16^{abcd}
FCV AH 9	18.14^{lmn}	33.86^{klm}	56.53^{j}	72.44^{i}	84.81^{ij}
FCV AH 10	35.89^{bcdefgh}	58.34^{bcdefghij}	81.45^{bcdefg}	92.78^{cdefgh}	102.34^{abcdefghi}
FCV AH 11	24.62^{hijklmn}	53.22^{bcdefghijk}	79.24^{bcdefgh}	90.96^{cdefgh}	102.34^{abcdefghi}
FCV AH 12	43.62^{abc}	70.20^{abcd}	90.00^{b}	103.64^{bc}	107.94^{abcde}
FCV AH 13	34.93^{bcdefghi}	64.69^{bcdefg}	82.56^{bcdef}	96.85^{bcdefg}	97.30^{bcdefghij}
FCV AH 14	16.00^{mn}	40.93^{hijklm}	66.57^{fghij}	80.78^{hi}	87.61^{hij}
FCV AH 15	15.23^{n}	49.15^{fghijklm}	78.01^{bcdefghi}	97.05^{bcdefg}	117.77^{a}
FCV AH 16	30.90^{defghijk}	67.77^{bcdef}	89.68^{b}	101.83^{bcd}	89.96^{fghij}
FCV AH 17	52.75^{a}	71.90^{ab}	87.84^{bc}	107.69^{b}	117.62^{a}
FCV AH 18	22.71^{ijklmn}	39.71^{ijklm}	62.22^{ij}	88.20^{defgh}	103.18^{abcdefgh}
FCV AH 19	41.01^{bcd}	71.21^{abc}	91.50^{b}	102.04^{bcd}	106.45^{abcdefg}
FCV AH 20	20.29^{jklmn}	42.56^{hijklm}	70.82^{defghij}	87.89^{defgh}	89.50^{ghij}
FCV AH 21	30.55^{defghijk}	52.35^{bcdefghijk}	90.87^{b}	102.39^{bcd}	111.49^{abc}
FCV AH 22	46.36^{ab}	69.64^{abcde}	84.00^{bcde}	96.45^{bcdefg}	112.75^{ab}
FCV AH 23	26.09^{hijklmn}	59.17^{bcdefghi}	81.40^{bcdefg}	88.55^{defgh}	93.23^{defghij}
FCV AH 24	28.22^{efghijklm}	53.14^{bcdefghijk}	76.58^{bcdefghi}	92.60^{cdefgh}	94.84^{cdefghij}
FCV AH 25	17.65^{lmn}	47.15^{ghijklm}	65.78^{ghij}	83.77^{ghi}	95.92^{bcdefghij}
FCV AH 26	15.20^{n}	31.67^{m}	57.64^{j}	73.28^{i}	82.13^{j}
FCV AH 27	17.63^{lmn}	46.99^{ghijklm}	76.39^{bcdefghi}	92.48^{cdefgh}	101.73^{abcdefghi}
FCV AH 28	27.62^{fghijklm}	59.42^{bcdefghi}	78.33^{bcdefghi}	90.34^{cdefgh}	105.17^{abcdefgh}
FCV AH 29	23.08^{ijklmn}	47.22^{ghijklm}	71.28^{cdefghij}	87.72^{defgh}	94.75^{cdefghij}
FCV AH 30	16.57^{lmn}	32.60^{lm}	55.21^{j}	72.72^{i}	84.67^{ij}
FCV AH 31	39.02^{bcdefg}	51.58^{cdefghijkl}	90.70^{b}	100.68^{bcdef}	101.24^{abcdefghi}
FCV AH 32	31.85^{cdefghij}	52.73^{bcdefghijk}	78.37^{bcdefghi}	73.14^{i}	81.34^{j}
FCV AH 33	40.13^{bcde}	68.32^{bcdef}	88.68^{b}	101.16^{bcde}	108.65^{abcd}
FCV AH 34	26.39^{hijklmn}	57.14^{bcdefghij}	76.57^{bcdefghi}	89.65^{cdefgh}	100.13^{abcdefghi}
FCV AH 35	28.36^{efghijklm}	52.45^{bcdefghijk}	79.34^{bcdefgh}	92.00^{cdefgh}	98.99^{bcdefghij}
FCV AH 36	40.77^{bcd}	69.39^{abcde}	89.75^{b}	99.97^{bcdef}	107.44^{abcdef}
FCV AH 37	16.26^{lmn}	60.20^{bcdefgh}	82.66^{bcdef}	92.37^{cdefgh}	97.39^{bcdefghij}
FCV AH 38	19.18^{klmn}	51.12^{defghijklm}	77.89^{bcdefghi}	92.80^{cdefgh}	108.29^{abcde}
FCV AH 39	27.13^{ghijklmn}	48.72^{fghijklm}	69.16^{efghij}	86.32^{efghi}	90.64^{efghij}
FCV AH 40	39.11^{bcdefg}	67.57^{bcdef}	86.70^{bcd}	93.77^{bcdefgh}	92.55^{defghij}
Mean	28.42	54.56	78.14	91.91	99.72
P	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

leaf area. The overall mean for leaf area at 120 DAP was 91.91 cm^2. The mean leaf area at 150 DAP was 99.72 cm^2 with FCV AH 15 (117.77 cm^2) being the highest and FCV AH 32 (81.34 cm^2) the lowest.

4.1.12 Leaf area ratio

Analysis of variance revealed significance difference in leaf area ratio at 60 DAP, 90 DAP, 120 DAP and 150 DAP, however, there was no significant variation at 30 DAP (Table 14). At 30 DAP, the mean leaf area ratio of all the seedlings was 80.89 cm^2g^{-1}. The highest value (111.91 cm^2g^{-1}) was recorded for seedlings from FCV AH 4 seed source and lowest (46.20 cm^2g^{-1}) for FCV AH 37. At 60 DAP, the average leaf area ratio from all the sources was 68.91 cm^2g^{-1}. The highest (130.85 cm^2g^{-1}) leaf area ratio was observed in FCV AH 4 and the lowest (28.04 cm^2g^{-1}) in FCV AH 26. At 90 DAP, the mean leaf area ratio of the seedlings was 56.49 cm^2g^{-1}. FCV AH 4 was the highest (100.34 cm^2g^{-1}) among the progenies and FCV AH 9 (32.02 cm^2g^{-1}) was having the lowest leaf area ratio at 90 DAP. At 120 DAP, FCV AH 12 (69.21 cm^2g^{-1}) was having the highest and FCV AH 9 (32.42 cm^2g^{-1}) the lowest leaf area ratio. The overall mean for leaf area ratio at 120 DAP was 50.36 cm^2g^{-1}. The mean leaf area ratio at 150 DAP was 41.69 cm^2g^{-1} with FCV AH 12 (55.80 cm^2g^{-1}) being the highest and FCV AH 32 (27.64 cm^2g^{-1}) the lowest.

4.1.13 Specific leaf area

Analysis of variance revealed significance difference in specific leaf area in seedlings from different seed sources (Table 15). Variations were not significant at 30 DAP and 150 DAP but significant variations was observed at 60 DAP, 90 DAP and 120 DAP. At 60 DAP, the average specific leaf area from all the sources was 189.22 cm^2g^{-1}. The highest (358.39 cm^2g^{-1}) specific leaf area was observed in FCV AH 33 and the lowest (81.60 cm^2g^{-1}) in FCV AH 30. At 90 DAP, the mean specific leaf area of the seedlings was 172.44 cm^2g^{-1}. FCV AH 4 was the highest (283.73 cm^2g^{-1}) among the progenies and FCV AH 26 (120.65 cm^2g^{-1}) was having the lowest specific leaf area at 90 DAP. At 120 DAP, FCV AH 4 (312.14 cm^2g^{-1})

73

Table 14. Variation in leaf area ratio (cm^2g^{-1}) of seedlings from different seed sources.

Seed source	Leaf Area Ratio (cm^2g^{-1})				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	50.81	$74.72^{bcdefghi}$	$65.38^{bcdefgh}$	65.09^{abc}	46.55^{abcdef}
FCV AH 2	51.07	44.09^{ghi}	$50.97^{cdefghijk}$	44.13^{fghij}	$41.26^{bcdefghi}$
FCV AH 3	79.02	96.43^{abcde}	$52.79^{cdefghijk}$	43.52^{ghijk}	$38.61^{cdefghi}$
FCV AH 4	111.91	130.85^{a}	100.34^{a}	63.87^{abc}	$39.04^{cdefghi}$
FCV AH 5	91.47	$58.32^{cdefghi}$	$58.79^{cdefghi}$	52.09^{defgh}	$42.01^{bcdefgh}$
FCV AH 6	114.98	$89.16^{abcdefg}$	$63.65^{bcdefgh}$	44.48^{fghij}	33.43^{efghi}
FCV AH 7	101.04	$61.22^{cdefghi}$	$53.11^{cdefghijk}$	49.69^{efgh}	$38.39^{cdefghi}$
FCV AH 8	61.26	$65.04^{cdefghi}$	$58.16^{cdefghi}$	54.41^{bcdefg}	$39.03^{cdefghi}$
FCV AH 9	47.74	43.91^{ghi}	32.02^{l}	32.42^{k}	32.09^{ghi}
FCV AH 10	102.63	54.03^{defghi}	$60.91^{bcdefgh}$	56.85^{bcde}	54.57^{ab}
FCV AH 11	52.72	$61.89^{cdefghi}$	67.33^{bcde}	56.54^{bcde}	$41.51^{bcdefgh}$
FCV AH 12	86.42	$69.96^{bcdefghi}$	66.01^{bcdefg}	69.21^{a}	55.80^{a}
FCV AH 13	90.60	$70.38^{bcdefghi}$	$49.75^{efghijk}$	44.48^{fghij}	32.66^{fghi}
FCV AH 14	99.75	49.19^{fghi}	47.62^{hijkl}	46.09^{efghi}	$38.78^{cdefghi}$
FCV AH 15	65.71	$64.89^{cdefghi}$	47.46^{hijkl}	48.44^{efgh}	46.12^{abcdef}
FCV AH 16	110.05	114.29^{ab}	$62.11^{bcdefgh}$	61.63^{abcd}	$40.69^{cdefghi}$
FCV AH 17	113.20	$80.28^{bcdefgh}$	66.24^{bcdef}	54.74^{bcdefg}	52.01^{abc}
FCV AH 18	67.97	$60.59^{cdefghi}$	$55.97^{cdefghij}$	50.15^{defgh}	$43.46^{abcdefgh}$
FCV AH 19	103.12	93.14^{abcdef}	77.80^{b}	65.80^{ab}	49.66^{abcd}
FCV AH 20	70.25	$61.17^{cdefghi}$	68.78^{bc}	54.57^{bcdefg}	$42.85^{abcdefgh}$
FCV AH 21	111.75	$66.89^{cdefghi}$	$64.60^{bcdefgh}$	63.96^{abc}	$44.05^{abcdefgh}$
FCV AH 22	124.54	101.82^{abc}	$60.29^{bcdefghi}$	50.32^{defgh}	$45.35^{abcdefg}$
FCV AH 23	94.37	50.04^{efghi}	$58.77^{cdefghi}$	51.83^{defgh}	$44.92^{abcdefgh}$
FCV AH 24	93.89	$59.02^{cdefghi}$	$52.73^{cdefghijk}$	41.67^{hijk}	$41.42^{bcdefghi}$
FCV AH 25	68.41	$56.83^{cdefghi}$	$56.28^{cdefghij}$	49.87^{efgh}	37.28^{defghi}
FCV AH 26	61.13	28.04^{i}	42.75^{ijkl}	47.33^{efghi}	$41.76^{bcdefgh}$
FCV AH 27	64.78	$68.42^{bcdefghi}$	$63.91^{bcdefgh}$	45.97^{efghi}	47.51^{abcd}
FCV AH 28	60.50	$59.47^{cdefghi}$	48.01^{ghijkl}	46.05^{efghi}	$38.59^{cdefghi}$
FCV AH 29	57.67	43.03^{ghi}	$49.30^{efghijkl}$	45.92^{efghi}	$39.24^{cdefghi}$
FCV AH 30	47.88	33.53^{hi}	37.46^{kl}	36.27^{ijk}	31.09^{hi}
FCV AH 31	82.53	99.19^{abcd}	$51.92^{cdefghijk}$	48.53^{efgh}	$43.69^{abcdefgh}$
FCV AH 32	86.43	$74.69^{bcdefghi}$	39.70^{jkl}	34.22^{jk}	27.64^{i}
FCV AH 33	100.96	101.83^{abc}	68.29^{bcd}	49.54^{efgh}	$42.22^{abcdefgh}$
FCV AH 34	87.57	$61.29^{cdefghi}$	42.58^{ijkl}	43.19^{ghijk}	$38.83^{cdefghi}$
FCV AH 35	67.31	$70.08^{bcdefghi}$	$51.17^{cdefghijk}$	48.84^{efgh}	$45.04^{abcdefg}$
FCV AH 36	78.85	$77.72^{bcdefgh}$	$49.95^{efghijk}$	53.51^{cdefgh}	48.76^{abcd}
FCV AH 37	46.20	$61.32^{cdefghi}$	$49.10^{fghijkl}$	47.16^{efghi}	33.08^{efghi}
FCV AH 38	55.08	$62.56^{cdefghi}$	$55.94^{cdefghij}$	55.89^{bcdef}	46.82^{abcde}
FCV AH 39	82.12	$60.16^{cdefghi}$	$50.28^{defghijk}$	47.75^{efghi}	$39.53^{cdefghi}$
FCV AH 40	92.01	$76.69^{bcdefgh}$	$61.61^{bcdefgh}$	48.35^{efgh}	$42.48^{abcdefgh}$
Mean	80.89	68.91	56.49	50.36	41.69
P	0.05^{ns}	0.002**	<0.001**	<0.001**	0.004**

*** significant at 1 per cent level and superscript 'ns' indicate non-significant*

Values with the same superscript along the column are homogenous

Table 15. Variation in specific leaf area (cm^2g^{-1}) of seedlings from different seed sources.

Seed source	Specific Leaf Area (cm^2g^{-1})				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	180.26	174.37^{bcdefg}	163.02^{bcdefghij}	203.93^{cdefghijk}	191.08
FCV AH 2	231.02	137.06^{cdefg}	150.37^{cdefghij}	161.63^{jk}	166.82
FCV AH 3	232.76	219.60^{bcdef}	164.69^{bcdefghij}	190.48^{cdefghijk}	162.70
FCV AH 4	279.68	255.29^{b}	283.73^{a}	312.14^{a}	199.50
FCV AH 5	316.95	167.55^{bcdefg}	163.92^{bcdefghij}	187.07^{cdefghijk}	196.59
FCV AH 6	240.44	200.44^{bcdef}	174.38^{bcdefghij}	198.35^{cdefghijk}	163.27
FCV AH 7	214.61	160.84^{bcdefg}	146.51^{efghij}	182.43^{efghijk}	197.23
FCV AH 8	137.52	178.81^{bcdefg}	159.15^{bcdefghij}	185.03^{defghijk}	137.14
FCV AH 9	101.67	106.37^{fg}	130.23^{hij}	164.38^{ijk}	181.12
FCV AH 10	212.87	181.56^{bcdefg}	183.42^{bcdefgh}	196.86^{cdefghijk}	183.69
FCV AH 11	170.06	204.82^{bcdef}	213.72^{b}	215.23^{bcdefghi}	223.77
FCV AH 12	231.70	210.78^{bcdef}	187.10^{bcdefg}	235.60^{bcd}	171.80
FCV AH 13	325.69	193.70^{bcdefg}	175.83^{bcdefghij}	187.24^{cdefghijk}	168.29
FCV AH 14	308.24	130.95^{cdefg}	152.87^{cdefghij}	177.47^{fghijk}	170.43
FCV AH 15	186.71	210.09^{bcdef}	206.55^{bc}	263.70^{b}	209.42
FCV AH 16	390.86	233.18^{bcd}	204.18^{bcd}	236.35^{bcd}	163.55
FCV AH 17	259.74	212.40^{bcdef}	173.53^{bcdefghij}	174.97^{fghijk}	188.76
FCV AH 18	217.31	129.99^{cdefg}	137.72^{ghij}	196.73^{cdefghijk}	172.96
FCV AH 19	334.69	186.73^{bcdefg}	195.35^{bcdef}	220.23^{bcdefg}	188.08
FCV AH 20	190.98	158.91^{bcdefg}	158.84^{bcdefghij}	200.15^{cdefghijk}	157.26
FCV AH 21	305.11	213.88^{bcdef}	181.05^{bcdefgh}	211.64^{cdefghij}	187.60
FCV AH 22	246.02	257.63^{b}	199.54^{bcde}	164.69^{ijk}	150.35
FCV AH 23	230.52	184.48^{bcdefg}	195.53^{bcdef}	224.29^{bcdef}	201.14
FCV AH 24	378.58	181.37^{bcdefg}	177.55^{bcdefghi}	187.30^{cdefghijk}	170.47
FCV AH 25	244.80	225.04^{bcde}	139.03^{fghij}	217.76^{bcdefgh}	215.83
FCV AH 26	166.11	112.39^{efg}	120.65^{j}	175.36^{fghijk}	192.32
FCV AH 27	191.03	201.18^{bcdef}	163.47^{bcdefghij}	167.75^{hijk}	175.85
FCV AH 28	174.56	185.81^{bcdefg}	172.39^{bcdefghij}	172.41^{ghijk}	171.40
FCV AH 29	130.49	122.59^{defg}	148.61^{defghij}	185.27^{defghijk}	216.32
FCV AH 30	78.47	81.60^{g}	122.18^{ij}	153.39^{k}	165.78
FCV AH 31	273.84	241.40^{bc}	153.77^{cdefghij}	164.89^{ijk}	166.10
FCV AH 32	224.61	241.90^{bc}	160.47^{bcdefghij}	167.71^{hijk}	157.09
FCV AH 33	256.74	358.39^{a}	201.05^{bcde}	204.67^{cdefghijk}	186.56
FCV AH 34	348.47	161.67^{bcdefg}	139.10^{fghij}	178.11^{fghijk}	174.39
FCV AH 35	203.91	172.08^{bcdefg}	164.11^{bcdefghij}	196.77^{cdefghijk}	169.84
FCV AH 36	215.83	260.66^{b}	214.10^{b}	232.30^{bcde}	184.18
FCV AH 37	212.30	156.97^{bcdefg}	160.25^{bcdefghij}	182.60e^{fghijk}	156.94
FCV AH 38	195.15	174.92^{bcdefg}	195.15^{bcdef}	198.49^{cdefghijk}	180.80
FCV AH 39	184.72	154.70^{bcdefg}	161.59^{bcdefghij}	203.08^{cdefghijk}	188.30
FCV AH 40	193.89	226.71^{bcde}	203.09^{bcde}	238.70^{bcd}	222.07
Mean	230.47	189.22	172.44	197.93	180.67
P	0.511^{ns}	0.003**	<0.001**	<0.001**	0.230^{ns}

*** significant at 1 per cent level and superscript 'ns' indicate non- significant*

Values with the same superscript along the column are homogenous

was having the highest and FCV AH 30 (153.39 cm^2g^{-1}) the lowest specific leaf area. The overall mean for specific leaf area at 120 DAP was 197.93 cm^2g^{-1}.

4.1.14 Absolute growth rate

Absolute growth rate was analysed for variation between the different seed sources. Significant variations were found at 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 16). At 60 DAP, the average absolute growth rate from all the sources was 0.60 cm day^{-1}. The highest (1.10 cm day^{-1}) absolute growth rate was observed in FCV AH 38 and the lowest (0.35 cm day^{-1}) in FCV AH 24. At 90 DAP, the mean absolute growth rate of the seedlings was 0.58 cm day^{-1}. FCV AH 26 was the highest (1.01 cm day^{-1}) among the progenies and FCV AH 37 (0.21 cm day^{-1}) was having the lowest absolute growth rate at 90 DAP. At 120 DAP, FCV AH 21 (1.00 cm day^{-1}) was having the highest and FCV AH 5 (0.18 cm day^{-1}) the lowest absolute growth rate. The overall mean for absolute growth rate at 120 DAP was 0.48 cm day^{-1}. The mean absolute growth rate at 150 DAP was 0.43 cm day^{-1} with FCV AH 22 (0.94 cm day^{-1}) being the highest and FCV AH 2 (0.17 cm day^{-1}) the lowest.

4.1.15 Relative growth rate

Relative growth rate was analysed for variation between the different seed sources. Significant variations were found at 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 17). At 60 DAP, the average relative growth rate from all the sources was 0.022 g $g^{-1}day^{-1}$. The highest (0.032 g $g^{-1}day^{-1}$) absolute growth rate was observed in FCV AH 14 and the lowest (0.012 g $g^{-1}day^{-1}$) in FCV AH 1. At 90 DAP, the mean absolute growth rate of the seedlings was 0.012 g $g^{-1}day^{-1}$. FCV AH 31 was the highest (0.020 g $g^{-1}day^{-1}$) among the progenies and FCV AH 23 (0.007 g $g^{-1}day^{-1}$) was having the lowest absolute growth rate at 90 DAP. At 120 DAP, FCV AH 33 (0.010 g $g^{-1}day^{-1}$) was having the highest and FCV AH 32 (0.004 g $g^{-1}day^{-1}$) the lowest absolute growth rate. The overall mean for absolute growth rate at 120 DAP was 0.007 g $g^{-1}day^{-1}$. The mean absolute

76

Table 16. Variation in absolute growth rate (cm day^{-1}) of seedlings from different seed sources.

Seed source	**Absolute Growth Rate (cm day^{-1})**			
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	0.39^{op}	0.36^{qr}	0.39^{jklmn}	0.24^{jk}
FCV AH 2	0.81^{cd}	0.39^{pqr}	0.42^{ghijklm}	0.17^{k}
FCV AH 3	0.80^{cd}	0.51^{jklmnopq}	0.52^{efghijk}	0.37^{fghij}
FCV AH 4	0.69^{defghi}	0.59^{fghijklm}	0.30^{mno}	0.78^{bc}
FCV AH 5	0.55^{hijklmno}	0.48^{klmnopq}	0.18^{o}	0.39^{efghi}
FCV AH 6	0.52^{jklmnop}	0.56^{ghijklmno}	0.43^{fghijklm}	0.65^{cd}
FCV AH 7	0.47^{klmnop}	0.58^{fghijklmn}	0.56^{efghi}	0.60^{d}
FCV AH 8	0.89^{bc}	0.65^{defghij}	0.49^{efghijk}	0.52^{de}
FCV AH 9	0.53^{ijklmno}	0.72^{bcdefg}	0.55^{efghi}	0.93^{a}
FCV AH 10	0.39^{op}	0.43^{nopqr}	0.53^{efghij}	0.36^{fghij}
FCV AH 11	0.46^{klmnop}	0.48^{klmnopq}	0.29^{mno}	0.24^{jk}
FCV AH 12	0.60^{ghijklm}	0.53^{hijklmnop}	0.37^{klmn}	0.34^{fghij}
FCV AH 13	0.43^{mnop}	0.59^{fghijklm}	0.74^{bc}	0.64^{cd}
FCV AH 14	0.65^{defghij}	0.78^{bcd}	0.63^{cde}	0.32^{fghij}
FCV AH 15	0.71^{defgh}	0.58^{fghijklmn}	0.57^{efg}	0.42^{efghi}
FCV AH 16	0.67^{defghij}	0.42^{opqr}	0.64^{cde}	0.37^{efghij}
FCV AH 17	0.76^{cdef}	0.67^{defghi}	0.41^{hijklm}	0.41^{efghi}
FCV AH 18	0.69^{defghi}	0.63^{defghijk}	0.49^{efghijk}	0.24^{jk}
FCV AH 19	0.77^{cde}	0.63^{efghijk}	0.53^{efghij}	0.43^{efghi}
FCV AH 20	0.73^{cdefg}	0.73^{bcdef}	0.52^{efghijk}	0.29^{ghijk}
FCV AH 21	0.43^{nop}	0.39^{pqr}	1.00^{a}	0.82^{ab}
FCV AH 22	0.73^{cdefg}	0.68^{cdefgh}	0.57^{efgh}	0.94^{a}
FCV AH 23	0.97^{ab}	0.75^{bcde}	0.58^{def}	0.78^{bc}
FCV AH 24	0.35^{p}	0.61^{efghijkl}	0.87^{b}	0.37^{efghij}
FCV AH 25	0.41^{op}	0.76^{bcde}	0.32^{lmno}	0.40^{efghi}
FCV AH 26	0.63^{efghij}	1.01^{a}	0.24^{no}	0.39^{efghij}
FCV AH 27	0.50^{jklmnop}	0.62^{efghijkl}	0.57^{efghi}	0.43^{efgh}
FCV AH 28	0.51^{jklmnop}	0.46^{lmnopq}	0.41^{hijklm}	0.32^{fghij}
FCV AH 29	0.55^{hijklmno}	0.85^{b}	0.25^{no}	0.30^{fghijk}
FCV AH 30	0.44^{lmnop}	0.54^{hijklmnop}	0.72^{cd}	0.28^{ijk}
FCV AH 31	0.62^{efghijk}	0.44^{mnopqr}	0.25^{no}	0.30^{fghijk}
FCV AH 32	0.50^{jklmnop}	0.83^{bc}	0.41^{ijklm}	0.29^{hijk}
FCV AH 33	0.65^{defghij}	0.52^{ijklmnopq}	0.55^{efghij}	0.45^{ef}
FCV AH 34	0.59^{ghijklmn}	0.59^{fghijklm}	0.43^{fghijklm}	0.32^{fghij}
FCV AH 35	0.42^{op}	0.44^{mnopqr}	0.30^{mno}	0.34^{fghij}
FCV AH 36	0.36^{p}	0.43^{nopqr}	0.43^{fghijklm}	0.37^{efghij}
FCV AH 37	0.77^{cde}	0.21^{s}	0.44^{fghijklm}	0.34^{fghij}
FCV AH 38	1.10^{a}	0.30^{rs}	0.33^{lmno}	0.23^{jk}
FCV AH 39	0.41^{op}	0.68^{cdefgh}	0.63^{cde}	0.44^{efg}
FCV AH 40	0.60^{fghijkl}	0.73^{bcdef}	0.46^{fghijkl}	0.42^{efghi}
Mean	0.60	0.58	0.48	0.43
P	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

Table 17. Variation in relative growth rate (g g^{-1} day^{-1}) of seedlings from different seed sources.

Seed source	Relative Growth Rate (g g^{-1} day^{-1})			
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	0.012^{p}	0.015^{cd}	0.006^{fghij}	0.006^{cde}
FCV AH 2	0.026^{abcdefg}	0.009^{lmnopqr}	0.007^{defghij}	0.005^{defghi}
FCV AH 3	0.019^{jklmno}	0.014^{defg}	0.009^{bc}	0.005^{defg}
FCV AH 4	0.02^{hijklmno}	0.013^{defghijk}	0.01a^{b}	0.007^{bc}
FCV AH 5	0.022^{fghijklm}	0.007^{qr}	0.007^{defghij}	0.006^{bcd}
FCV AH 6	0.025^{cdefghi}	0.013^{defghij}	0.01a^{b}	0.005^{defg}
FCV AH 7	0.026^{bcdefg}	0.011^{ijklmno}	0.007^{defghij}	0.007^{ab}
FCV AH 8	0.021^{ghijklm}	0.008^{opqr}	0.006^{efghij}	0.008^{a}
FCV AH 9	0.017^{mnop}	0.015^{cd}	0.006^{fghij}	0.005^{defghij}
FCV AH 10	0.028^{abcdef}	0.007^{pqr}	0.006^{fghij}	0.003^{jklm}
FCV AH 11	0.018^{lmno}	0.009^{mnopqr}	0.007^{cdefghi}	0.004^{ijklm}
FCV AH 12	0.021^{ghijklmn}	0.01^{klmnopq}	0.005^{klm}	0.004^{efghijk}
FCV AH 13	0.026^{bcdefg}	0.014^{defgh}	0.007^{cdefg}	0.004^{hijklm}
FCV AH 14	0.032^{a}	0.011^{ijklmno}	0.006^{ghijkl}	0.003^{lmn}
FCV AH 15	0.026^{bcdefg}	0.014^{defg}	0.007^{cdefgh}	0.007^{bc}
FCV AH 16	0.02^{hijklmno}	0.017^{bc}	0.005^{jklm}	0.004^{jklm}
FCV AH 17	0.02^{hijklmno}	0.009^{lmnopqr}	0.01^{ab}	0.004^{efghijk}
FCV AH 18	0.017^{lmnop}	0.012^{defghijkl}	0.01^{ab}	0.004^{jklm}
FCV AH 19	0.017^{mnop}	0.011^{jklmnop}	0.006^{defghij}	0.005^{defghij}
FCV AH 20	0.02^{hijklmno}	0.009^{mnopqr}	0.01^{ab}	0.004^{hijkl}
FCV AH 21	0.023^{fghijkl}	0.011^{ijklmno}	0.006^{fghijk}	0.006^{bcd}
FCV AH 22	0.017^{mnop}	0.014^{defghij}	0.008^{cd}	0.006^{bcd}
FCV AH 23	0.029^{abcd}	0.007^{r}	0.006^{defghij}	0.002^{n}
FCV AH 24	0.029^{abcde}	0.011^{ijklmno}	0.01^{ab}	0.003^{lmn}
FCV AH 25	0.03^{abc}	0.011^{ijklmno}	0.007^{cdefghi}	0.004^{efghijk}
FCV AH 26	0.031^{ab}	0.009^{nopqr}	0.006^{ijkl}	0.004^{jklm}
FCV AH 27	0.024^{defghij}	0.011^{hijklmn}	0.01^{ab}	0.002^{mn}
FCV AH 28	0.018^{klmno}	0.012^{ghijklmn}	0.006^{fghij}	0.003^{klmn}
FCV AH 29	0.025^{cdefghi}	0.01^{lmnopqr}	0.007^{cdef}	0.003^{jklm}
FCV AH 30	0.024^{defghij}	0.009^{mnopqr}	0.007^{defghi}	0.004^{ijklm}
FCV AH 31	0.017^{mnop}	0.02^{a}	0.006^{fghij}	0.004^{ghijkl}
FCV AH 32	0.019^{ijklmno}	0.019^{ab}	0.004^{m}	0.005^{efghij}
FCV AH 33	0.015^{nop}	0.012^{fghijklmn}	0.01^{a}	0.006^{cde}
FCV AH 34	0.025^{cdefgh}	0.015^{cdef}	0.006^{fghijk}	0.004^{efghijkl}
FCV AH 35	0.015^{op}	0.015^{cdef}	0.006^{fghij}	0.003^{klmn}
FCV AH 36	0.018^{klmno}	0.014^{defghi}	0.004^{lm}	0.004^{fghijkl}
FCV AH 37	0.026^{abcdefg}	0.012^{efghijklm}	0.006^{efghij}	0.006^{bcd}
FCV AH 38	0.027^{abcdef}	0.013^{defghij}	0.006^{hijkl}	0.005^{cde}
FCV AH 39	0.023^{efghijk}	0.011^{ghijklmn}	0.008^{cde}	0.005^{defgh}
FCV AH 40	0.017^{lmnop}	0.011^{ghijklmn}	0.007^{cdefghi}	0.004^{fghijkl}
Mean	0.022	0.012	0.007	0.005
P	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

growth rate at 150 DAP was 0.005 g $g^{-1}day^{-1}$ with FCV AH 8 (0.008 g $g^{-1}day^{-1}$) being the highest and FCV AH 23 (0.002 g $g^{-1}day^{-1}$) the lowest.

4.1.16 Net assimilation rate

Analysis of variance revealed significance difference in net assimilation rate at 60 DAP, 90 DAP, 120 DAP and 150 DAP (Table 18). At 60 DAP, the average net assimilation rate from all the sources was 0.063 g $g^{-1}day^{-1}$. The highest (0.114 g $g^{-1}day^{-1}$) net assimilation rate was observed in FCV AH 25 and the lowest (0.033 g $g^{-1}day^{-1}$) in FCV AH 1. At 90 DAP, the mean net assimilation rate of the seedlings was 0.035 g $g^{-1}day^{-1}$. FCV AH 32 was the highest (0.070g $g^{-1}day^{-1}$) among the progenies and FCV AH 5 (0.019 g $g^{-1}day^{-1}$) was having the lowest net assimilation rate at 90 DAP. At 120 DAP, FCV AH 24 (0.040 g $g^{-1}day^{-1}$) was having the highest and FCV AH 12 (0.014 g $g^{-1}day^{-1}$) the lowest net assimilation rate. The overall mean for net assimilation rate at 120 DAP was 0.025 g $g^{-1}day^{-1.}$ The mean net assimilation rate at 150 DAP was 0.019 g $g^{-1}day^{-1}$ with FCV AH 15 (0.033 g $g^{-1}day^{-1}$) being the highest and FCV AH 27 (0.009 g $g^{-1}day^{-1}$) the lowest.

Table 18. Variation in net assimilation rate (g g^{-1} day^{-1}) of seedlings from different seed sources.

Seed source	Net Assimilation Rate (g g^{-1} day^{-1})			
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**
FCV AH 1	0.033^{m}	0.037^{fghijk}	0.018^{lm}	$0.02^{defghijk}$
FCV AH 2	0.091^{abcd}	$0.028^{klmnopq}$	0.022^{ghijkl}	$0.019^{fghijkl}$
FCV AH 3	0.047^{ijklm}	$0.039^{efghijk}$	0.032^{bcd}	$0.022^{cdefghij}$
FCV AH 4	0.043^{jklm}	$0.031^{ijklmnop}$	0.037^{ab}	0.034^{a}
FCV AH 5	$0.067^{cdefghijkl}$	0.019^{q}	0.021^{hijklm}	0.025^{cdef}
FCV AH 6	$0.055^{efghijklm}$	$0.034^{ghijklmno}$	0.036^{abc}	0.024^{cdef}
FCV AH 7	$0.065^{cdefghijkl}$	$0.03^{jklmnopq}$	0.022^{ghijkl}	0.032^{ab}
FCV AH 8	$0.055^{efghijklm}$	0.021^{pq}	0.02^{hijklm}	0.028^{abc}
FCV AH 9	0.039^{klm}	0.05^{bcde}	0.029^{defg}	0.026^{cde}
FCV AH 10	$0.079^{bcdefgh}$	0.024^{nopq}	0.02^{hijklm}	0.012^{mn}
FCV AH 11	$0.058^{efghijklm}$	$0.029^{jklmnopq}$	0.025^{efghij}	0.016^{ijklm}
FCV AH 12	$0.063^{defghijklm}$	$0.029^{jklmnopq}$	0.014^{m}	0.014^{klmn}
FCV AH 13	0.079^{bcdefg}	0.045^{bcdefg}	0.029^{defg}	0.017^{ijklm}
FCV AH 14	0.089^{abcd}	$0.032^{hijklmnop}$	0.021^{hijklm}	0.012^{mn}
FCV AH 15	0.083^{bcdef}	0.055^{bc}	0.036^{abc}	0.033^{a}
FCV AH 16	$0.049^{ghijklm}$	0.047^{bcdef}	0.019^{ijklm}	0.014^{klmn}
FCV AH 17	0.049^{hijklm}	0.025^{mnopq}	0.028^{defg}	0.015^{klmn}
FCV AH 18	0.042^{jklm}	$0.029^{jklmnopq}$	0.032^{bcde}	0.014^{klmn}
FCV AH 19	0.041^{jklm}	0.024^{mnopq}	0.019^{jklm}	0.017^{hijklm}
FCV AH 20	$0.054^{fghijklm}$	0.022^{pq}	0.029^{cdef}	0.014^{klmn}
FCV AH 21	$0.069^{cdefghijk}$	$0.032^{hijklmnop}$	0.018^{jklm}	$0.023^{cdefghi}$
FCV AH 22	0.038^{lm}	0.04^{efghij}	0.026^{defgh}	$0.02^{efghijk}$
FCV AH 23	0.093^{abcd}	0.023^{opq}	$0.025^{efghijk}$	0.010^{n}
FCV AH 24	0.093^{abc}	$0.036^{fghijklm}$	0.04^{a}	0.012^{mn}
FCV AH 25	0.114^{a}	$0.033^{hijklmnop}$	$0.024^{fghijkl}$	$0.022^{cdefghij}$
FCV AH 26	0.107^{ab}	$0.029^{jklmnopq}$	0.019^{jklm}	0.015^{klmn}
FCV AH 27	$0.071^{cdefghij}$	$0.03^{ijklmnop}$	0.031^{bcde}	0.009^{n}
FCV AH 28	$0.054^{fghijklm}$	$0.039^{efghijk}$	$0.023^{fghijkl}$	0.013^{lm}
FCV AH 29	$0.065^{cdefghijkl}$	$0.028^{jklmnopq}$	0.026^{defgh}	0.016^{ijklm}
FCV AH 30	$0.051^{ghijklm}$	0.026^{lmnopq}	0.026^{defghi}	$0.017^{ghijklm}$
FCV AH 31	0.047^{ijklm}	0.056^{b}	0.02^{hijklm}	0.014^{klmn}
FCV AH 32	$0.057^{efghijklm}$	0.070^{a}	0.018^{klm}	0.024^{cdefg}
FCV AH 33	0.047^{ijklm}	$0.037^{fghijkl}$	0.036^{abc}	0.024^{cdefgh}
FCV AH 34	$0.075^{cdefghi}$	0.045^{cdefg}	0.022^{ghijkl}	0.017^{ijklm}
FCV AH 35	0.041^{jklm}	0.043^{defgh}	$0.023^{fghijkl}$	0.012^{mn}
FCV AH 36	$0.056^{efghijklm}$	0.054^{bcd}	0.019^{ijklm}	0.016^{jklm}
FCV AH 37	0.081^{bcdef}	$0.035^{fghijklmn}$	$0.023^{fghijkl}$	0.026^{bcd}
FCV AH 38	0.085^{bcde}	0.042^{efghi}	0.02^{hijklm}	$0.02^{defghijk}$
FCV AH 39	$0.057^{efghijklm}$	$0.033^{hijklmnop}$	0.029^{cdef}	$0.023^{cdefghi}$
FCV AH 40	0.044^{jklm}	$0.035^{fghijklmn}$	0.029^{cdef}	$0.02^{defghijk}$
Mean	0.063	0.035	0.025	0.019
P	<0.001**	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level*

Values with the same superscript along the column are homogenous

80

4.1.17 Cluster analysis

A hierarchical cluster analysis based on the morphological and biometric characters was carried out for the 40 plus tree sources based on Euclidian squared distance method. The 40 plus tree sources were grouped into twenty-one clusters. Details of the twenty-one clusters are given in Table 19. The trees coming in a cluster have similar morphological and biometric characters whereas it differs between two clusters. From the table, it can be seen that cluster 14 possess maximum number of trees (6) whereas the minimum number (1) observed for the cluster 2, 7, 8, 10, 11, 12, 15, 16, 17, 18 and 21. Therefore, the tree sources FCV AH 2, FCV AH 8, FCV AH 9, FCV AH 11, FCV AH 12, FCV AH 15, FCV AH 21, FCV AH 22, FCV AH 23, FCV AH 25 and FCV AH 37 possess difference in their morphological and biochemical characters with others. Dendrogram of the analysis is presented in (Figure 1)

Table 19. Grouping of plus trees from various seed sources into different clusters based on morphological and biometric characters

Cluster No.	Plus trees
Cluster 1	FCV AH 1, FCV AH 5
Cluster 2	FCV AH 2
Cluster 3	FCV AH 3, FCV AH 24, FCV AH 16, FCV AH 20, FCV AH 14
Cluster 4	FCV AH 6, FCV AH 13
Cluster 5	FCV AH 30, FCV AH 32
Cluster 6	FCV AH 10, FCV AH 36, FCV AH 38
Cluster 7	FCV AH 12
Cluster 8	FCV AH 37
Cluster 9	FCV AH 7, FCV AH 39, FCV AH 26
Cluster 10	FCV AH 21
Cluster 11	FCV AH 15
Cluster 12	FCV AH 9
Cluster 13	FCV AH 4, FCV AH 33
Cluster 14	FCV AH 18, FCV AH 27, FCV AH 28, FCV AH 34, FCV AH 31, FCV AH 35
Cluster 15	FCV AH 23
Cluster 16	FCV AH 11
Cluster 17	FCV AH 25
Cluster 18	FCV AH 8
Cluster 19	FCV AH 17, FCV AH 19
Cluster 20	FCV AH 29, FCV AH 40
Cluster 21	FCV AH 22

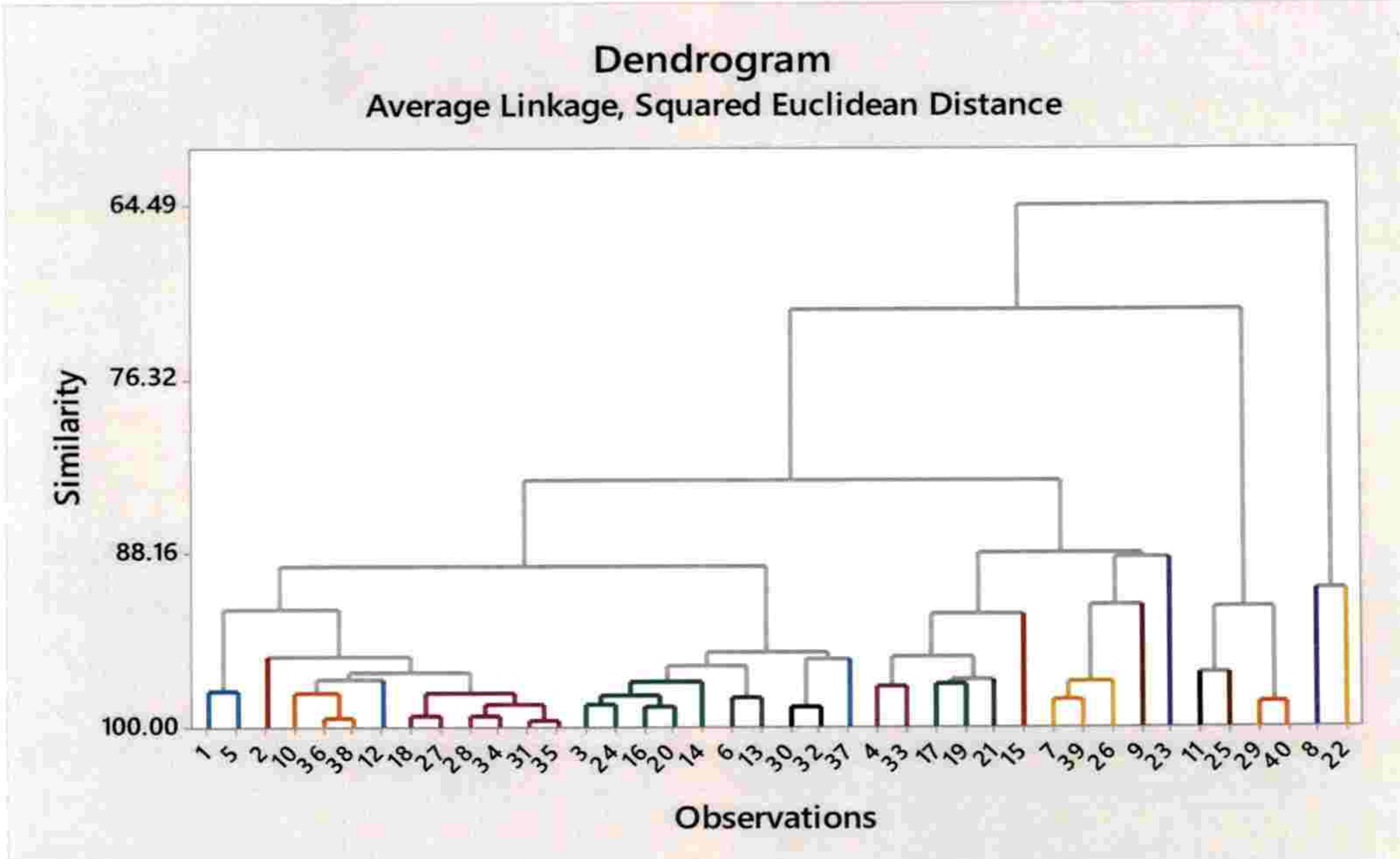


Figure 1. Dendrogram of hierarchial cluster analysis of seedlings of *Artocarpus heterophyllus* based on sixteen traits

82

4.2 ANATOMICAL PROPERTIES OF STEM WOOD (180 DAP)

4.2.1 Vessel morphology

Analysis of variance revealed vessel area to be significantly different among koozha and varikka varieties from different panchayats of Thrissur and Palakkad district (Table 20). Generally vessel area of koozha variety from each panchayat were found to be high (Figure 2). The overall mean vessel area was 4199.14 μm^2 with koozha variety from Madakkathara panchayat of Thrissur district (6399.16 μm^2) having the highest and varikka variety from Ongallur panchayat of Palakkad district (3487.02 μm^2) having the lowest vessel area. Vessel diameter did not show any significant difference. Mean vessel diameter was found to be 126.43 µm with values ranging from 138.81 µm to 112.80 µm.

4.2.2 Ray morphology

Ray height and ray width were found to be significantly different among both varieties of all panchayats under study from Thrissur and Palakkad district (Table 20). Both ray height and ray width of koozha variety generally had highest values. The mean ray height was 466.98 µm with koozha variety from Adat panchayat of Thrissur district (674.87 µm) having the highest and varikka variety from Nenmara panchayat of Palakkad district (316.45 µm) having the lowest ray height (Figure 3). Ray width of koozha variety recorded from Adat panchayat also had the highest value (46.47 µm) and koozha variety of Mathur panchayat of Palakkad district had the lowest value (24.73 µm) (Figure 4). The average ray width was 34.58 µm.

4.2.3 Fibre morphology

Fibre morphological parameters like fibre length and fibre wall thickness were found to be significantly different (Table 21). The overall mean fibre length was 801.13 µm with koozha variety from Ongallur panchayat of Palakkad district

(999.31 μm) having the highest and varikka variety from Madakkathara panchayat of Thrissur district (689.47 μm) having the lowest fibre length (Figure 5). In case of fibre wall thickness, koozha variety from Vaniyamkulam panchayat of Palakkad district (4.52 μm) had the highest wall thickness and varikka variety from Thrikkur panchayat of Thrissur district (2.47 μm) had the lowest value (Figure 6). The average fibre wall thickness was 3.27 μm. Fibre width did not show any significant difference among different progenies under study. The mean fibre width was 22.74 μm with values ranging from 27.35 μm to 19.36 μm.

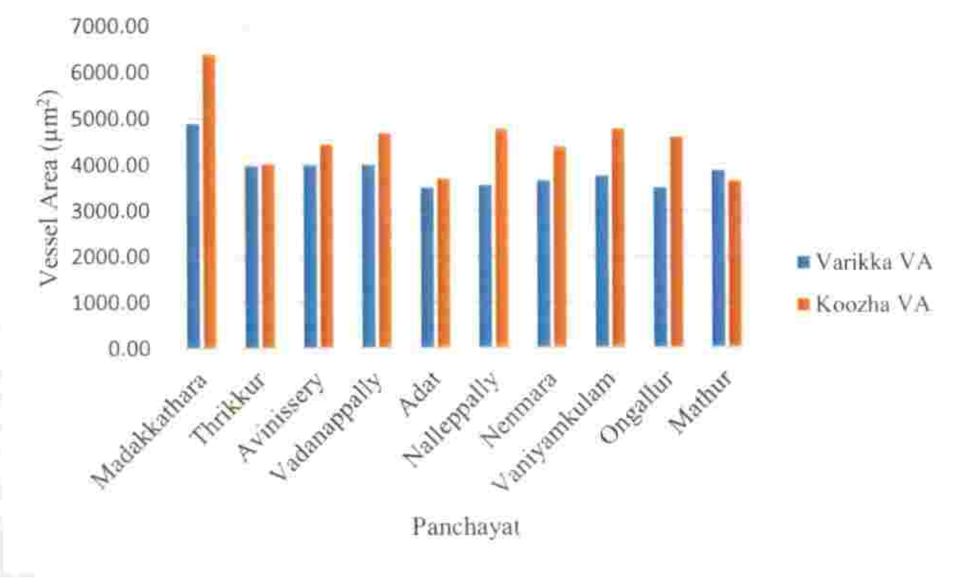


Figure 2. Variation in vessel area (μm^2) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.

84

Table 20. Variation in vessel and ray morphology of six month old seedling from different seed sources

Sl. No	Panchayat	Variety	Vessel Diameter (μm)	Vessel Area (μm^2)	Ray Height (μm)	Ray Width (μm)
1	Madakkathara	varikka	138.81	4888.52^{b}	405.53^{defg}	31.96^{defghi}
		koozha	131.35	6399.16^{a}	495.06^{bcdef}	41.48^{ab}
2	Thrikkur	varikka	133.01	3968.65^{bcde}	474.88^{bcdef}	$32.41^{cdefghi}$
		koozha	126.91	4012.53^{bcde}	401.08^{efg}	$35.85^{bcdefgh}$
3	Avinissery	varikka	121.50	3978.88^{bcde}	375.44^{efg}	36.04^{bcdefg}
		koozha	128.59	4440.63^{bcde}	467.32^{bcdefg}	38.85^{bcd}
4	Vadanappally	varikka	120.60	3986.36^{bcde}	512.48^{bcdef}	$35.32^{bcdefgh}$
		koozha	128.83	4677.19^{bcde}	378.42^{efg}	28.17^{ghi}
5	Adat	varikka	120.90	3495.86^{e}	467.58^{bcdefg}	29.57^{fghi}
		koozha	118.49	3699.02^{bcde}	674.87^{a}	46.47^{a}
6	Nalleppally	varikka	131.45	3553.33^{de}	418.07^{cdefg}	40.19^{abc}
		koozha	129.56	4779.17^{bc}	380.83^{efg}	38.71^{bcd}
7	Nenmara	varikka	129.94	3645.05^{cde}	316.45^{g}	28.46^{fghi}
		koozha	133.07	4384.77^{bcde}	525.79^{bcde}	38.85^{bcd}
8	Vaniyamkulam	varikka	117.11	3745.53^{bcde}	609.94^{ab}	36.35^{bcdef}
		koozha	132.27	4768.53^{bcd}	413.92^{cdefg}	38.08^{bcde}
9	Ongallur	varikka	128.54	3487.02^{e}	367.36^{fg}	27.90^{hi}
		koozha	126.57	4590.51^{bcde}	558.99^{abcd}	30.41^{efghi}
10	Mathur	varikka	112.80	3855.28^{bcde}	529.12^{bcde}	31.91^{defghi}
		koozha	118.18	3626.79^{cde}	566.58^{abc}	24.73^{i}
	Mean		**126.43**	**4199.14**	**466.98**	**34.58**
	p		0.396^{ns}	<0.001**	<0.001**	<0.001**

*** significant at 1 per cent level and superscript 'ns' indicate non- significant*

Values with the same superscript along the column are homogenous

Table 21. Variation in fibre morphology of six month old seedling from different seed sources.

Sl. No	Panchayat	variety	Fibre Length (μm)	Fibre Width (μm)	Wall Thickness (μm)
1	Madakkathara	varikka	689.47^{c}	24.29	2.67^{cd}
		koozha	841.11^{abc}	20.99	2.76^{cd}
2	Thrikkur	varikka	854.33^{abc}	23.63	2.47^{d}
		koozha	754.29^{bc}	22.38	3.20^{bcd}
3	Avinissery	varikka	874.12^{ab}	20.21	3.69^{abc}
		koozha	773.69^{bc}	21.88	3.08^{bcd}
4	Vadanappally	varikka	739.44^{bc}	22.88	3.68^{abc}
		koozha	718.65^{bc}	23.09	3.21^{bcd}
5	Adat	varikka	713.27^{bc}	21.97	3.26^{bcd}
		koozha	805.94^{bc}	24.11	2.82^{cd}
6	Nalleppally	varikka	777.16^{bc}	22.46	2.88^{cd}
		koozha	825.10^{bc}	22.05	2.98^{bcd}
7	Nenmara	varikka	873.54^{ab}	27.35	4.16^{ab}
		koozha	845.68^{abc}	25.71	3.74^{abc}
8	Vaniyamkulam	varikka	754.73^{bc}	21.37	3.49^{abcd}
		koozha	877.72^{ab}	24.12	4.52^{a}
9	Ongallur	varikka	716.87^{bc}	19.36	2.64^{cd}
		koozha	999.31^{a}	24.12	3.83^{abc}
10	Mathur	varikka	813.31^{bc}	20.53	2.88^{cd}
		koozha	774.83^{bc}	22.37	3.52^{abcd}
	Mean		**801.13**	**22.74**	**3.27**
	p		0.007**	0.128^{ns}	0.004**

*** significant at 1 per cent level and superscript 'ns' indicate non- significant*
Values with the same superscript along the column are homogenous

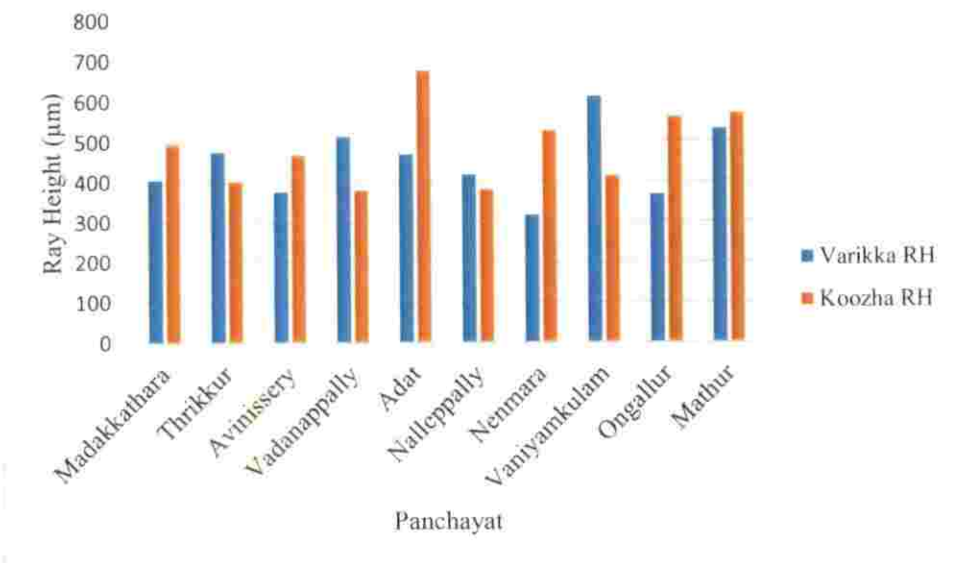


Figure 3. Variation in ray height (µm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.

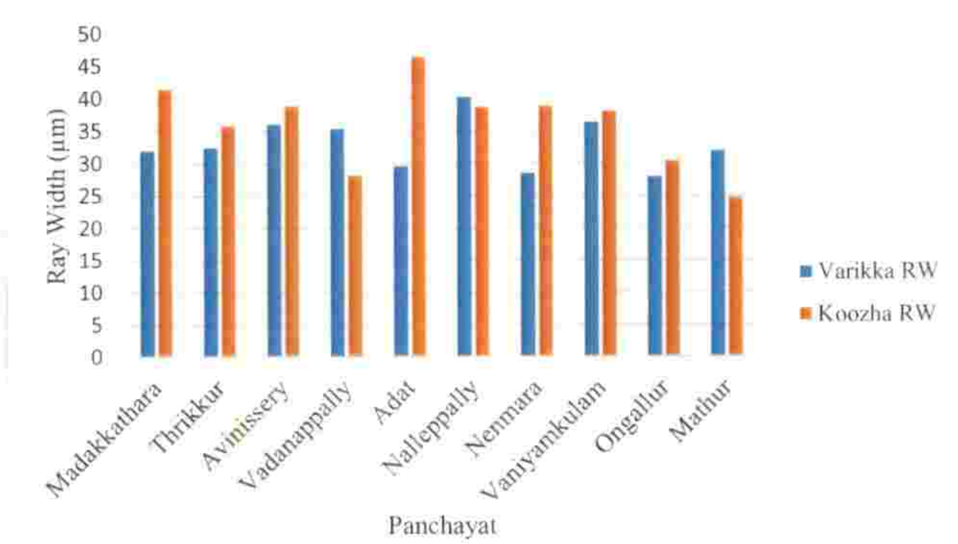


Figure 4. Variation in ray width (µm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.

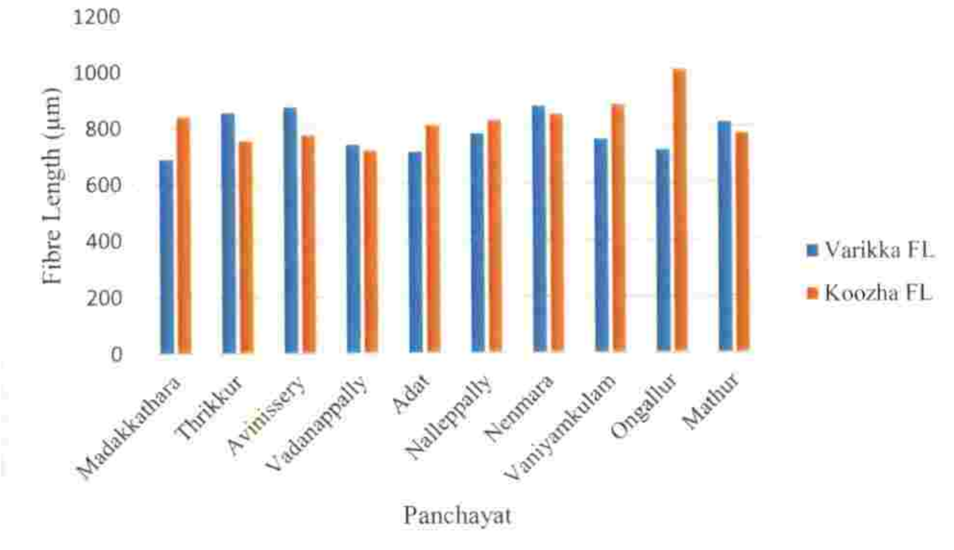


Figure 5. Variation in fibre length (µm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.

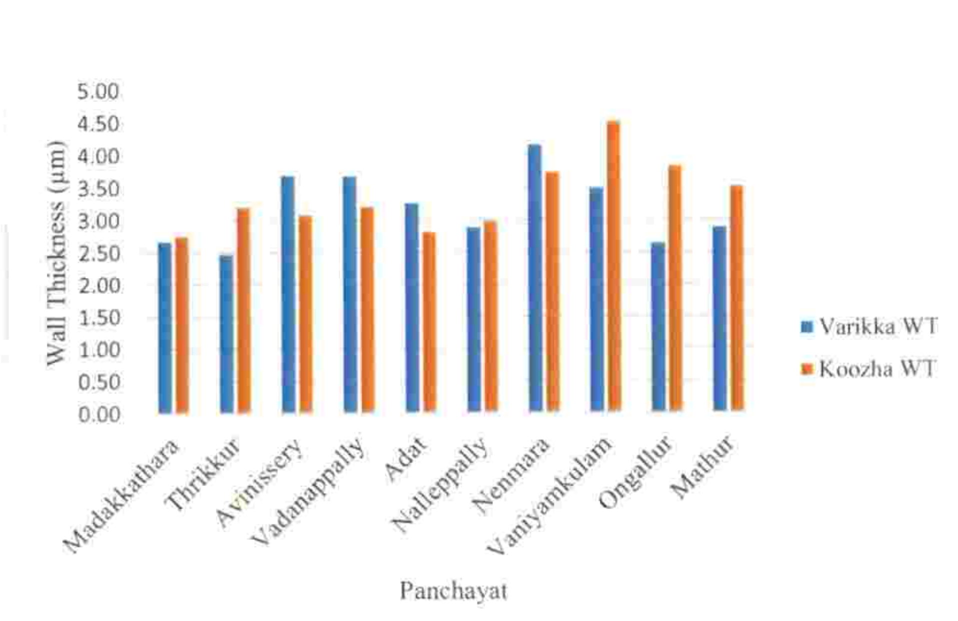


Figure 6. Variation in fibre wall thickness (µm) in varikka and koozha varieties from different panchayats of Thrissur and Palakkad district.

4.3 FIELD EXPERIMENT- OBSERVATIONS

Parameters like seedling height and collar diameter were measured 30 days after planting and found that both parameters possess significant differences among different seed sources (Table 22). The average seedling height was 117.30 cm with values ranging from 143.94 cm to 96.35 cm and FCV AH 22 being the tallest. The mean collar diameter was 12.27 mm with FCV AH 29 having the highest (14.67 mm) and FCV AH 20 having the least value (9.29 mm).

Table 22. Variation in Height (cm) and Collar Diameter (mm) of seedlings 30 days after field planting

Seed source	**Seedling Height (cm)**	**Collar Diameter (mm)**	**Seed source**	**Seedling Height (cm)**	**Collar Diameter (mm)**
FCV AH 1	111.28^{ijk}	12.64^{fghij}	FCV AH 21	136.24^{b}	13.26^{ef}
FCV AH 2	103.14^{lmno}	12.40^{ijkl}	FCV AH 22	143.94^{a}	13.99^{bc}
FCV AH 3	135.51^{b}	13.91^{bcd}	FCV AH 23	122.15^{def}	12.19^{jkl}
FCV AH 4	129.24^{c}	13.07^{efgh}	FCV AH 24	114.79^{ghi}	14.01^{bc}
FCV AH 5	104.41^{lmn}	12.43^{hijkl}	FCV AH 25	115.54^{ghi}	9.91^{t}
FCV AH 6	99.30^{nop}	11.53^{mnop}	FCV AH 26	107.93^{jkl}	10.30^{st}
FCV AH 7	137.23^{b}	10.65^{qrs}	FCV AH 27	105.59^{klm}	12.60^{ghij}
FCV AH 8	126.59^{cd}	14.50^{ab}	FCV AH 28	117.85^{fgh}	11.19^{opq}
FCV AH 9	128.05^{c}	11.10^{pqr}	FCV AH 29	123.87^{cde}	14.67^{a}
FCV AH 10	113.38^{hij}	10.90^{pqrs}	FCV AH 30	109^{jkl}	11.51^{mnop}
FCV AH 11	128.35^{c}	12.63^{fghij}	FCV AH 31	111.16^{ijk}	12.52^{hijk}
FCV AH 12	107.14^{kl}	11.785^{lmno}	FCV AH 32	137.17^{b}	13.32^{de}
FCV AH 13	138.04^{b}	13.20^{efg}	FCV AH 33	124.20^{cde}	13.30^{de}
FCV AH 14	137.16^{b}	10.94^{pqr}	FCV AH 34	119.61^{efg}	12.58^{ghij}
FCV AH 15	121.28^{def}	11.35^{nop}	FCV AH 35	96.35^{p}	12.11^{jklm}
FCV AH 16	101.16^{mnop}	11.92^{klmn}	FCV AH 36	106.97^{klm}	11.90^{klmn}
FCV AH 17	116.65^{fghi}	11.17^{opq}	FCV AH 37	112.89^{hij}	12.61^{ghij}
FCV AH 18	97.63^{op}	10.49^{rst}	FCV AH 38	96.44^{p}	14.09^{abc}
FCV AH 19	129.33^{c}	12.11^{jklm}	FCV AH 39	103.81^{lmn}	13.58^{cde}
FCV AH 20	118.11^{fgh}	9.29u	FCV AH 40	103.28^{klmn}	13.05^{efghi}
Mean				**117.30**	**12.27**
p				<0.001**	<0.001**

*** significant at 1 per cent level*

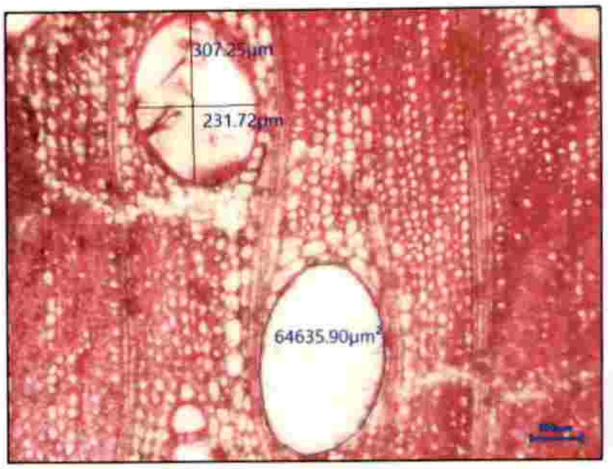
Values with the same superscript along the column are homogenous

4.4 ANATOMICAL CHARACTERISTICS OF KOOZHA AND VARIKKA VARIETIES

To check the anatomical differences among *varikka* and *koozh*a varieties of *Artocarpus heterophyllus*, a study was conducted in a 'Jack Gene Sanctuary' at the Agricultural Research Station (ARS), Mannuthy. Parameters like vessel diameter, vessel area, vessel frequency, ray height and ray width were found to be significantly different among two varieties whereas, the parameters like ray frequency, fibre length, fibre width and fibre wall thickness did not show any significant difference (Table 23).

The average vessel diameter was 276.58 μm with values ranging from 255.92 μm to 312.87 μm and the largest value was for *koozha* 1. The vessel area had an average value of 62569.05 μm^2 with values ranging from 49672.81 μm^2 to 80692.34 μm^2 and the largest value was for *koozha* 1. The average vessel frequency was 3.52 per mm^2 with values ranging from 2.90 per mm^2 to 3.80 per mm^2 and the highest frequency was observed in *varikka* 2. The ray height had an average value of 498.38 μm with values ranging from 374.82 μm to 639.77 μm and the highest was observed in *koozha* 1. The ray width ranges between 42.98 μm to 68.32 μm with a mean of 52.97 μm and the highest value was for *koozha* 1.

12. a



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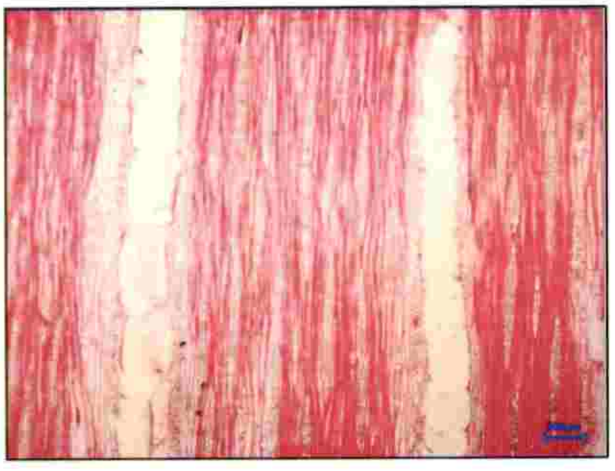

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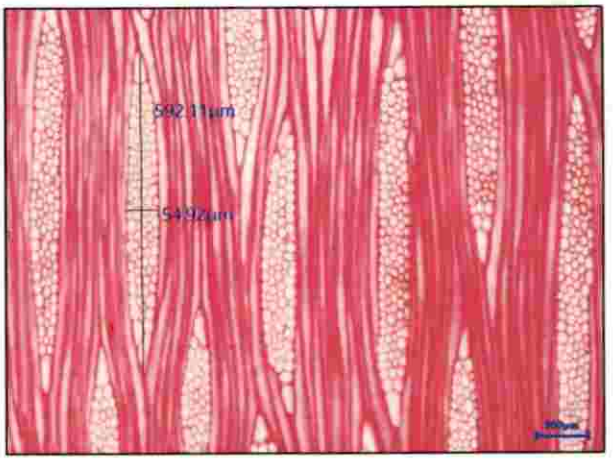
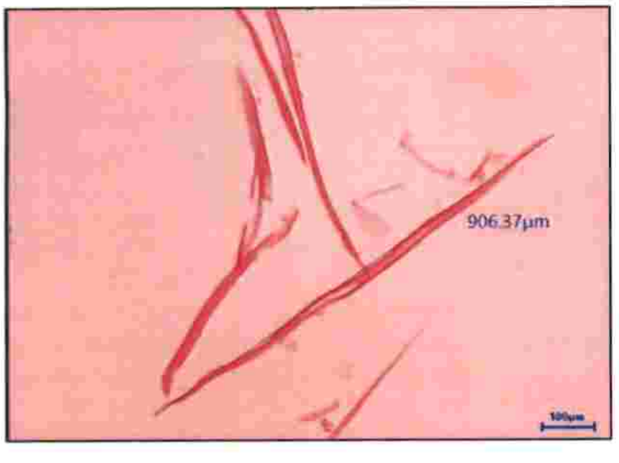


12. d



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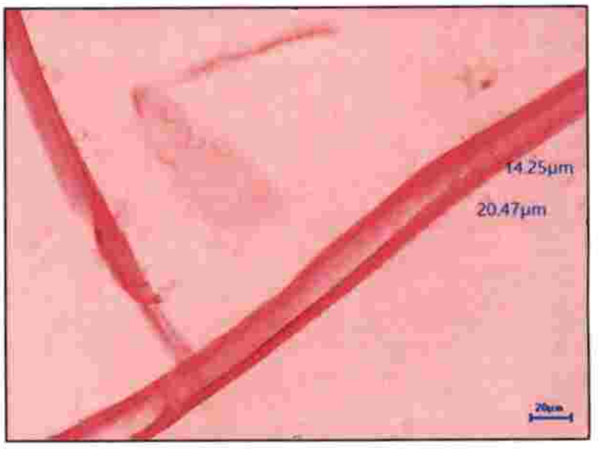
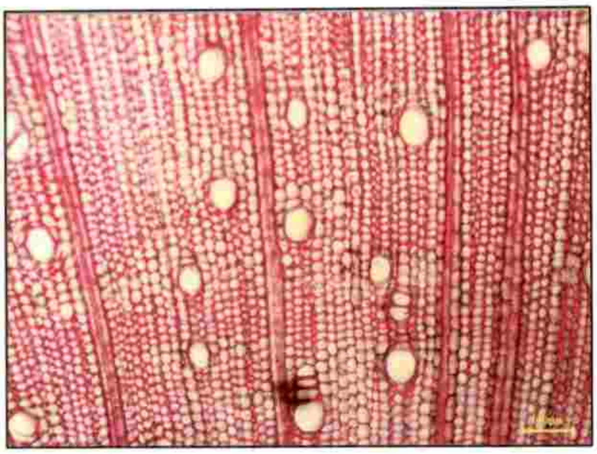
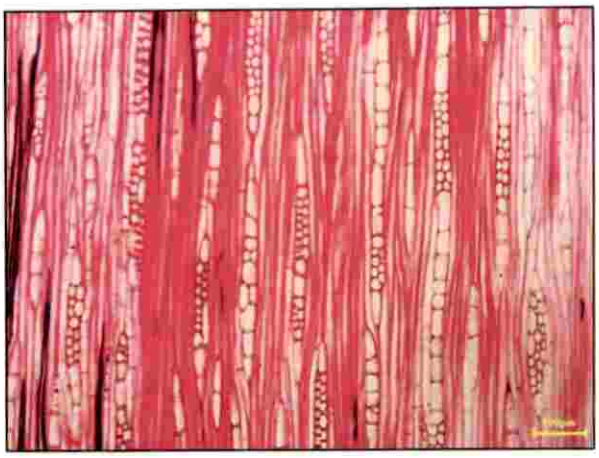


12. f

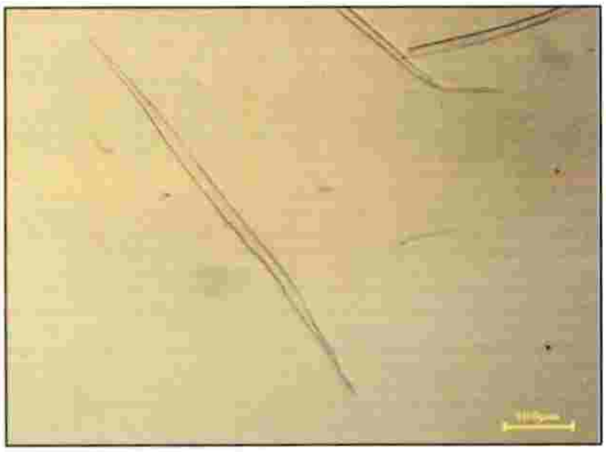
Plate 12. Anatomical features of mature wood of *Artocarpus heterophyllus* Lam. from ARS, Mannuthy. a. TS (4X). b. TS (10 X). c. TLS (4X). d. TLS (10X). e. Fibre (Maceration, 10 X). f. Fibre (Maceration, 40X).



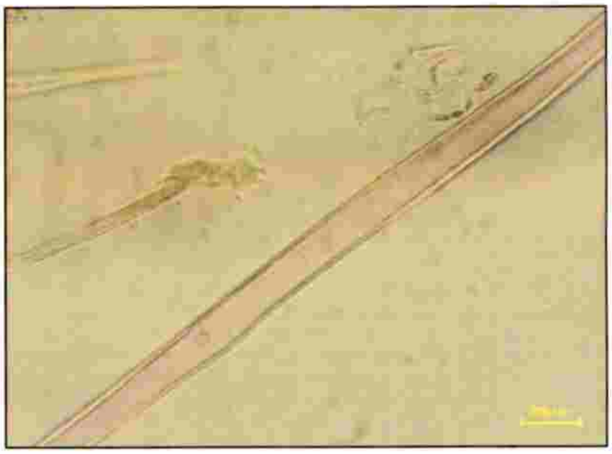
13. a



13. b



13. c



13. d

Plate 13. Anatomical features of six month old *Artocarpus heterophyllus* Lam seedlings.

a. TS (10 X). b. TLS (10 X). c. Fibre (Maceration, 10 X). d. Fibre (Maceration, 40X).

Table 23. Variation in anatomical features of *varikka* and *koozha* varieties of *Artocarpus heterophyllus* wood samples collected from the Jack Gene Sanctuary at ARS, Mannuthy

Parameter	Varikka 1	Varikka 2	Koozha 1	Koozha 2	Mean	*p*
Vessel Diameter (µm)	281.28[ab]	256.27[b]	312.87[a]	255.92[b]	**276.58**	0.005**
Vessel Area (μm^2)	65699.42[ab]	54211.63[b]	80692.34[a]	49672.81[b]	**62569.05**	0.001**
Vessel Frequency (per mm^2)	3.60[a]	3.80[a]	2.90[b]	3.70[a]	**3.52**	0.015**
Ray Height (µm)	374.82[c]	452.17[bc]	639.77[a]	526.76[b]	**498.38**	<0.001**
Ray Width (µm)	51.04[b]	49.54[b]	68.32[a]	42.98[b]	**52.97**	<0.001**
Ray Frequency (per mm)	5.20	5.10	5.70	5.50	**5.37**	0.291[ns]
Fibre Length (µm)	1095.15	938.50	1058.23	874.87	**993.10**	0.25[ns]
Fibre Width (µm)	20.52	17.51	19.19	17.98	**18.78**	0.391[ns]
Wall Thickness (µm)	4.31	4.64	4.14	4.09	**4.37**	0.588[ns]

*** significant at 1 per cent level and superscript 'ns' indicate non- significant*

Values with the same superscript along the row are homogenous

93

4.5 QUESTIONNAIRE SURVEY

A structured questionnaire survey was conducted to study the Farmers' perception towards growing jack tree as a timber species in the homegardens of Thrissur and Palakkad District.

People's opinion towards growing jack tree as a timber species in the homegardens were analysed with the help of twelve statements and the farmers' opinion were noted with a five point Likert scale indicating preferences, i.e.; Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree and were assigned scores 5,4,3,2 and 1 respectively.

The statements were;

i. Wood of jack tree is a good timber species

ii. There is a knowledge regarding the uses of jack wood

iii. Jack wood is used in the household because of the availability

iv. Jack tree was planted in the homestead for timber purpose

v. There is an interest in planting more jack trees in the household

vi. There is a preference for dwarf varieties over tall varieties

vii. Jack wood will get good market price

viii. Jack wood has good strength properties

ix. Among jack varieties, Varikka is the most preferable for planting

x. For growing jack as a timber species ,willing to do pruning on the tree

xi. There is an interest in knowing more about jack wood as a timber species

xii. Jack wood can be employed for many purposes

In Thrissur district, 46.34 per cent of the respondents agreed (12.34 per cent- Strongly Agreed and 34 per cent- Agreed) with the statements. 36 per cent of the responses were neutral and 17.66 per cent of the responses were negative

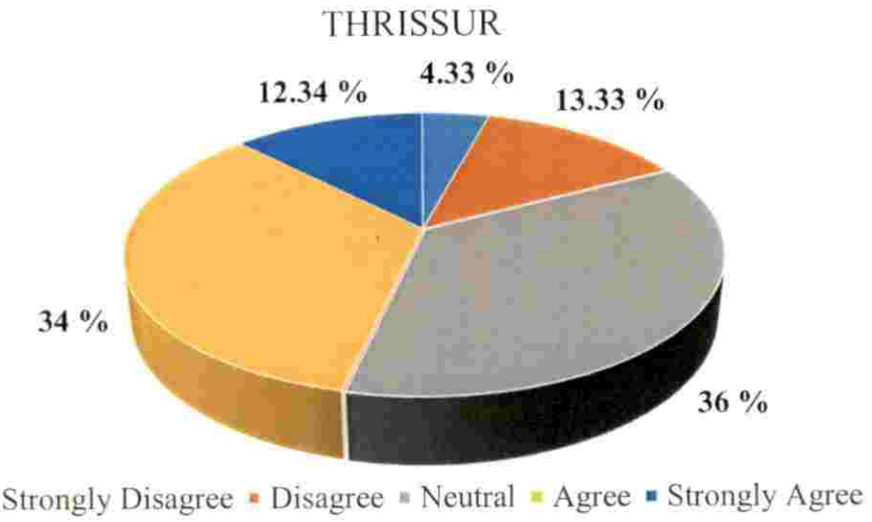


Figure 7. Farmers' perception towards growing jack tree as a timber species in Thrissur district.

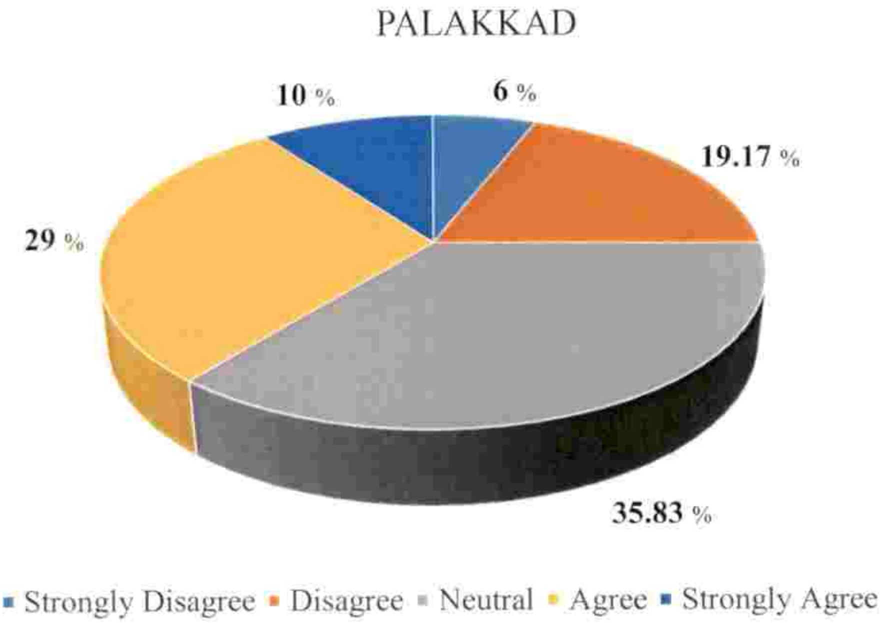


Figure 8. Farmers' perception towards growing jack tree as a timber species in Palakkad district.

95

(4.33 per cent- Strongly Disagreed and 13.33 per cent- Disagreed) for the statements (Figure 7).

Results of survey conducted in Palakkad district revealed that 39 per cent of the responses were positive (10 per cent- Strongly Agreed and 29 per cent- Agreed) for the statements. 35.83 per cent of the responses were neutral and 25.17 per cent of the respondents disagreed (6 per cent- Strongly Disagreed and 19.17 per cent- Disagreed) with the statements (Figure 8).

4.5.1 Mann-Whitney test

Mann –Whitney test, a non-parametric test was carried out to know the Farmers' perception towards growing jack tree as a timber species in the homegardens changes at various locations. From each district, fifty persons were surveyed and total scores obtained for each individual were subjected to Mann – Whitney test. The test was found to be significant, which means there is significant difference between the perception of farmers in both districts. Mean rank was highest for Thrissur district, indicating a higher positive response of farmers towards growing jack tree as a timber species in homegardens in this district (Table 24).

Table 24. Mean rank of respondents in Thrissur and Palakkad district based on Mann –Whitney test

District (group)	Respondents	Mean Rank
Thrissur (1)	50	57.32
Palakkad (2)	50	43.68
Total	100	
Mann-Whitney value	909.00	
p value	0.018*	

** Significant at 5 per cent level.*

Table 25. Approval rate of statements regarding Farmers' perception towards growing jack tree as a timber species

Sl. No	Statements	Thrissur					Palakkad				
		SDA (%)	DA (%)	N (%)	A (%)	SA (%)	SDA (%)	DA (%)	N (%)	A (%)	SA (%)
1	Wood of jack tree is a good timber species	0	4	30	40	26	2	6	32	54	6
2	There is a knowledge regarding the uses of jack wood	0	6	42	32	20	2	20	48	24	6
3	Jack wood is used in the household because of the availability	4	16	34	34	12	16	24	42	16	2
4	Jack tree was planted in the homestead for timber purpose	10	42	34	10	4	12	36	28	16	8
5	There is an interest in planting more jack trees in the household	14	28	32	22	4	8	36	28	26	2
6	There is a preference for dwarf varieties over tall varieties	4	4	34	30	28	2	6	36	28	28
7	Jack wood will get good market price	2	16	44	34	4	4	20	42	26	8
8	Jack wood has good strength properties	2	4	42	44	8	8	10	36	28	18
9	Among jack varieties, Varikka is the most preferable for planting	2	10	40	34	14	2	26	32	26	14
10	For growing jack as a timber species ,willing to do pruning on the tree	6	18	42	32	2	4	16	44	30	6
11	There is an interest in knowing more about jack wood as a timber species	4	4	24	46	22	10	8	28	36	18
12	Jack wood can be employed for many purposes	4	8	34	50	4	2	22	34	38	4

SDA- Strongly Disagree, DA- Disagree, N- Neutral, A- Agree, SA- Strongly Agree

97

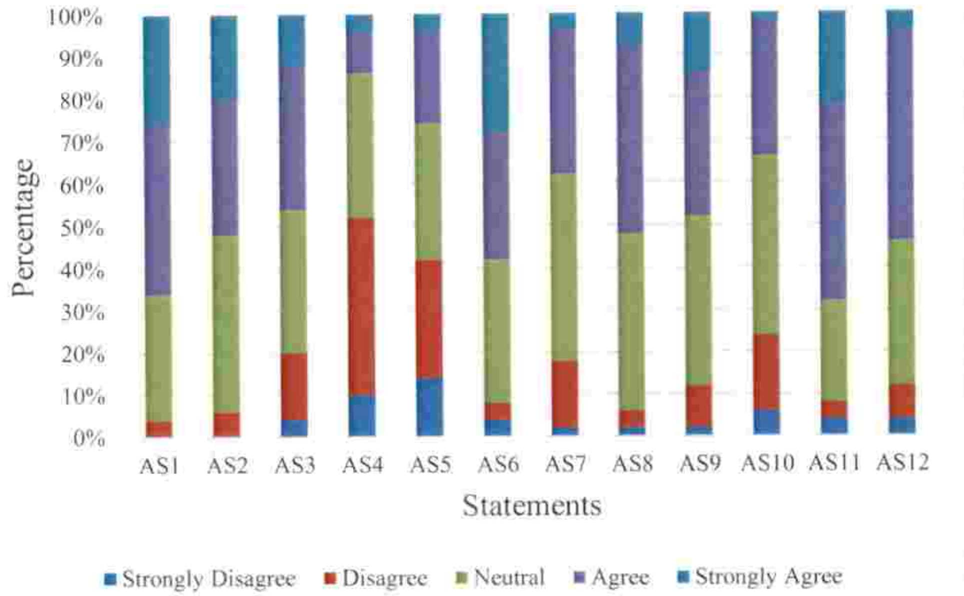


Figure 9. Perception percentage scored against each statement in Thrissur District

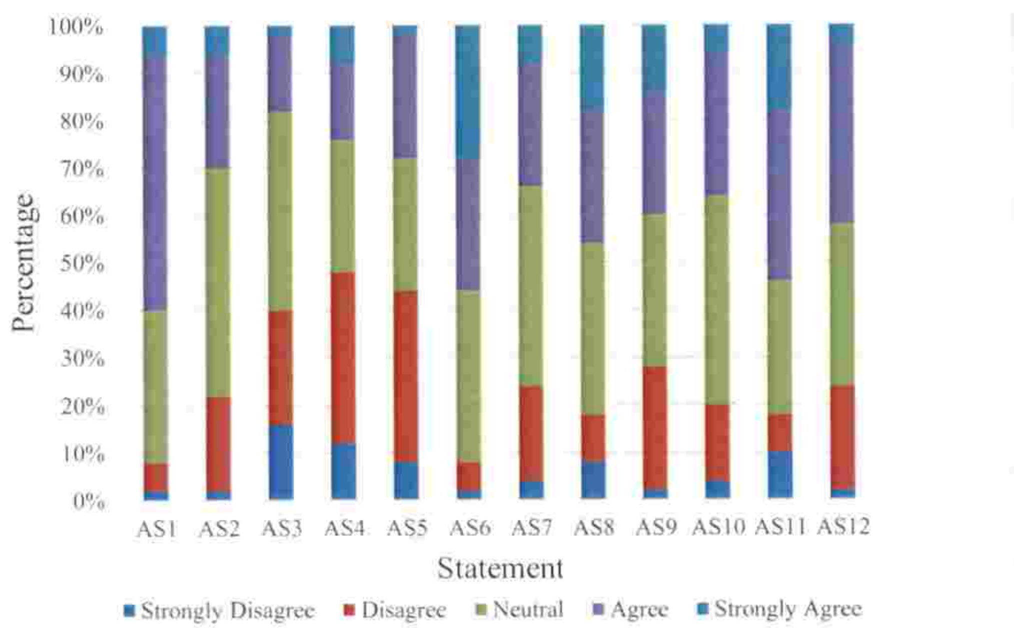


Figure 10. Perception percentage scored against each statement in Palakkad district.

Discussion

5. DISCUSSION

The results obtained from the study titled "Screening of jack trees (*Artocarpus heterophyllus* Lam) for quality timber production" are discussed in this chapter.

In the present study, forty plus trees and their half-sib progenies from five panchayats each of Thrissur and Palakkad districts were evaluated to identify the variations that exist in growth attributes and anatomical differences. The study also focused on the general perception of farmers towards growing jack tree as a timber species in their homesteads.

5.1 NURSERY PERFORMANCE

Seedling growth is a precondition for conservation and sustainable use of genetic resources which depends upon understanding of breeding system, genetic inconsistency and evolutionary forces in forest tree improvement (Krishan and Toky, 1996). The success of any breeding programme is determined by the growth of seedling in the nursery. In the present study, seedling biometric observations were recorded for the first five months after planting. Statistical analysis shows significant differences in almost all biometric observations over time.

Seedling height and collar diameter were found to be significantly different from 30 DAP to 150 DAP (Table 3 and Table 4). At 150 DAP seedling height ranges from 123.10 cm (FCV AH 22) to 68.35 cm (FCV AH 1) and collar diameter ranges from 14.39 mm (FCV AH 8) to 7.18 mm (FCV AH 7). A similar trend in variation of seedling height and collar diameter were observed by Krishan and Toky (1996) in *Acacia nilotica* from 21 provenances across India. Cundall *et al.* (2003) reported a similar highly significant variation between the provenances in *Fraxinus excelsior*, a broadleaved species. Azad *et al.* (2014) also reported a similar variation in growth performance in seedling height and collar diameter in *Tamarindus indica* from five different seed sources. As the experiment was conducted under similar environmental conditions, the variation based on height and collar diameter growth

100

among the seedlings from different seed sources may be due to genotypic differences and site verses genotypes.

Root system is generally the first part of the plant to be affected by environmental changes and the success of any plant in different region depends upon the adoptability of roots to these changes. Taproot length of *Artocarpus heterophyllus* showed significant variation between different seed sources, however the differences were not significant at all stages during the study (Table 5). The taproot length observed at 30 DAP upto 90 DAP showed significant difference among different seed sources but at 120 DAP and 150 DAP it did not show much variation. Highest taproot length was noticed in FCV AH 2 (48.85 cm) and the least taproot length was in FCV AH 14 (30.45 cm) at 150 DAP. The variation in root length was also reported by Kackar *et al.* (1986) in *Prosopis cineraria,* Kumar *et al.* (2007) in *Pongamia pinnata* and Ghildiyal *et al.* (2009) in *Pinus roxburghii* from different seed sources.

There was a significant difference in the number of leaves observed at 30 and 120 DAP but the differences were not pronounced in observations taken at 60, 90 and 120 DAP (Table 12). The number of leaves at 150 DAP ranges from 12.00 (FCV AH 15) to 7.00 (FCV AH 25). Similar results were reported by Dangasuk *et al.* (1997) in *Faidherbia albida* and Xiao *et al.* (2012) in *Magnolia officinalis.* Rehfildt and Wycoff (1981) reported that the Pinus seedlings raised from different provenance often display different pattern of leaf growth as observed in this study also. These variations in growth characteristics of seedlings from different seed sources may be attributed to adaptation because the seedlings from all the sources were raised under identical conditions (Singh and Pokhriyal, 2000).

5.1.1 Biomass and growth

Plant biomass is a much better parameter for analysing the growth of seedling in the nursery than seedling height or collar diameter as the latter do not take into account the below ground growth in plants and direct correlation between above ground and below ground may not be present. Present study revealed significant difference in fresh weights and dry weights of stem, root and leaves from different seed sources in Thrissur and Palakkad districts throughout the study period *ie* from 30 DAP to 150 DAP (Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11). Fresh weights and dry weights of root had more variation followed by fresh weights and dry weights of stem and least in fresh weights and dry weights of leaves as analysed through Duncan's Multiple Range Test (DMRT). At 150 DAP, FCV AH 4 seed source from Thrikkur panchayat of Thrissur district had the highest value for both fresh weight (33.88 g) and dry weight (16.41 g) of stem. Whereas, FCV AH 1 seed source from Madakkathara panchayat of Thrissur district had least fresh weight (17.84 g) of stem and FCV AH 10 seed source from Adat panchayat of Thrissur district had least dry weight (8.39 g) of stem. In the case of leaf and root biomass, FCV AH 22 seed source from Madakkathara panchayat had the highest fresh weight (25.22 g) and dry weight (8.26 g) of leaves. FCV AH 15 seed source from Vaniyamkulam panchayat of Palakkad district had the highest fresh weight (25.25 g) and dry weight (8.54 g) of root. Least value for fresh weights and dry weights of leaf and root were observed for FCV AH 25 seed source from Avinissery panchayat of Thrissur district. The results obtained in this study are in line with Jayasankar *et al.* (1999) in *Tectona grandis* and Gerhardt and Fredriksson (1995) in *Swietenia macrophylla.*

Analysis of variance revealed significant differences in leaf area, Leaf Area Ratio and Specific Leaf Area of seedlings from different seed sources over time (Table 13, Table 14 and Table 15). Leaf area of the seedlings increased throughout the study period and was significantly different from 30 DAP to 150 DAP. Salazar (1989) in *Acacia mangium* and (Ginwal and Mandal, 2004) in *Acacia nilotica* reported significant differences in leaf area in seedlings from different provenances. At 150 DAP the highest value for leaf area (117.77 cm^2) was for FCV AH 15 and least (81.34 cm^2) for FCV AH 32. Leaf area ratio and Specific Leaf Area depicts an irregular pattern and decreases mostly after 90 DAP. Variation in Leaf Area Ratio was not significant during the initial growth *ie* 30 DAP. Specific Leaf Area showed no significant variation at 30 and 150 DAP. Since both these parameters take leaf

102

biomass and plant biomass as a whole, its disproportionate increase is responsible for the reduction in the same.

5.1.2 Cluster Analysis

In this study, a hierarchical cluster analysis based on the morphological and biometric characters was carried out for the 40 plus tree sources. The 40 plus tree sources were grouped into twenty-one clusters. Trees coming in a cluster have similar morphological and biometric characters and it differs between two clusters. Cluster 14 possess maximum number of trees (6) with more than 95 per cent similarity whereas the minimum number (1) was observed for cluster 2, 7, 8, 10, 11, 12, 15, 16, 17, 18 and 21. Clusters with only one plus tree can either possess superior or inferior quality among the selected plus trees. Based on the biometric observations for 150 DAP and cluster analysis it was found that Cluster 2 (FCV AH 2), Cluster 18 (FCV AH 8), Cluster 12 (FCV AH 9), Cluster 11 (FCV AH 15), Cluster 10 (FCV AH 21), Cluster 21 (FCV AH 22), and Cluster 15 (FCV AH 23) possess superior quality. Whereas Cluster 16 (FCV AH 11), Cluster 7 (FCV AH 12), Cluster 17 (FCV AH 25) and Cluster 8 (FCV AH 37) were of inferior quality.

5.2 ANATOMY

Anatomical studies of young (six month old) *Artocarpus heterophyllus* seedlings from different seed sources and core samples of mature trees from a 'Jack Gene Sanctuary' of the Agricultural Research Station (ARS) of KAU at Mannuthy revealed significant differences in various parameters. Vessel area, ray height, ray width, fibre length and fibre wall thickness were found to be significantly different in six month old seedlings (Table 20 and Table 21). Whereas samples from mature trees showed significant difference in vessel diameter, vessel area, vessel frequency, ray height and ray width (Table 23).

Vessels were found to be circular or oval in outline, solitary or in radial multiples of 2-3 for both young seedlings and mature trees. Mean vessel area increased from 4199.14 μm^2 in young seedlings to 62569.05 μm^2 in mature trees. Anatomical studies by Husen and Pal (2006) in *Tectona grandis* found that wood anatomical features, especially in numbers, length and width of vessel elements and fibre elements increases with age. Vessel diameter also showed a similar trend. Mean vessel diameter increased from 126.43 μm in young seedlings to 276.58 μm in mature trees. In the case of young seedlings, vessel diameter and vessel area range between 138.81 μm to 112.80 μm and 6399.16 μm^2 to 3487.02 μm^2 respectively. Samples from mature trees had vessel diameter and vessel area values ranging from 312.87 μm to 255.92 μm and 80692.34 μm^2 to 49672.81 μm^2 respectively. These results are in line with the observations of Anoop *et al.* (2011) in the same species from the results observed in a trial at LRS Thiruvazhamkunnu, Palakkad, Kerala.

In the case of young seedlings, rays were found to be mostly uniseriate and biseriate in nature but in mature trees, multiseriate rays were also found. Mean ray height and mean ray width were found to be 466.98 μm and 34.58 μm in young seedlings and 498.38 μm and 52.97 μm in mature trees respectively. In young seedlings, the maximum ray height was found to be 674.87 μm and the minimum value was 316.45 μm. Ray width values ranged between 46.47 μm to 24.73 μm. In the case of mature trees, ray height and ray width were in the range of 639.77 μm to 374.82 μm and 68.32 μm to 42.98 μm respectively. Mean ray frequency was 5.37 per mm. Similar observations were made by Sahoo *et al.* (2017) in *Artocarpus hirsutus* where ray frequency was found to be 4 to 5 per mm. Anoop *et al.* (2014) also observed a similar trend in ray height in *Swietenia macrophylla*.

Mean fibre length and fibre wall thickness were found to be 801.13 μm and 3.27 μm in young seedlings and 993.10 μm and 4.37 μm in mature trees. In case of young seedlings fibre length ranges between 999.31 μm to 689.47 μm and fibre wall thickness had values between 4.52 μm to 2.47 μm. Mature trees also had more or less similar observations. Here, fibre length and fibre wall thickness ranged between 874.87 μm to 1095.15 μm and 4.09 μm to 4.64 μm respectively. Singh *et al.* (2017) also observed a similar trend in fibre morphology in *Artocarpus heterophyllus* in a comparative study of four Artocarpus species of North East India. Varghese *et al.* (2000) reported that there was no significant difference in fibre characteristics of 60 year old teak among different locations in Peninsular India as observed in our study among mature trees.

5.3 QUESTIONNAIRE SURVEY

A questionnaire survey was conducted to study the perception of farmers towards planting jack tree as a timber species in Thrissur and Palakkad district. Generally, there is awareness about the quality of jack tree as a timber species and regarding the uses to which it can be employed to. This knowledge may be acquired traditionally. In Thrissur district, 46.34 per cent agree with the idea of growing jack tree as a timber species, while in Palakkad district, 39 percentage agreed with the idea of growing jack tree as a timber species in their homestead. This might be due to the general consensus that they can benefit additionally from the wood part when the trees reach senescence. There is a high rate of neutral response for planting more jack trees in the households in both districts. The main reason for this can be the small size of the holdings and preference for other high quality timber species. High per cent of the respondents disagreed to the statement "Jack tree was planted in the homestead for timber purpose". Around 52 per cent of respondents disagreed to this in Thrissur district, while 48 per cent disagreed to this in Palakkad district. This can be due to the fact that jack tree was not intentionally planted but has grown naturally in their households.

There is an increasing preference for dwarf varieties over tall indigenous varieties among the respondents in both districts. This may be due to the early bearing quality of dwarf varieties and also difficulty of plucking jackfruits from tall varieties. The small holding of size of homesteads can also be a reason for opting dwarf varieties over tall varieties. The increasing trend of planting dwarf varieties can have a deleterious effect on the easily available good quality wood from our homesteads. So there is an immediate need to protect the existing high quality tall varieties of jack trees.

Most of the respondents from both districts were aware of the good strength properties and satisfactory market price of wood of jack trees. It can be understood that most of the respondents were updated about the timber market trends and the changing legislation related to wood. The distinction between the koozha and varikka varieties was also a key factor for preferring jack trees in homesteads. A large group of respondents from both districts were preferring varikka variety over koozha variety, which can be inferred to crisp carpers of high quality in varikka fruits and also its commercial importance. There is a neutral response to the pruning activities in the jack trees among respondents in both districts. This might be due to the lack of understanding of the cauliflorous bearing habit of jack trees.

While analysing the farmers' perception towards growing jack tree as a timber species, the requirement of scientific guidance for increasing jack tree planting as a timber species was suggested by many respondents. A large group of respondents are interested to know more about the wood qualities of jack tree and its timber purposes.

Summary

6. SUMMARY

A study titled "Screening of jack trees (*Artocarpus heterophyllus* Lam) for quality timber production" was carried out at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur during 2017- 2019. The salient findings of the study are as follows:

- Seedling height and collar diameter were found to be significantly different from 30 DAP to 150 DAP. At 150 DAP seedling height ranged from 123.10 cm (FCV AH 22) to 68.35 cm (FCV AH 1) and collar diameter ranged from 14.39 mm (FCV AH 8) to 7.18 mm (FCV AH 7).
- Taproot length observed at 30 DAP to 90 DAP showed significant difference among different seed sources but at 120 DAP and 150 DAP it did not show much variation. The highest taproot length was noticed in FCV AH 2 (48.85 cm) and the least taproot length was in FCV AH 14 (30.45 cm) at 150 DAP.
- Significant difference in number of leaves was observed at 30 and 120 DAP but the differences were not pronounced at 60, 90 and 120 DAP. The number of leaves at 150 DAP ranges from 12.00 (FCV AH 15) to 7.00 (FCV AH 25).
- Analysis of variance revealed significant difference in fresh weights and dry weights of stem, root and leaves from different seed sources throughout the study period *ie* from 30 DAP to 150 DAP.
- At 150 DAP, FCV AH 4, FCV AH 22 and FCV AH 15 had the highest value for both fresh weight (33.88 g, 25.22 g and 25.25 g) and dry weight (16.41 g, 8.26 g and 8.54 g) of stem, leaf and root respectively.
- Least value for fresh weight and dry weight of leaf and root was observed for FCV AH 25 seed source. FCV AH 1 and FCV AH 10 seed sources had the least fresh weight of stem and the least dry weight of stem respectively.

- Leaf area of the seedlings increased throughout the study period and was significantly different from 30 DAP to 150 DAP with FCV AH 15 (117.77 cm^2) having the highest and FCV AH 32 (81.34 cm^2) having the lowest leaf area at 150 DAP.
- Leaf Area Ratio showed significant difference for all observations except at 30 DAP, whereas Specific Leaf Area varied significantly only at 60, 90 and 120 DAP.
- Hierarchical cluster analysis grouped 40 plus tree sources into twenty-one clusters. Cluster 14 possess maximum number of trees (6) with more than 95 per cent similarity. FCV AH 2, FCV AH 8, FCV AH 9, FCV AH 15, FCV AH 21, FCV AH 22 and FCV AH 23 were different from all the other seed sources and possess superior quality.
- Vessel area, ray height, ray width, fibre length and fibre wall thickness were found to be significantly different in young (six month old) seedlings, whereas samples from mature trees showed significant difference in vessel diameter, vessel area, vessel frequency, ray height and ray width.
- Vessels were found to be circular or oval in outline, solitary or in radial multiples of 2-3 for both young seedlings and mature trees
- Mean vessel area increased from 4199.14 μm^2 in young seedlings to 62569.05 μm^2 in mature trees. Mean vessel diameter also increased from 126.43 μm in young seedlings to 276.58 μm in mature trees.
- In the case of young seedlings, vessel diameter and vessel area ranged between 138.81 μm to 112.80 μm and 6399.16 μm^2 to 3487.02 μm^2 respectively. Samples from mature trees had vessel diameter and vessel area with values ranging from 312.87 μm to 255.92 μm and 80692.34 μm^2 to 49672.81 μm^2 respectively
- Rays were found to be Uniseriate, Biseriate and Multiseriate in nature. Mean ray height and mean ray width were found to be

466.98 μm and 34.58 μm in young seedlings and 498.38 μm and 52.97 μm in mature trees respectively.

- Mean fibre length and fibre wall thickness were found to be 801.13 μm and 3.27 μm in young seedlings and 993.10 μm and 4.37 μm in mature trees.
- During the field trial, both seedling height and collar diameter were found to be significantly different at 30 DAP. The average seedling height was 117.30 cm with values ranging from 143.94 cm to 96.35 cm and FCV AH 22 being the tallest. The mean collar diameter was 12.27 mm with FCV AH 29 having the highest (14.67 mm) value.
- The questionnaire survey conducted in Thrissur and Palakkad district had 46.34 per cent and 39 per cent positive response respectively towards growing jack tree as a timber species in homegardens.
- The statement "There is a preference for dwarf varieties over tall varieties" had an acceptance of 58 per cent in Thrissur district and 56 percent in Palakkad district. This increasing trend of planting dwarf varieties can seriously affect the easy and plentiful availability of a good quality timber from our homesteads.
- A large group of respondents from both districts were preferring varikka over koozha variety and there is a neutral response to the pruning activities in jack trees.

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122

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SCREENING OF JACK TREES (*Artocarpus heterophyllus* Lam.) FOR QUALITY TIMBER PRODUCTION

By

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ABSTRACT

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MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF FOREST PRODUCTS AND UTILIZATION

COLLEGE OF FORESTRY

VELLANIKKARA, THRISSUR- 680 656

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ABSTRACT

Artocarpus heterophyllus Lam, belonging to the family Moraceae and popularly known as jackfruit tree, is one of the important timber species commonly found in the homegardens of Kerala. The main objective of the present study was to identify plus trees of *Artocarpus heterophyllus* from Thrissur and Palakkad districts and to evaluate their seedling growth performance for quality timber production.

Forty plus trees, twenty each of *varikka* and *koozha* variety were selected from both districts. Seedling biometric observations like stem height, collar diameter, leaf area, fresh weights and dry weights of stem, leaves and root showed significant differences throughout the study period, *i e* from 30 DAP (Days After Planting) to 150 DAP. At 150 DAP, seedling height ranged from 123.10 cm (FCV AH 22) to 68.35 cm (FCV AH 1) and collar diameter ranged from 14.39 mm (FCV AH 8) to 7.18 mm (FCV AH 7). At 150 DAP, FCV AH 4, FCV AH 22 and FCV AH 15 had the highest value for both fresh weight (33.88 g, 25.22 g and 25.25 g) and dry weight (16.41 g, 8.26 g and 8.54 g) of stem, leaf and root respectively. Other parameters like taproot length, number of leaves, Leaf Area Ratio, Specific Leaf Area, Absolute Growth Rate, Relative Growth Rate and Net Assimilation Rate were also found to be significant but not throughout the study period. The highest taproot length was noticed in FCV AH 2 (48.85 cm) and the least taproot length was in FCV AH 14 (30.45 cm) at 150 DAP.

To establish a field trial plot, seedlings were out planted one year after nursery growth near the International Hostel at KAU, Vellanikkara. Field performance of the progenies were evaluated at 30 DAP. Seedling height and collar diameter were found to be significantly different among various seed sources. The average seedling height was 117.30 cm with values ranging from 143.94 cm to 96.35 cm and FCV AH 22 being the tallest. The mean collar diameter was 12.27 mm with FCV AH 29 having the highest (14.67 mm) value.

Hierarchical cluster analysis based on the morphological and biometric characters was carried out and 40 plus tree sources were grouped into twenty-one

clusters. Based on the biometric observations for 150 DAP and cluster analysis, it was found that Cluster 2 (FCV AH 2), Cluster 18 (FCV AH 8), Cluster 12 (FCV AH 9), Cluster 11 (FCV AH 15), Cluster 10 (FCV AH 21), Cluster 21 (FCV AH 22), and Cluster 15 (FCV AH 23) possess superior quality.

Anatomical studies of young (six month old) *Artocarpus heterophyllus* seedlings from different seed sources and core samples of mature trees from a 'Jack Gene Sanctuary' of the Agricultural Research Station (ARS), KAU at Mannuthy revealed significant differences in various parameters. Vessel area, ray height, ray width, fibre length and fibre wall thickness were found to be significantly different in six month old seedlings, whereas samples from mature trees showed significant difference in vessel diameter, vessel area, vessel frequency, ray height and ray width. Mean vessel area increased from 4199.14 μm^2 in young seedlings to 62569.05 μm^2 in mature trees. Mean vessel diameter also increased from 126.43 μm in young seedlings to 276.58 μm in mature trees. Mean ray height and mean ray width were found to be 466.98 μm and 34.58 μm in young seedlings and 498.38 μm and 52.97 μm in mature trees respectively. Mean fibre length and fibre wall thickness were found to be 801.13 μm and 3.27 μm in young seedlings and 993.10 μm and 4.37 μm in mature trees

Questionnaire survey conducted in Thrissur and Palakkad district had 46.34 per cent and 39 per cent positive response respectively towards growing jack tree as a timber species in homegardens. There is an increasing preference for dwarf varieties over tall indigenous varieties among the respondents in both districts. The increasing trend of planting dwarf varieties can have an adverse effect on the easy availability of good quality wood from our homesteads. Therefore, there is a pertinent need to protect the existing high quality tall varieties of jack trees.

Appendices

APPENDIX I

		32	33	34	35	
		31	30	29	28	
INTERNATIONAL HOSTEL		24	25	26	27	
		23	22	21	20	
		16	17	18	19	
		15	14	13	12	
		8	9	10	11	
		7	6	5	4	
		39	*40*	1	2	3
		38	*37*	*36*	*35*	*34*
		29	*30*	*31*	*32*	*33*
28	*27*	*26*	*25*	*24*	*23*	*22*
16	*17*	*18*	*19*	*20*	*21*	
15	*14*	*13*	*12*	*11*	*10*	*9*
2	*3*	*4*	*5*	*6*	*7*	*8*
1	**40**	**39**	**38**	**37**	**36**	
29	**30**	**31**	**32**	**33**	**34**	**35**
28	**27**	**26**	**25**	**24**	**23**	**22**
15	**16**	**17**	**18**	**19**	**20**	**21**
14	**13**	**12**	**11**	**10**	**9**	**8**
1	**2**	**3**	**4**	**5**	**6**	**7**

Layout of field planted seedlings at the International Hostel premises at KAU Main Campus, Vellanikkara

APPENDIX II

STRUCTURED QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY

FARMERS' PERCEPTION TOWARDS GROWING JACK TREE AS A TIMBER SPECIES IN HOMESTEADS OF THRISSUR AND PALAKKAD DISTRICTS

District: Interviewer's Name:

Panchayath: Date:

Ward:

Name of Farmer & Address:

Respondent No.

1. Basic Details

Family Details

Name of the member (a)	Age (b)	Gender (c)	Education (d)	Main Occupation (e)	Monthly Income (f)	
					Main	Sub

g) Size of holding (Farm size)

Area

< 1 acre	1- 2 acre	2-3 acre	3-4 acre	4- 5 acre	> 5 acre

h) Soil Type

i) Source of Irrigation (Rainfed/Irrigated)

2 a. Tree Crops

Sl. No.	Species	Area(acres)/Number of trees	Rotation age	Purpose of growing

b. Preference of timber species

SL.NO	Species	Rank	Description
1	Jack		
2	Aini		
3	Teak		
4	Mahogany		
5	Acacia		
6			

Statements

Sl.No	Questions	SDA	DA	N	A	SA
1	Wood of jack tree is a good timber species					
2	There is a knowledge regarding the uses of jack wood					
3	Jack wood is used in the household because of the availability					
4	Jack tree was planted in the homestead for timber purpose					
5	There is an interest in planting more jack trees in the household					
6	There is a preference for tall varieties over dwarf varieties					
7	Jack wood will get good market price					
8	Jack wood has good strength properties					
9	Among jack varieties, Varikka is the most preferable for planting					
10	For growing jack as a timber species ,willing to do pruning on the tree					
11	There is an interest in knowing more about jack wood as a timber species					
12	Jack wood can be employed for many purposes					

SDA- Strongly Disagree, DA- Disagree, N- Neutral, A- Agree, SA- Strongly Agree