SCREENING OF *Ailanthus triphysa* (Dennst.) Alston. FOR PREFERRED MATCH WOOD QUALITIES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Screening of *Ailanthus triphysa* (Dennst.) Alston. for preferred match wood qualities**." is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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INTRODUCTION

INTRODUCTION

The genus Ailanthus have about five species of deciduous and evergreen trees, is native to India, eastern China, Thailand, Malaysia, Borneo, the Philippines, Sumatra, Java, Indonesia, the Solomon Islands, New Guinea, and northern Australia (Nooteboom, 1962). *Ailanthus triphysa* is recommended as a short rotation plantation species due to its quick rate of growth. The tree attains utilizable girth in 6-8 years. *Ailanthus triphysa* produces an aromatic resin (halmaddi) which is used in the manufacture of traditional incense sticks. A dye obtained from the plant's leaves can be used for staining satin black. The plant roots, leaves, bark and gum exudates are reportedly used as medicine in India.

Ailanthus triphysa and *Melicope lunu-ankenda* are generally considered to be the best Indian tree species for match splints (Nair, 1961). The highly viscous aromatic resin present in *Ailanthus triphysa* reduces the necessity of dipping the splints in the wax (Indira, 1996). The branch spread of the species is low and hence it needs very little aerial space making it suitable for growing in homesteads. Not much of the tree goes to waste when harvested due to the fewer number of branches and owing to the fact that even small branches not less than 35 cm including bark are accepted in match industry. Young trees are often used as live stakes for supporting black pepper (*Piper nigrum*). Indira (1996) reported that *Ailanthus integrifolia ssp. Calycina* was performing better in terms of growth during early years besides having a high level of pest resistance. However, small scale field planting done in various localities showed that *A. triphysa* performed equally well in degraded soils as in fertile land, whereas *A. integrifolia* failed to survive in such degraded areas.

Pines and hardwoods are mostly used in temperate regions and hardwoods are commonly used in tropics for match splints. In south India *Ailanthus triphysa*, *Bombax ceiba, Alstonia scholaris*, *Macaranga peltata*, *Melicope lunu-ankenda* and

Albizia falcataria are commonly used for producing match splints. There are approximately 500 match industries in Kerala; many of which are facing acute shortage of raw materials. Only 10 percent of the total requirement of the industry is met from the forests of Kerala and hence the demand is very high (Nair *et al*., 1984). In this scenario, the College of Forestry, Kerala Agricultural University, Vellanikkara had conducted a workshop on the topic "Homestead grown trees and Match industry" on 12th July 2011. The main emphasis of the workshop was the need for research on wood quality improvement aspects of raw material species. A suggestion was also made to develop and supply quality planting stock by Kerala Agricultural University to the farmers as a part of farm forestry programme.

Taking trees successfully to non-forest areas can be achieved only through proper extension support (Mahapatra and Mitchell, 2001). 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). 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 so in a subsistence farming system, which is a typical farm scenario in Kerala (Nair and Sreedharan, 1986; Jose, 1992).

Efforts towards breeding and producing better planting material has not been taken up widely even though *Ailanthus triphysa* is in high demand for the match industry. Tree improvement can be taken strictly to include enhancement of silviculture and management systems as well as genetic improvement (tree breeding), together with the enhancement of processing and use of products and benefits derived from trees (Burley, 2004). It is effective only when it consists of the combination of all tree breeding and silvicultural skills of the forester to grow the most valuable forest products as quickly as possible and as inexpensively as possible. Zobel and Talbert (1984) define forest tree breeding as "activities geared to solve some specific problem or to produce a specifically desired product." 14

Development of breeding objectives relies on determining the relationships between end product properties and tree and wood properties, but this information is currently limited in *Ailanthus triphysa*.

Against this backdrop, this study is designed to screen superior genotypes and analyse the wood properties of different seed sources of *Ailanthus triphysa* with the following objectives

- Assessment of the variation in growth and wood traits of *Ailanthus triphysa* grown in home gardens of Thrissur and Palakkad districts for match manufacture.
- Selection of plus trees of *Ailanthus triphysa* for seed collection, their evaluation and selection of superior planting materials.
- Assessment of growth performance of *Ailanthus triphysa* seedlings in nursery and field conditions.
- Analysis of farmers' perceptions towards growing raw material species for matchwood industries in selected panchayats of Thrissur and Palakkad districts.

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REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Taxonomy and Distribution

The genus Ailanthus belong to the family simarubaceae ranging from tropic and subtropical regions of both the hemispheres, particularly in tropical America (Mexico to Argentina, tropical west Africa and southeast Asia) and have 30 genera and 200 species with 5 genera and 11 species in India (BSI). The placement of the genus Ailanthus within the family Simaroubaceae is supported by morphological, biochemical, and DNA sequence data (Fernando and Quinn, 1995; Fernando *et al*., 1995). There are about four species and a subspecies reported from India (CSIR, 1985) and these are *Ailanthus altissima* (Mill) Swingle [syn. *Ailanthus glandulosa* (Desf)], *Ailanthus excelsa* (Roxb.), *Ailanthus integrifolia* Lam., *Ailanthus integrifolia* (Lamk.) (ssp.) *calycina* (Pierre) Noot. [syn. *Ailanthus grandis* (Prain)] and *Ailanthus triphysa* (Dennst.) Alston [syn. *Ailanthus malabarica* (DC)] (CSIR, 1985).

Ailanthus triphysa is a fast-growing multi-purpose tree species, of considerable economic importance. It is a large deciduous tree with cylindrical bole and is distributed in tropical Peninsular India up to an elevation of 4500 m above sea level (Troup, 1975) and is found in evergreen forests of Western Ghats from Konkan to Southwards (CSIR, 1985). In Kerala, Ailanthus occurs in all physiographic provinces except in the hills and it tolerates a wide range of soils (Kumar, 2000). It is common in homestead gardens of this region and the wood is used for a variety of uses such as making plywood, packing cases, toys, match industry etc. The tree also yields a resinous gum that is used as incense and in the production of indigenous medicines.

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 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, 1975). The majority of economic traits such as yields of crops, diameter and height of trees, differ in degree. These quantitative traits, the phenotypic expression of which is much influenced by environment and genes that are having small effects. 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, 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 phenotypes 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 resultant of adaptation and evolutionary process of the species (Namkoong, 1981). This provides evolutionary flexibility and determines the responsiveness to future variations in the genetic and external environments (Namkoong, 1981; 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 18 to successfully plan a breeding program. *Ailanthus triphysa* as a dioecious species, should be completely cross breeding leading to less intrapopulation variation (Indira, 1996). 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, 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, 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; Logan and Pollard, 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 *et al.*, 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 N.C. 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 7-1 per cent more volume per hectare at harvest than trees grown from wild seed. 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 offspring's 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 should 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)

2.3 Dormancy and germination of seed

Dormancy is an innate property of the species where seeds are prevented from germinating even under favourable environmental conditions for germination. Seed of the genus Ailanthus are usually easy to germinate however cold stratification in *Ailanthus altissima* was found to increase the percentage germination 7 days after moist pre-treatment at stratification temperatures (Graves, 1990). Ailanthus have samaras as fruits and the wings are usually removed before sowing.

Germination percentage shows high coefficient of variation among seed traits. Nayak *et al.* (2002) studied the variability in *Cassurina equesetifolia* among parameters such as fruit, no of seeds per fruit, seed weight and germination per cent. The germination percentage showed maximum (CV = 29.60%) co-efficient of variation. Indira (1996) studied seed weight and germination per cent of *Ailanthus triphysa* from twenty trees individually. Ten fruits from each of 3 replications were used and the variation in germination percentage and seed weight were found to be high the germination percentage of *Ailanthus triphysa* seeds were found to be ranging from zero per cent to 69.20 per cent and the seed weight ranged from 60 to 112 seeds per kg. Ailanthus seeds generally have better germination when soaked in water. *Ailanthus altissima* seed that had floated for 3 days had an increased level of seed germination (87%), while a 20-day stay in water water-curbed germination to 32 per cent compared to 53 per cent in control (Kowarik and Sa¨umel, 2008).

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(Kaproth and McGraw, 2008) studied germinability of *Ailanthus altissima* seeds floated and submerged in cages at two study sites (Monongahela River and Cheat lake). Seeds recovered from submerged cages retained high germinability (94.4%), showing no significant decline over a 5-month period. The effect of environment on seed germinability depended on site with germination at a lower rate on land (relative to those incubated in water) at Cheat Lake, but this pattern was not observed at the Monongahela River site.

Bhat and Chauhan (2002) found that the germination percentage was positively correlated with seed size in *Albezia lebbeck*. The germination percentage varied from 16.20 per cent to 38.05 per cent with the heaviest seeds having the maximum germination percentage. Similar pattern in seed weight and germination can be seen *Jatropha curcus* (Kumar, 2003). Seed parameters and germination parameters of *Jatropha curcus* seeds collected from 10 different seed sources shows considerable variations with highest germination and vigour index in Walayar and least from Paripati (Kumar, 2003). This is in alignment with the report of varying germination percentages of 61.90 to 95.23 Per cent in large seeds, 47.61 to 91.47 per cent in medium sized seed and 39.09 to 71.42 per cent in small seed of *Jatropha curcus* (Sridhar, 2006). However, Seed size or weight should not be used exclusively as criteria for grading of bulked seed lots of different clones, as it can narrow down genetic diversity by rejecting small size seeds which are shown to perform as well as those larger (Singh and Sofi, 2011).

Intra-population variation in *Albizzia procera* was studied with respect to germination percentage, hard seed per cent among the 33 trees in Jabalpur. Huge variation was recorded in germination percentage among the seed sources with values varying from 20.00 per cent to 81.33 per cent and hard seed per cent varied from 1.33 per cent to 79.33 per cent (Gera *et al*., 2001). Significant differences were recorded among the seed sources with respect to seed and seedling attributes while evaluating the performance of five seed sources (Chikmagalur, Uttara Kannada, Mandya, Dharwad and Gulbarga) of *Albizia lebbeck* in Karnataka) of which Seeds collected from Mandya and Chikmagalur sources showed better performance for germination attributes (Nayak *et al*., 2004). Kumar *et al*. (2004), in his study revealed variation in germination of seeds collected from 13 superior *Acacia catechu* trees at different locations studied on seed source variation in Samples of 21 pods were collected from superior trees at 13 different places of Haryana, J&K, Punjab and Uttaranchal. Study revealed that highest germination (38.80%) was recorded in seeds from Manjhil seed source whereas lowest germination (9.80%) was recorded in seeds from Basoli.

Rawat *et al.* (2006) studied the seed and germination characteristics in Jharkhand in *Pinus wallichiana*. Significant variations in germination percentage and germination energy among the different seed sources. Maximum germination was reported in Jubbal seed source while minimum in Kalpa. Germination energy was found high in Sewai, Jubbai, Harsi and Tutu seed sources while Himagiri and Kalpa source had low germination energy. Variations in germination percentage and germination energy was found in *Azadiractha indica* seeds among the different provenances from Jharkhand. Maximum germination percentage (72%) was found in Ranchi provenance and minimum (36%) in Giridih provenance and the germination energy was also high (38) in Ranchi following a similar pattern of germination percentage (Mahto *et al.*, 2006). The variation in germination parameters of a species from different provenances is further evident from the study by Kumar and Siddiqui (2008). Out of 12 provenances of *Pongamia pinnata* from different parts of India (Tamil Nadu, Kerala, Karnataka, Bihar, Jharkhand), maximum germination percentage (64.33%) was recorded from Ranchi (Jharkhand) provenance and minimum (30.67%) was found in Mettupalayum (Tamil Nadu) source, whereas germination energy was maximum (44.6%) in Ranchi provenance and minimum (28%) in Mettupalayum provenance.

Singh *et al.* (2005) studied six different seed sources of *Saraca asoca* (Roxb) De Wilde in Kerala and statistically significant differences was found among the seed sources with respect to seed and seedling traits. The overall germination per cent varies from 63 to 93 per cent and Oorakam seed source was found to be superior with respect to all traits studied. Sivakumar *et al.* (2002) studied on Variability in drupe characters and their relationship on seed germination in *Tectona grandis* seeds of teak were collected from 30 sources covering India, Bangladesh and Laos. Karalai Nilanmbur provenance showed maximum germination per cent (49%) and Dehra Dhun showed least germination per cent (0.03%). The Nilambur, Konni, Tura and Bagafa sources exhibited higher germination percentages and the sources like Tarai, Dehra Dun, Kariar Road, Wimberligunj and 22

Sampangi had poor germination. (Bing *et al.*,2007) Studied the effect of NaCl stress on the seed germination and seedling growth of *Ailanthus altissima* from three provenances by treating the seeds with different NaCl concentrations (0, 50, 100, 200 m mol / L) during seed germination. Results show that the germination percentage, germination energy, germination index, seed Vigour index, root length and seedling height all decrease gradually with increasing NaCl concentration. The responses of seed germination for the three provenances to NaCl stress are also differ significantly. The seeds from Baofeng, Henan Province exhibit the greatest salt tolerance, and the salt tolerance of the seeds from Pengyang and Ningxia is the worst.

Oyebade *et al.* (2012), in his study on Provenance variations in *Chrysophyllum albidum* (G. Don) from six localities in rivers state, Nigeria Seed source from Bori was found to have the highest germination percentage (53%) and less mortality rate (47%), whereas Bonny had the lowest germination percentage (21%) and more mortality rate (78.92%). Hembrom *et al.* (2010), in his study on germination and germination speed in seeds of *Terminalia arjuna* and *Terminalia tomentosa* from different provenance reported maximum germination (23.3%) in the seeds of *T. tomentosa* from Pipariya. Germination speed was maximum (83.33) in *T. arjuna* from Bahargoda in Jharkhand.

Reddy *et al.* (2007) in his study on seed source variation in *Pongamia pinnata* for seed and seedling traits in Karnataka. found significant differences in germination percentage and their attributes among seed sources. Germination percentage ranges from 42.70 per cent (Mandya) to 94.87 per cent (Kolar). Kolar seed source had recorded significantly highest germination vigour (12.65) with higher mean daily germination (3.30) and peak value of germination (3.82). Germination of *Populas ciliate* from different seed sources also showed significant difference in germination percentage with values ranging from 41.75 per cent in Kathpudia seed source to 71.55 per cent in Nainital seed source. Germination percentage was also found to be positively and significantly correlated with shoot length, root length, total seedling length, vigour index and number of leaves per seedling in poplar the seedlings (Singh and Lavania, 2004). Bahar (2008) found significant variation in germination per cent and vigour index among the seed sources of *Albezia lebbeck*. Seed germination varied from 62.80 per cent (Chandra nagar)

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to 96.36 per cent (Dehra Dun). Highest vigour index (2022) was recorded in Nahan and lowest (1177) in Chinglepet seed source.

Singh and Sofi (2011) studied the clonal variation of seed traits, germination and seedling growth in *Dalbergia sissoo* among 20 clones originating from different agro-climatic conditions of four northern states (Uttar Pradesh, Rajasthan, Haryana and Uttarakhand), in India. There was lot of variation in seed size, seed weight, germination per cent, germination value and growth rate in nursery of different clones over the years. During 2007, the maximum germination of 84 per cent was recorded in clone 88 and minimum 71 per cent in clone 66. The germination value (*GV*) varied significantly among seeds of different clones and highest *GV* was observed in clone 88 (87.04), which was significantly superior to all other clones and Minimum *GV* was observed in clone 66 (63.04). In the year 2008, germination percentage varied from 66 per cent in clone 66 to 97 per cent in clone 83. The *GV* was also highest in clone 83 (115.99) and Minimum in clone 66 (53.72.).

2.3 Seedling growth

The growth of seedling in the nursery determines the success of plantation in the field. The seedling parameters show significant difference among different seed sources in the nursery. This is evident from the study by Liu (2002) where he compared seedling parameters like height, root biomass, total biomass, number of leaves 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.

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Moya *et al*. (2015) found that significant differences in performances existed between sixteen provenances of *A. mangium* in Costa Rica and concluded that *high* genetic variation exist in the species for seedling characteristics. The provenances with the best growth in both height and basal diameter at 3.5 months were from Indonesia, Papua New Guinea and Queensland. The basal diameter varied between 1.7 mm for Oriomo River, Papua New Guinea and 3.2 mm for W. of Morehead, Papua New Guinea; the provenances with the best heights showed the best basal diameters. Gera and Gera (2006) observed the heritability values which ranged from 30. 43 per cent for seed length to 87 .18 per cent for seedling and collar diameter in *Acacia catechu* and expected genetic gain were also high.

Singh and Bhatt (2008) studied on Provenance variation in seedling traits of *Dalbergia sissoo* in nursery of central Himalaya, India and reported that considerable variations between provenances for plant height and collar diameter. Among various parameters, plant height was most heritable traits, followed by genetic advance and genetic gain. Height growth varied significantly ($P < 0.05$) between provenances. On average, Fathepur population had highest shoot length (60 cm). Collar diameter of seedlings varied from 2.01 to 4.32 mm among various populations. In a later study by Singh and Sofi (2011), the clonal variation of seed traits, germination and seedling growth in *Dalbergia sissoo* among 20 clones originating from different agro-climatic conditions of four northern states (Uttar Pradesh, Rajasthan, Haryana and Uttarakhand) in India were evaluated. Seedling height was greatest in clone 204 (62.16 cm) and least in clone 85 (30.64 cm). The root collar diameter varied from 3.35 mm to 6.60 mm and it was maximal in clone 204 and minimum in clone 85.

Lester (1970), in his study reported seedling height of balsam fir from 100 locations showed statistically significant differences with the five tallest (Three collections from New Brunswick and one each from Quebec and New Hampshire), the five shortest (Collections from Saskatchewan, Western Ontario, Minnesota, Upper Peninsula of Michigan), and a high-altitude collection from New York. Bergin and Kimberley (1992) studied the provenance variation for seedling height in *Podocarpus totara* among 42 sites in New Zealand for 3 years. Otaki provenance showed highest seedling height (104 cm) and dean forest provenance showed lowest seedling height (57

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cm). Ghildiyal *et al*. (2009) studied on environmental variation in seedling characteristics of *Pinus roxburghii* (Sarg.) among 16 provenances of Uttarakhand, India. The performance of seedlings raised from Pabo seed source was superior, having maximum height (10.16 cm) and minimum seedling height (8.70 cm) was recorded for Agustmuni seed source. The highest root length was recorded for the seedlings of Pabo seed source (14.62 cm) and lowest (12.38 cm) for Mayali seed source. Rawat and Bakshi (2011) studied the variation in seedling parameters of *Pinus wallichiana* among 20 provenances in Himachal Pradesh and Uttaranchal. Seedling length varied from 5.58 cm to 8.31 cm with coefficient of variance of 20.80 per cent, collar diameter varied from 6.28 mm to 8.88 mm with coefficient of variance of 8.79 per cent and vigour index showed coefficient of variance of 48.62 per cent.

Rao (2008) studied the genetic associations, variability and diversity in seed characters, growth, reproductive phenology and yield in *Jatropha curcas* (L.) in 32 high yielding Candidate Plus Trees (CPTs) from different locations covering 11 locations in an area spread of 150,000 km^2. Significant trait differences were observed in growth characters (plant height, and female to male flower ratio and seed yield in the progeny trial). Maximum plant height of 134.0 cm was recorded in CRDJ 24 followed by CRDJ 26 which recorded a height of 128.6. Manjunath *et al*. (2009) studied on seed source variation for seed and seedling traits in *Jatropha curcas* (L.). The seed source from Gudnapura (CPT-15) of Uttara Kannada district and Bankapura (CPT-17) of Haveri district were found to be promising with respect to seedling traits. Ghosh and Singh (2011) studied the variation in seedling characters of *Jatropha curcas* (L.) among 6 geographical zones within India with four to six provenances within each zone. Highest seedling height (16.41 cm), collar diameter (1.59 cm) and number of leaves per seedling (7.12) were observed in zone sub-humid to humid eastern and south eastern uplands whereas lowest seedling height (13.87 cm), collar diameter (1.38 cm) and number of leaves per seedling (4.87) were observed in zone humid western Himalayan region.

Gera *et al*. (2001) noticed significant differences among the families for all seedling parameters studied twenty genotypes of *Albezia procera* sampled from their natural range in Jammu. The family F12 gave the maximum value for seedling height (56.37 cm) and total seedling biomass (5.35 g), further maximum seedling collar diameter 26 was recorded for family F5 (0.47 cm). Nayak *et al.* (2004) study was undertaken to evaluate the performance of five seed sources of *Albizia lebbeck* (L.) Benth, in Karnataka, viz., Chikmagalur, Uttara Kannada, Mandya, Dharwad and Gulbarga. Significant differences were recorded among the seed sources with respect to seed and seedling attributes. Seeds collected from Mandya and Chikmagalur sources showed better performance for seedling attributes. Bahar (2008) studied 29 seed sources of *Albizzia lebbeck* (L.) revealing that best population on the basis of weight, germination percentage and vigour index were Dehradhun (Uttarakhand), Kathua (J&K) and Tirunelveli (Tamil Nadu).

Kumar *et al.* (2008) studied variation for seed traits of *Pongamia pinnata* (L.) of different agro climatic zones of southern Karnataka. Seedling attributes such as seedling height, root length, shoot and root dry weight showed statistically significant differences among five seed sources. Among all seed sources Central dry zone performed better for all the seedling characters and it was least in Eastern dry zone. Patil *et al.* (2008) studied variability for seed traits of *Pongamia pinnata* (L.) of different agro climatic zones of northern Karnataka. Study revealed that Seedling of Northern dry zone showed higher shoot length (35.94 cm), root length (34.23 cm), shoot dry weight (3.37g), root dry weight (3.37g), shoot vigour index (3286.90) and root vigour index (3136.90). Among all seed sources Northern dry zone performed better for all the seedling characters and it was least in North eastern dry zone. Chauhan *et al.* (2011) reported the seedling growth parameter had shown significant variation among progenies of *Pongamia pinnata,* except collar diameter and primary root length.

Evaluation of provenances for seedling attributes in *Tectona grandis* was studied by Jayasankar *et al.* (1999). Seeds were collected from 7 provenances from Kerala (India) from 10 phenotypically superior trees in each provenance. Leaf area was found maximum in Parambikulam (4663.6 cm^2) and least in Trichur (2003.9 cm^2) 360 days after sowing. Significant variation for was found in various biometric traits like height, collar diameter and survival per cent among 40 clones of *Tectona grandis* (Gera *et al.*, 2001). Hedge *et al.* (2004) reported significant variation in seedling height, collar diameter, number of nodes, leaf length, leaf breath and leaf length/breath ratio was observed at three months and six months old teak seedlings in nursery. 27

Vinod and Kumar (1998) studied seeds and seedling variations in eight provenances of *Azadirachta indica* collected from Kerala Tamil Nadu and Karnataka. Genetic analysis indicated more or less equal contribution of both genotype and environment to them. High heritability in conjunction with high genetic gain was recorded for seedling height fallowed by collar girth. Dhillon *et al.* (2003) reported that among the various parameters studied, height was observed to be the most reliable selection index at nursery level in *Azadirachta indica*. Significant variations for all the plant growth characters like stem height, seedling height; number of branches were also reported among 36 progenies of neem. Bharti (2007) reported the highest heritability in number of leaves and lowest heritability for collar diameter whereas volume index recorded the highest genetic advance with lowest for collar diameter in *Melia dubia.*

Manjunath *et al.* (2009) studied on variation for seed and seedling traits in *Garcinia indica* (Choisy). Study revealed that seed size and fresh seeds of *Garcinia indica* strongly influenced seed germination. With regard to elite germplasm identified CPTDK-31 collected from Mavinakara of Udupi district followed by CPTUK-13 from Basavanakere of Uttara Kannada district were found to be promising with respect to seedling traits.

Sekar (2003) reported that the seed sources of *Simarouba glauca* exhibited significant variation in terms of plant height, collar diameter, number of leaves and leaf area index in early stages of growth. Oyebade *et al.* (2012) studied on Provenance variations in *Chrysophyllum albidum* (G. Don) from six localities in rivers state, Nigeria. Ahoada provenance showed highest seedling height (36.84 cm) and Bonny provenance showed lowest Seedling height (12.45 cm). Bori showed highest collar diameter (0.81 cm) and Bonny showed least collar diameter (0.485 cm). Leaf number was seen highest in Bori (18) and least in Degema (8) with highest leaf area in Ogbakiri (364.52 cm^2) and least in Degema (261.78 cm^2). Shu *et al.* (2012) studied seedling parameters of *Magnolia officinalis* on the fifteen different provenances of showed that significant difference existed among provenances in shoot length, collar diameter, number of leaves per plant, main root length and dry weights except for relative growth rate and net assimilation rate. Contribution of provenance effect was 93 per cent of the total variation in seedling height and collar diameter.

Balaji (2000) observed in *Eucalyptus tereticornis* that the trait volume registered the maximum genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) followed by crown length which recorded rnoderat PCV and GCV. The lowest PCV and GCV was recorded for plant height and collar diameter. Sasikumar (2003) reported heritability values were high for all the traits barring the number of branches. The highest heritability was recorded by plant height, followed by collar diameter, volume and number of branches in *E. tereticornis* clones.

Verma and Bangawa (2007) indicated that the estimates of PCV and GCV clearly reflected the presence of large amount of genetic variability for number of branches, clear bole height, total height and basal diameter in *Populus deltoides*. Takuathung *et al*. (2012) studied the growth performance of *Senna siamea* (Lam.) among nine provenances of Thailand. Genetic effect associated with seedling height varied from 53-85 per cent and diameter at ground level varied from 33-62 per cent. Dlamini (2010) reported high significant differences between provenances in seedling height and root collar diameter of *Sclerocarya birrea* at five and eight months but no significant differences were observed in percentage increment of height and root collar diameter at eight months. This shows even though provenance effect in the seedling traits may be significant but does not always imply that the increment percentage will be as significant.

2.4 Field growth

Cornelius (1994) stated that progeny of plus-trees selected for yield traits tend to be faster growing than their controls. Which is most likely to be due or at least in part to a response to selection. The reported values from his compilation indicate that genetic gains of up to 15 per cent in height and diameter growth, and up to 35 per cent in volume per unit area, can readily be achieved through plus-tree selection. However, it should be emphasised that the amount of gain from any particular plus-tree selection system depends on the values of the parameters (selection intensity, genetic variance, heritability) that determine the response to selection. The increase in productivity resulting from tree improvement programs are visible in growth parameters in the field. Li *et al*. (1999) reported loblolly pines grown from seeds of first-generation seed orchards in USA have produced seven per cent to 12 per cent more volume per acre at harvest than trees grown from wild seed. Second-generation seed orchards were producing more than 50 per cent of the total seed harvest in the region with estimated gains ranging from 13 per cent to 21 per cent in rotation volume over unimproved seed lots. Gains of 26 per cent to 35 per cent in volume production at harvest was expected when second generation seed orchards are rogued with 14 per cent to 23 per cent additional for first generation orchards.

Ailanthus triphysa is an important tree species for match industry. Indira (1996) started the screening of natural variation and selection of superior phenotype in *Ailanthus triphysa* for further improvement. The study conducted has revealed that *A. triphysa* has a high family heritability for height and moderately high heritability for basal girth. The single tree heritability was found to be moderately high for height while it was low for basal girth and decreased with age. The phenotypic and genotypic coefficient of variation were found to be low for height and collar girth Strong Since phenotypic variance was very low, genetic gain also happened to be low. High heritability was not accompanied by greater genetic progress. For basal girth, phenotypic and genotypic coefficient of variation were very low. Single tree heritability and genetic advance were also low. Family heritability was found to be moderate. Moderate family heritability and low single tree heritability for girth was attributable to non-additive gene effects. The genetic correlation between height and basal girth was found to be high as 1.0, while phenotypic correlation was 0.69 at the age of three years. The strong positive correlation makes the improvement programme easy since positive selection made for one character will automatically improve the other. *Ailanthus integrifolia* ssp. *calycina* was found to be better in growth performance in early years besides having a high level of pest resistance. However, *Ailanthus triphysa* is considered superior due to an aromatic resin that is present in it removing the need splints to be dipped in wax. *A. triphysa* performed well in degraded soils whereas *A. integrifolia* failed to survive in small scale field planting done at various localities.

The genetic control over growth characteristics like branching, stem straightness persistence of axis, etc. vary depending upon the species and sites. Provenance trial of *Grewia arborea* from different geographical areas of India shows that branch thickness is strongly controlled by the environment. But mode of branching of the species is found to have moderate heritability (Indira, 2006). McKeand (1988) reported average intra class correlation coefficients for height of loblolly pines at ages four, eight, and twelve are 0.22, 30

0.30 and 0.27, respectively. This indicates that the maximum degree of genetic control for height was found at age eight. Verma and Bangarwa (2007) indicated that the estimates of PCV and GCV clearly reflected the presence of large amount of genetic variability for number of branches, clear bole height, total height and basal diameter in *Populus deltoids*. Similarly, significant differences in girth at ground level, girth at breast height and straightness of stem were observed between families of *Casuarina equisetifolia* and also GBH showed the maximum GCV and PCV i.e., 11.23 per cent and 64.30 per cent respectively (Rao *et al.*, 2001).

Meena *et al.* (2014) studied different growth parameters of 54 *Melia azedarach* progenies selected from 11 geographical locations in India, at a seed farm of Punjab Agricultural University. The highest variations were recorded in the number of branches (35.63%), followed by DBH (26.89%), basal diameter (25.25%), and MAI for DBH (25.07%). Total height (16.01%) had the lowest variation among the progenies. Maximum heritability on a progeny basis and within-progeny basis was observed in MAI for height and on an individual plant basis in MAI for DBH. Minimum heritability was observed in total height, basal diameter, and DBH at the progeny level. Genetic gain on a progeny and within-progeny basis reflected higher gains within progeny than in the progeny selection for all the characters.

Brodie and Debell (2004) evaluated the field performance of poplar clones using selected competition indices. A poplar research trial was established with testing 4 clones 3 of which were *Populus trichocarpa* x *P. deltoides* hybrids (11–11, 47–174, 49–177) and one was a local *Populus trichocarpa* clone. Diameters ranged from 0.2 to 4.2 cm (with a coefficient of variation (Cv) of 24.9) and heights from 1.3 to 5.2 m (with a coefficient of variation of 14.4) after the first growing season. After the third growing season, diameters ranged from 0.8 to 11.1 cm (Cv = 38.5) and heights from 2.25 to 13.2 m (Cv = 25.4). significant variation among various provenances of *Populus alba* were also documented with reference to height, diameter at breast height (DBH), taper, clear bole, leaf area and number of stomata (Ramesh and Khurana, 2003). Lazdiņa *et al.* (2016) studied the early growth and frost damage in 23 five-year-old poplar clones in Latvia. The height of clones ranged from 273.3 to 711.0 cm. Each of the three highest clones (LV3, LV1 and LV4) was significantly higher than most of the other clones. The same three clones had the highest biomass and exceeded others by 65 per cent. The fresh above-ground biomass of clones LV3, LV1 and LV4 was 8.47, 6.40 and 5.19 kg

Korwar *et al.* (2008), studied the genetic associations, variability and diversity in seed characters, growth, reproductive phenology and yield in *Jatropha curcas* (L.) from 32 high yielding Candidate Plus Trees (CPTs) covering 11 locations. Significant trait differences were observed in all the seed characters (seed morphology and oil content), growth characters (plant height, and female to male flower ratio and seed yield in the progeny trial). Broad sense heritability was high in general and exceeded 80 per cent for all the seed traits studied. Female to male flower ratio showed near to 100 per cent heritability followed by yield (83.61) and plant height (87.73).

Li *et al.* (1999) reported loblolly pines grown from seeds of first-generation seed orchards in USA have produced 7-12 per cent more volume per acre at harvest than trees grown from wild seed. Second-generation seed orchards were producing more than 50 per cent of the total seed harvest in the region with estimated gains ranging from 13 per cent to 21 per cent in rotation volume over unimproved seed lots. Gains of 26 per cent to 35 per cent in volume production at harvest was expected when second-generation seed orchards are rogued to and 14 to 23 per cent additional for first generation orchards.

Pliura *et al.* (2007), studied the genotypic variation in wood density and growth traits of poplar hybrids at four clonal trials. The growth of hybrid poplars was fastest at the Saint-Ours site and slowest at the Platon site with Saint-Anselme and Windsor sites being intermediate. The stem volume and stem dry fibre weight of trees at the Saint-Ours site were almost twice those at the Platon site. However, phenotypic variation of these composite traits was highest at the less productive Platon and Saint-Anselme sites. The phenotypic variation was found to be low for height and diameter at breast height.

Cappa *et al.* (2010) estimated narrow sense heritability in *Eucalyptus viminalis* for diameter (0.27) and for total height (0.17). He observed that values of heritability also increased with age. Individual tree heritability estimates ranged from 0.12 at three years to 0.44 at six years for DBH and from 0.07 at two years to 0.27 at three years for height. Callister and Collins (2008) estimated narrow sense heritability in teak for growth

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parameters such as diameter (0.22), height and volume (0.18). Broad sense heritability was found to be 0.37 for diameter, 0.28 for height and 0.35 for volume.

Vergara *et al.* (2004), estimated realized gains for first-generation slash pine (*Pinus elliottii* var. *elliottii*) in south-eastern United States. Moderate gains were found in site index (4.3%) while gains in individual tree volume and stand yield were 7.7 per cent and 10.2 per cent respectively. On average, realized gain in stand yield for first-generation material was approximately 10 per cent. Realized genetic gain is the best way to justify utility of genetic improvement and to quantify the progress in wood production and economic returns (Zobel and Talbert 1984).

Balocchi *et al.* (1993) studied age trends in genetic parameters for tree height in a non-selected population of loblolly pine. Additive variance for height of loblolly pine (*Pinus taeda*) in Georgia was very low at younger ages (1 to 8) but rapidly increased thereafter. Nonadditive variance increased from ages one to ten and then remained constant through age 26. The ratio of nonadditive variance to total genetic variance increased from 17 per cent at age one to a maximum of 82 per cent at age six, and then declined to 20 per cent at age 26. Heritability values ranged from almost zero to approximately 0.75 with the lowest values occurring at very young ages and for within-family and individual-tree heritabilities. The largest values were associated mainly with family heritabilities and older ages. Almost all estimates of heritability exhibited similar trends; values were very low at early ages and a maximum value between ages 14 and 16. Finally, the coefficient of genetic prediction for tree height between juvenile ages (1 to 16) and the final measurement age for tree height, when based on the total genetic component(CGP_G), showed a nearly linear increase from age one to age 16. The maximum values for this parameter were those associated with full-sib family means and ranged from 0.13 at age one to 0.67 at age 16. The additive (CGP_A) and nonadditive (CGP_D) components of CGP_G followed the same patterns the additive and nonadditive variances followed.

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2.5 Wood properties

2.5.1 Fibre morphology

Genetics of wood properties have been subjected to numerous studies (Zobel and van Buijtenen 1989). It is important that the genetic correlation of major wood properties with growth traits be examined before wood quality traits can be incorporated into tree breeding programs to maximize the genetic gains. (Zhang *et al*., 2003). A large proportion of the variability in wood properties is under genetic control (Zobel and Jett, 1995). The environment under which a tree grows is also a major driver of variation (Zobel and van Buijtenen, 1989). In majority of cases within tree variation is the largest source of differences in wood and fibre properties due to the fact that various factors within the tree have significant impacts on the fibres produced.

Gartner *et al*. (2007) studied six 40-year-old red alders (*Alnus rubra* Bong.) that were harvested from a mixed stand of *A. rubra* and big-leaf maple (*Acer macrophyllum*) in the Oregon Coast Range to evaluate variation in their wood characteristics. Vessel diameter and specific gravity varied significantly among trees Mean vessel diameter varied from 43 to 71 μm among the six trees. The trees were classified into three homogeneous categories of vessel diameter: (A) trees four and six had the smallest vessel diameter; (B) trees one, two, and three had the largest; and (C) tree five had a vessel diameter between (A) and (B).

Leal *et al*. (2003) studied the vessel anatomy in 17 clones of 7-year-old *Eucalyptus globulus* trees grown on two sites in Portugal. Significant differences were found for vessel coverage with site (67%)and clone (30%) accounting respectively for and of the total variation. The variation in vessel characteristics was assigned to clonal and site effects. However, Malan (1993) studied four eucalypt hybrids and reported that site had only a limited effect on vessel size and distribution. Sass and Eckstein (1995) reported that the formation of vessels during the beginning of the cambial activity was controlled by internal factors, while adult wood formation was affected by environmental factors in *Fagus sylvatica*. Eckstein and Frisse (1979) pointed out that precipitation

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caused a significant portion of the vessel variability in *Fagus sylvatica* among the external factors. Fritts (1976) stated that the cambium produces narrower cells under water stress conditions. This trend further strengthened by Knigge and Schulz (1961) reporting that vessel properties of *Fagus sylvatica*, *F. moesiaca*, is controlled by water.

Oluwadare and Ashimiyu (2007) reported that fibre characteristics and their morphologies significantly influenced the strength properties of the pulp sheet of *Leucaena leucocephala* with cell-wall thickness and fibre length having the greatest influence on the strength properties of the unbeaten pulp. Fibre length was important in as much as minimum length is required for bonding ages distribution once beating commences. According to Kibblewhite *et al.* (2001), there were substantial and often significant differences in various fibre dimensions between species and between the 8 and 11-year-old trees. *Eucalyptus maidenii* had longer fibres than *E. nitens* and E. globulus of the same age, and the fibre length of its 11-year-old samples was longer than the 8-year-old. The 11-year-old *E. maidenii* also had larger fibres perimeter, wall thickness, wall area than *E. globulus.*

2.5.2 Wood density

Density of wood can be defined as the weight of a unit volume of the material and the relative density or specific gravity of a material is the ratio of the weight of the material to the weight of an equal volume of water at 4°C. These terms are often used interchangeably although they each have precise and different definitions (Bowyer and Smith, 1998). Both terms are used to indicate the amount of actual wood substance present in a unit volume of wood and also both terms can be calculated from one another (Zobel and Jett, 1995). It is an important property of wood and positively correlates with other properties like mechanical properties, value of both fibrous and solid wood products (Pliura *et al.,* 2007). The specific gravity of wood is its single most important physical property. Most mechanical properties of wood are closely correlated to specific gravity and density (Haygreen and Bowyer, 1996; Walker, 1993). It appears to influence machinability, conversion, strength, paper yield and many other properties (Wimmer *et al.*, 2002). Wood density due to its highly heritable nature and good response to genetic improvement is a desirable trait from the breeding point of view (Zhang *et al.,* 2003).

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Byram and Lowe (1988) studied the provenance variation of specific gravity of Loblolly Pine in Western Gulf region. Trees from south Arkansas had the highest specific gravity (0.424) while those from south Louisiana had the lowest (0.398). Southeast Texas and north Louisiana trees were intermediate with an average specific gravity of 0.405. Trees from a North Carolina coastal source had the lowest specific gravity among the five plantings in Arkansas and Oklahoma in which they were included. Specific gravity in 1oblolly pine (*Pinus taeda* L.) can be altered by breeding because it is under strong genetic control with family heritabilities of 0.5 or higher (Talbert *et al.*, 1985).

Hylen (1997) studied the genetic variation of wood density and its relationship with growth traits in young Norway spruce. Juvenile wood density measured by direct X-ray analysis from increment cores of 47 open-pollinated families in 28-year-old Norway spruce located at Hordaland County (Norway) were examined to assess the magnitude of family differences of overall wood density and its components and to calculate the phenotypic and genetic correlations among traits. The overall wood density and its components varied significantly among the families, due to the high individual and family mean heritabilities. Beaudoin *et al.* (2007) studied the inter clonal and intra clonal variations in hybrid poplar. The analysis indicated that there are significant differences among the ten clones for wood density. The effect of clones was found to form approximately 64 per cent of the total variation. Since all clones came from the same site, thus reducing the environmental variation, the variance ratios obtained on the wood density of poplar hybrid appear to be under relatively strong genetic control. In this study, clones 3005, 37, and 205 had higher wood densities than clones 3308, 131, and 136

Magnussen and Keith (1990) studied six selection strategies aimed at genetically improving volume production and wood quality factors such as density, heartwood content, and stem taper in a 20-year-old jack pine progeny trial. Stem taper, wood density, and heartwood content were found to be under strong genetic control; however, the low phenotypic variation of wood density limits its potential for genetic improvement but heartwood content emerged as a trait amenable for rapid genetic improvement. Pliura *et al.* (2007) studied the genotypic variation in wood density and growth traits of poplar hybrids at four clonal trials. Moderate to strong negative correlations between weighted wood density and tree height (-0.59 and -0.72) were found in some sites but correlation between maximum wood density and growth traits were weak and not significant. Genetic gain due to direct clonal selection of weighted wood density ranges from 5.8 per cent to 7.8 per cent. Trees at the Saint-Ours site had the lowest weighted wood density and highest wood density was observed at the Windsor site.

Gartner *et al*. (2007) studied six 40-year-old red alders (*Alnus rubra*) that were harvested from a mixed stand of *A. rubra* and big-leaf maple (*Acer macrophyllum*) in the Oregon Coast Range to evaluate variation in their wood characteristics. The mean specific gravity was found to vary from 0.45 to 0.51 among trees. The trees were classified into four homogeneous categories based on specific gravity: (A) tree 2 had specific gravity of 0.45; (B) trees 1, 3, and 4 had specific gravity between 0.46 to 0.47; (C) tree 5 had specific gravity of 0.48; and (D) tree 6 had specific gravity of 0.51.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study on "Screening of *Ailanthus triphysa* (Dennst.) Alston. for preferred match wood qualities" was conducted to evaluate the variations in growth and wood properties of *Ailanthus triphysa* grown in Thrissur and Palakkad districts. With the view of fulfilling the objectives envisaged, experiments are carried out at College of Forestry Vellanikkara, Kerala.

Species under the study

i) Species description

Species: *Ailanthus triphysa*

Family: Simaroubaceae

Order: Sapindales

Synonyms: *Ailanthus malabarica*

The generic name 'Ailanthus' comes from 'ailanthos', the Indonesian name for *Ailanthus integrifolia*. Trees, evergreen, usually 15–30 m tall, leaves pinnate, large 45-60 cm, crowded at branch ends; long leaflets 6–17 pairs; petiole pubescent, 5–7 mm; blades ovate-lanceolate or oblong-lanceolate, 15–20 × 2.5–5.5 cm, oblique, margin entire, apex acuminate, or glabrous. Flowers white, polygamous in lax axillary panicles; pedicels short. Calyx lobes minute, pubescent, triangular, acute. Petals about 0.4 cm long, glabrous, oblong-lanceolate.

Flowering starts from December onwards with a peak time in January and February. With the start of flushing, floral buds also appear. Occasionally flowering could be seen in March also. The tree is dioecious and generally flower profusely. The appearance of male and the female trees are almost identical except that in male trees the crown and leaves are more compact and the leaves being more tufted at the end of the twig (Indira, 1996). Fruit is a samara, 5-7.5 cm long, reddish-brown and membranous. Seed is compressed in the samara and is circular in shape.

3.1 MATERIALS

The experimental materials for this study consisted of 20 *Ailanthus triphysa* trees from Thrissur and Palakkad districts. Nursery and field experiments were carried out at College of forestry Vellanikkara and research plot at Aaramkal.

3.1.1 Sources of progeny

Preliminary Survey was conducted in Thrissur and Palakkad districts to find areas where *Ailanthus triphysa* grows. Five panchayats each were selected from Thrissur and Palakkad districts. The candidate plus trees (CPTs) were identified from **Madakkathara, Nadathara, Kolazhi, Pannanchery, Mulakkunnathukavu, Cherupulashery, Vilayur, Koppam, Pattambi** and **Ongallur** panchayats. Two CPTS's from every panchayat which recorded seed set were included in the study. Selected CPTs were assigned with the accession number as FCV AT.

3.2 METHODS

3.2.1 Collection of seeds

The seeds were collected from the trees by breaking the small branches which support them and are lowered gradually to prevent seeds from flying off. The seeds are then cleaned to remove foliage, empty seeds and other impurities. They are then dried in shade to remove excessive moisture. The dried seeds are bulked according to their origin and stored at room temperature in polythene bags.

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Table 1. Details of the seed sources used in the study.

Location	Trees	Height (m)	Girth at breast height (cm)
Madakkathara	FCV AT 1	24	146
	FCV AT 2	17	153
Nadathara	FCV AT 3	22	109
	FCV AT 4	23	102
Kolazhi	FCV AT 5	19	137
	FCV AT 6	23	105
Pananchery	FCV AT 7	17	111
	FCV AT 8	19	107
Mulamkunnathukavu	FCV AT 9	16	118
	FCV AT 10	21	122
Cherpulassery	FCV AT 11	26	127
	FCV AT 12	18	120
Vilayur	FCV AT 13	19	119
	FCV AT 14	18	122
Koppam	FCV AT 15	22	129
	FCV AT 16	20	115
Pattambi	FCV AT 17	17	130
	FCV AT 18	22	116
Ongallur	FCV AT 19	24	135
	FCV AT 20	21	124

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3.2.2 Seed germination test

Germination tests for *Ailanthus triphysa* were carried out during the month of April. For testing the germination, three replicates of 80 seeds were de-winged and allowed to soak in cold water overnight. The soaked seeds were planted in trays with soil. The observations on daily germination were recorded for 25 days. The seed was considered germinated when radicle was visible. Germination parameters measured are given below;

$$\text{Germination percent} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100$$

$$\text{Mean Daily Germination} = \frac{\text{Final germination per cent}}{\text{The number of days that took to reach Peak Germination}}$$

$$\text{Peak Value} = \frac{\text{Total germination per cent}}{\text{Total number of days}}$$

Germination Value (GV) = PV X MDG

Where, PV- Peak Value of germination.

MDG- Mean Daily Germination

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Plate 1. Seedlings at 120 days after planting in the nursery.

Plate 2. Seedling at 120 days after planting in the nursery uprooted for morphometric measurement.

Plate 3. Leaf area meter (Model LI 3100 LI-Cor, Nebraska, USA) for measuring leaf area.

$$\text{Germination Rate} = \frac{G1}{T1} + \frac{G2}{T2} + \frac{G3}{T3} + \ldots\ldots\ldots\ldots + \frac{Gn}{Tn}$$

Where, G1 - Number of seeds germinated on the first day

G2 - Number of seeds germinated on the second day

G3 - Number of seeds germinated on the third day

T1 - day one

T2 - Day two

T3 - Day three

Gn- Number of seeds germinated on n^{th} day

Tn- n^{th} day

3.2.3 Seedling growth

For studying the seedling performances of the provenances, seeds were sown in the nursery beds located at College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur. The sown seeds were covered with a thin layer of soil and frequently irrigated to facilitate germination. After the germination, they were pricked out and transplanted to a polybag (11.43x15.24 cm, gauge 75 microns) filled with a potting mixture of sand, soil and manure at a ratio of 1: 2: I. The experiment designed was CRD. The transplanted seedlings were then placed under shade net before exposing to full sunlight.

3.2.3.1 Seedling biometric observations

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

a. Shoot height

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

b. Collar diameter

The collar diameter of the seedlings was measured along two diametrically opposite directions of the seedlings using Vernier calipers having least count = 0.02 mm expressed in millimeters.

c. Number of leaves

Number of functional leaves (fully opened) from four random seedlings were counted and recorded.

d. Leaf surface area

The leaves collected from different treatments were used for measuring the leaf area. It was first measured using leaf area meter (Model LI 3100 LI-Cor, Nebraska, USA) and was expressed in cm^2.

e. Fresh weight of shoot

Representative samples of four seedlings were selected randomly from each treatment at monthly intervals. The fresh weight of shoots was recorded using electronic balance and expressed in grams.

f. Dry weight of shoots

After finding out the fresh weight, the shoot portion was dried in hot air oven at a temperature of 70°C ± 2°C 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

Representative samples of four seedlings were selected randomly from each treatment at monthly intervals. The fresh weight of leaves was recorded using electronic balance and expressed in grams.

h. Dry weight of leaves

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

i. Number of leaflets

The number of leaflets was counted from four randomly selected seedlings at monthly intervals.

j. Tap root length

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

k. Number of lateral roots

Number of roots produced by individual seedlings was recorded.

l. Fresh weight of roots

Representative samples of four seedlings were selected randomly from each treatment at monthly intervals. The fresh weight of roots was recorded using electronic balance and expressed in grams.

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k. **Dry weight of roots**

The root portion was dried in hot air oven at a temperature of 70ºC ± 2ºC for about 48 hours. The dry weight also was recorded using an electronic balance. Drying and weighing were continued till constant weights obtained.

3.2.3.2 Plant growth analysis

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

a. **Leaf Area Ratio**

The term, Leaf Area Ratio (LAR) was 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 $cm^2\ g^{-1}$ 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 the leaf area of the plant to leaf dry weight and expressed in cm^2g^{-1} (Kvet *et al.*, 1971).

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

c. **Absolute Growth Rate**

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

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$$\text{Absolute Growth Rate} = \frac{h_2 - h_1}{t_2 - t_1}$$

Where,

h_1-Plant height at time (t_1)

h_2-Plant height at time (t_2)

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).

$$\text{Reltive Growth Rate} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

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 $g^{-1}day^{-1}$).

$$\text{Net Assimilation Rate} = \frac{(W2 - W1)}{(t_2 - t_1)} \text{x} \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)}$$

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Where,

W_1 and W_2 is 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

3.2.4 Performance of progenies at field

For the progeny evaluation trial in the field seedlings from 20 seed sources were planted in the field at Aaramkal. A total of 320 plants were planted with a spacing of 3×3 metres. The experiment was laid-out in RBD with four replications and having four members of each seed source within each replication. Observations are taken for 150 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 as cm.

3.2.4.2 Basal diameter (cm)

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

3.2.4.3 Survival percentage

The survival per cent was calculated by counting the established seedlings in the field and their mean was expressed as a percentage.

3.2.5. Basic density

For measuring the basic density one core sample was collected from each mother tree was soaked in distilled water for 24 hours to attain green volume condition. Green volumes were calculated by water displacement method. The specimens were then kept in a hot air oven to obtain the oven dry weight. The

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Plate 4. Field Planting of seedlings.

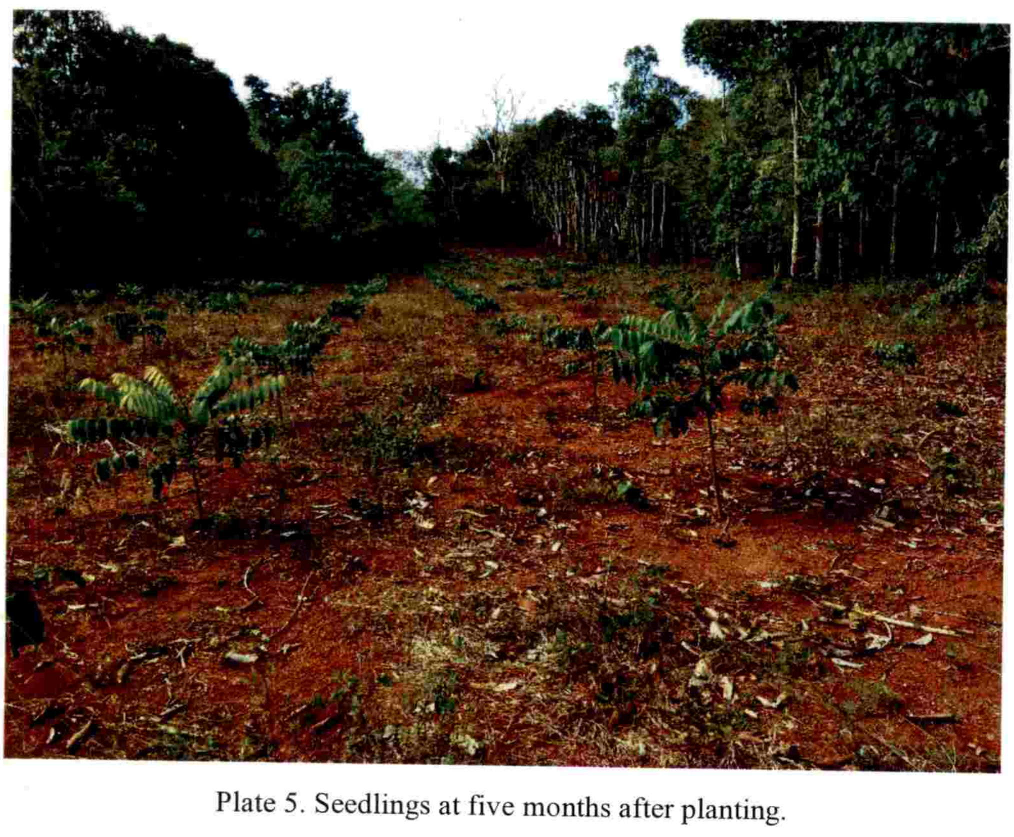

Plate 5. Seedlings at five months after planting.

temperature was set at 102°C ±1°C and the samples were not removed when until they attained constant weight. The samples were weighed using a precision balance with an accuracy of 1.0 mg and basic density was calculated.

$$\text{Basic density (kg m}^{-3)} = \frac{\text{Oven dry weight}}{\text{Green volume}}$$

3.2.6 Anatomical properties

3.2.6.1 Maceration

Maceration of the wood samples was done using Jeffrey's method (Sass, 1971). For maceration, Jeffrey's solution was used and it is prepared by mixing equal volumes of 10 per cent potassium dichromate and 10 per cent nitric acid. Radial chips of wood shavings were taken from the core samples collected from the seed sources. These shavings were boiled in the maceration fluid for 15-20 minutes so that the individual fibres were separated. Then these test tubes were kept undisturbed for 10-15 minutes so that the fibres settled at the bottom. The solution was discarded and the resultant material was washed repeatedly with distilled water until traces of acid were removed. The samples were stained using saffranin and mounted on temporary slides using glycerin as the mountant.

3.2.6.2 Observations

Microscopic examination and quantification of sections were undertaken using an Image Analyzer (Labomed-Digi 2). It consists of a microscope, digital camera and PC (Personal computer). The image analyzer provides quick and accurate data replacing the more laborious traditional methods. The digital camera provides digitized images which are analyzed by the computer software (Labomed DigiPro4). The software provides several classes of measurements like length, diameter, area and count. From the macerated wood sample, observations like fibre

Plate 6. Image analyser (Labomed Digi-2) used for anatomical quantification.

Plate 7. Fibre (10x) isolated by maceration.

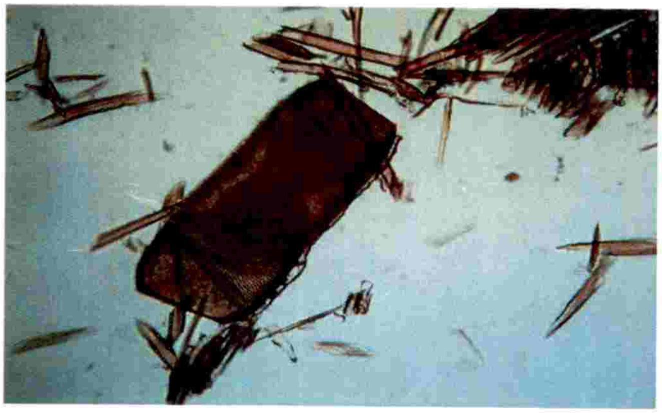

Plate 8. Vessel (10x) isolated by maceration.

length, fibre diameter, fibre wall thickness, fibre lumen diameter and vessel length for each of the samples were measured using the Image Analyzer. Each measurement was repeated fifteen times for all the above characters for all the samples and measurements are recorded in micrometers (μm). Different indices which are derived from the fibre measurements are estimated (Uju and Ucwoxe, 1997; Yáñez-Espinosa *et al.*, 2004):

$$\text{Runkel Ratio} = \frac{\text{Fibre lumen diameter (FLD)}}{\text{Fibre wall thickness (FWT)}}$$

$$\text{Slenderness Ratio} = \frac{\text{2 Fibre Length (FL)}}{\text{Fibre diameter (FD)}}$$

$$\text{Rigidity Coefficient} = \frac{\text{2 Fibre Wall Thickness (FWT)}}{\text{Fibre diameter (FD)}}$$

$$\text{Flexibility Coefficient} = \frac{\text{2 Fibre Lumen Diameter (FLD)}}{\text{Fibre diameter (FD)}}$$

3.2.3 Questionnaire Survey

A questionnaire survey was conducted to know the farmer's perception towards tree farming and the preference of incentives required for farming trees.

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3.2.4 Statistical analysis

The data were subjected to analysis using the statistical packages IBM SPSS version-20.0 for windows. Mean values were compared using least significant difference (LSD) method wherever the F-values were found to be significant.

RESULT

4. RESULTS

4.1 Germination parameters

To evaluate the variation associated with the seed sources in germination related parameters, germination test was conducted after de-winging seeds and soaking it overnight in cold water. The different parameters and their results are given in Table 2.

4.1.1 Germination percentage

During analysis, significant variations were found in, germination percentage. The germination percentage averaged to 48.82 per cent for all the seed sources. The highest value was for FCV AT 17 at 72.08 per cent and the lowest was for FCV AT 4 which was 21.67 per cent.

4.1.2 The peak value of germination

During analysis, significant variations were found in Peak value of germination. The peak value of germination was highest for FCV AT 17 (3.60) and the lowest was for FCV AT 4 (1.08). The average Peak Value of Germination for all the seed sources was 2.43.

4.1.3 Mean daily germination

During analysis, significant variations were found in Mean daily germination. The mean daily germination for all the seed sources was averaged to 4.42 with FCV AT 7 (7.23) having the highest and FCV AT 4 (1.80) having the lowest.

4.1.4 Germination Value

During analysis, significant variations were found in germination value. The germination value was highest for FCV AT 7 (25.28) and the lowest was for

FCV AT 4 (2.03). The mean of the germination values for all the seed sources was 11.80.

4.1.5 Germination rate

During analysis, significant variations were found in the germination rate Germination rate for all the seed sources averaged to 3.41, with FCV AT 7 (5.37) having the highest and FCV AT 4 (1.55) having the lowest value.

4.2.1. Shoot height

Shoot height was analysed for variation between the different seed sources. The results revealed a significant difference in seedling height due to different Seed sources over time (Table 3). At 30 DAP, the mean height of all the seedlings was 10.20 cm. The highest value (12.89 cm) was recorded for seedlings from FCV AT 20 seed source and least (7.13 cm) for FCV AT 18. At 60 DAP, significant variation was found in seedling height. The average height of seedlings from all the sources was 12.86 cm. The highest (16.43 cm) height was observed in FCV AT 16 and least (10.48 cm) in FCV AT 11. At 90 DAP the shoot height among the seed sources showed significant variation. The overall mean height of the seedlings was 28.2 cm. FCV AT 14 was the tallest (26.48 cm) among the progenies and FCV AT 20 was having the shortest seedlings. At 120 DAP, significant variation was found between the shoot height of *Ailanthus triphysa* seedlings. FCV AT 4 (37.55 cm) was having the highest shoot height and FCV AT 20 (15.93 cm) was having the shortest shoot height. At 150 DAP, shoot height showed significant variation and averaged at 27.65 cm. The tallest one was FCV AT 4 (36.23) and the shortest one was FCV AT 20 at 16.98 cm.

Table 2. Variation of germination parameters of seeds from different seed sources.

Seed sources	**Germination Parameters**				
	GP	**PVG**	**MDG**	**GV**	**GR**
FCV AT 1	44.58^{gh}	2.23^{gh}	3.8^{efgh}	8.68^{def}	2.94^{ghij}
FCV AT 2	36.25^{ghi}	1.81^{ghi}	3.32^{fghi}	6.11^{efg}	2.52^{hijk}
FCV AT 3	42.50^{hij}	2.13^{hij}	4.40^{defg}	9.35^{def}	2.98^{ghij}
FCV AT 4	21.67^{k}	1.08^{k}	1.81^{j}	2.03^{g}	1.55^{l}
FCV AT 5	45.83^{fgh}	2.29^{fgh}	4.64^{def}	10.61^{cde}	3.35^{efgh}
FCV AT 6	58.33^{bcde}	2.92^{bcde}	4.96^{cde}	14.67^{cd}	4.26^{cd}
FCV AT 7	69.58^{ab}	3.48^{ab}	7.23^{a}	25.28^{a}	5.37^{a}
FCV AT 8	40.00^{hi}	2.00^{hi}	3.46^{fghi}	6.93^{efg}	2.56^{hijk}
FCV AT 9	25.42^{jk}	1.27^{jk}	2.22^{ij}	2.90^{fg}	1.70^{kl}
FCV AT 10	47.08^{efgh}	2.35^{efgh}	4.28^{defg}	10.25^{cde}	3.19^{fghi}
FCV AT 11	59.58^{bcd}	2.98^{bcd}	4.99^{cde}	15.05^{cd}	3.80^{defg}
FCV AT 12	54.17^{defg}	2.71^{defg}	4.94^{cde}	14.15^{cd}	3.65^{defg}
FCV AT 13	56.25^{cdef}	2.81^{cdef}	5.11^{cde}	14.44^{cd}	4.00^{cdef}
FCV AT 14	36.25^{hij}	1.81^{hij}	2.97^{ghij}	5.52^{efg}	2.40^{ijkl}
FCV AT 15	58.75^{bcd}	2.94^{bcd}	5.35^{bcd}	15.97^{bc}	4.18^{cde}
FCV AT 16	60.00^{bcd}	3.00^{bcd}	5.30^{bcd}	15.91^{bc}	4.39^{bcd}
FCV AT 17	72.08^{a}	3.60^{a}	6.55^{ab}	23.69^{a}	5.18^{ab}
FCV AT 18	32.08^{ijk}	1.60^{ijk}	2.62^{hij}	4.20^{efg}	2.14^{jkl}
FCV AT 18	44.17^{gh}	2.21^{gh}	4.02^{defgh}	8.94^{def}	3.12^{fghi}
FCV AT 20	67.5^{abc}	3.38^{abc}	6.34^{abc}	21.39^{ab}	4.81^{abc}
Mean	48.82	2.43	4.42	11.80	3.41
P	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$

***Significant at 1 per cent level*

Values with same superscript along the column are homogenous

GP = Germination percentage; PVG = Peak value of germination; MDG = Mean daily germination; GV = Germination value; GR = Germination rate.

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

Seed sources	Seedling Height (cm)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	10.15^{abcd}	13.58^{abcd}	19.25^{cd}	23.43^{de}	25.23^{cde}
FCV AT 2	9.20^{bcd}	10.90^{cd}	21.85^{cd}	27.45^{bcde}	34.13^{ab}
FCV AT 3	12.08^{ab}	14.90^{ab}	21.90^{cd}	28.03^{bcde}	32.28^{abc}
FCV AT 4	10.15^{abcd}	13.93^{abcd}	23.70^{ab}	37.55^{a}	36.23^{a}
FCV AT 5	9.98^{abcd}	13.98^{abcd}	21.40^{cd}	30.95^{abc}	29.63^{abcd}
FCV AT 6	11.15^{ab}	13.03^{abcd}	23.58^{ab}	31.25^{abc}	29.40^{abcd}
FCV AT 7	9.88^{abcd}	14.20^{abcd}	19.63^{cd}	24.68^{cde}	23.45^{def}
FCV AT 8	8.98^{bcd}	11.48^{bcd}	17.83^{bc}	28.35^{bcde}	23.03^{def}
FCV AT 9	10.13^{abcd}	12.58^{abcd}	23.78^{ab}	30.98^{abc}	27.65^{bcde}
FCV AT 10	9.70^{abcd}	14.18^{abcd}	26.00^{a}	33.30^{ad}	32.28^{abc}
FCV AT 11	9.10^{bcd}	10.48^{d}	17.65^{bc}	27.23^{bcde}	20.03^{ef}
FCV AT 12	9.23^{bcd}	10.78^{d}	21.93^{cd}	27.95^{bcde}	27.80^{bcde}
FCV AT 13	10.68^{abc}	12.85^{abcd}	25.25^{a}	25.35^{cde}	27.85^{bcde}
FCV AT 14	7.75^{cd}	11.20^{bcd}	26.48^{a}	30.28^{bcd}	29.33^{abcd}
FCV AT 15	12.23^{ab}	16.43^{a}	22.60^{ab}	29.15^{bcde}	28.05^{bcd}
FCV AT 16	12.33^{ab}	14.78^{abcd}	24.70^{ab}	26.93^{bcde}	28.33^{bcd}
FCV AT 17	10.43^{abcd}	12.98^{abcd}	23.68^{ab}	28.45^{bcde}	26.83^{bcde}
FCV AT 18	7.13^{d}	12.95^{abcd}	24.08^{ab}	29.70^{bcd}	26.83^{bcde}
FCV AT 18	10.95^{abc}	12.10^{bcd}	19.40^{cd}	22.30^{d}	25.33^{cde}
FCV AT 20	12.68^{a}	10.53^{d}	15.28^{cd}	15.93^{e}	16.98^{f}
Mean	10.20	12.89	22.00	27.96	27.53
P	0.011*	0.016*	0.024*	<0.001**	<0.001**

**Significant at 5 per cent level, ** significant at 1 per cent level*
Values with the same superscript along the column are homogenous

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4.2.2 Collar diameter

Collar diameter was analysed for significant differences among the seedlings from different seed sources. Significant variations were found for collar diameter among the at 30 DAP (Table 4). The mean collar diameter at 30 DAP was 2.72 mm with the highest value for FCV AT 4 (3.16 mm) and the lowest one for FCV AT 16 at 2.2 mm. At 60 DAP, there was no significant difference among the progenies of different seed sources. The overall mean collar diameter for 60 DAP was 2.99 mm with FCV AT 13 (3.42 mm) having the highest and FCV AT 19 (2.52 mm) having the lowest collar diameter. There was no significant difference between the collar diameters at 90 DAP. The highest value was for FCV AT 10 (4.88 mm) and the lowest was for FCV AT 19 (3.19 mm). The mean collar diameter at 90 DAP was 3.95 mm. There was significant difference in the collar diameter measurements taken at 120 DAP. The overall mean value for collar diameter was 5.14 mm with FCV AT 10 (6.13 mm) having the highest and FCV AT 20 (3.24 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 AT 15 (6.12 mm) and the lowest for FCV AT 20 (3.75 mm). The mean collar diameter at 150 DAP was 5.17 mm.

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

Seed sources	Collar Diameter (mm)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	2.73^{abcde}	3.31	3.68	5.97^{a}	5.73^{abcde}
FCV AT 2	3.12^{ab}	3.20	4.25	5.93^{a}	4.95^{abcdef}
FCV AT 3	2.63^{abcde}	3.13	3.60	4.45^{abc}	5.54^{abcde}
FCV AT 4	3.16^{a}	3.23	4.20	5.58^{ab}	4.42^{ef}
FCV AT 5	2.64^{abcde}	3.07	3.81	5.37^{ab}	4.77^{bcdef}
FCV AT 6	2.58^{bcde}	3.24	3.72	4.68^{abc}	4.40^{ef}
FCV AT 7	2.73^{abcde}	3.29	4.54	5.79^{ab}	5.50^{abcde}
FCV AT 8	2.69^{abcde}	2.63	3.92	4.73^{abc}	4.69^{cdef}
FCV AT 9	2.79^{abcd}	2.88	3.92	5.24^{ab}	5.60^{abcde}
FCV AT 10	2.72^{abcde}	2.89	4.88	6.13^{a}	4.85^{abcdef}
FCV AT 11	2.73^{abcde}	2.81	3.35	5.11^{ab}	4.47^{def}
FCV AT 12	2.80^{abcd}	2.93	3.72	4.63^{abc}	5.06^{abcdef}
FCV AT 13	3.02^{abc}	3.42	3.86	4.87^{ab}	5.43^{abcde}
FCV AT 14	2.72^{abcde}	3.01	4.15	5.27^{ab}	5.82^{abc}
FCV AT 15	2.80^{abcd}	3.29	3.96	5.43^{ab}	6.12^{a}
FCV AT 16	2.20^{e}	2.74	4.27	5.76^{ab}	5.80^{abcd}
FCV AT 17	2.82^{abcd}	2.90	4.45	5.72^{ab}	5.97^{abc}
FCV AT 18	2.31^{de}	2.83	3.96	5.68^{ab}	6.10^{ab}
FCV AT 19	2.52^{cde}	2.52	3.19	4.09^{bc}	4.94^{abcdef}
FCV AT 20	2.76^{abcde}	2.71	3.31	3.24^{d}	3.75^{f}
Mean	2.72	3.00	3.94	5.18	5.20
P	.039*	.134^{ns}	.291^{ns}	.016*	0.001*

**Significant at 5 per cent level and superscript 'ns' indicate not significant*

Values with the same superscript along the column are homogenous

4.2.3 Number of leaves

The number of leaves among the progenies of different seed sources was found to have no significant differences at 30 DAP (Table 5). The mean number of leaves at 30 DAP was 4.7 with FCV AT9 (5.75) having the highest and FCV AT 7 (3.25) with the lowest number of leaves. At 60 DAP, there was no significant difference in the number of leaves among the seedlings. The mean number of leaves was 7.11 with the highest number of leaves observed in FCV AT 10 (9) and lowest for FCV AT 16 (5). There was no significant difference in the number of leaves at 90 and 150 DAP, while the number of leaves varied significantly in observations at 120 DAP. At 90 DAP the mean number of leave were 11.25 with FCV AT 10 (13.75) having the highest and FCV AT 20 (8.5) the lowest. The mean, highest and lowest number of leaves observed at 150 DAP is 10.06, 13 and 7.75 respectively. The number of leaves at 120 DAP is highest for FCV AT 18 (13.5) and the lowest for FCV AT 19 (7.75) with an overall mean of 11.22.

4.2.4 Number of leaflets

The number of leaflets does not have significant difference at 30 DAP (Table 6). The mean number of leaflets at 30 DAP was 18.44 with highest for FCV AT 1 (22) and the lowest for FCV AT 5 (14.25). The number of leaflets showed significant variation at 60 DAP with FCV AT 10 (38) having the highest and FCV AT 16 (23) the lowest. The average number of leaflets for 60 DAP was 30.56. There was no significant variation in number of leaflets at 90 DAP and 150 DAP whereas, at 120 DAP there was significant variation in the number of leaflets between the seed sources. The highest number recorded at 90 DAP was for FCV AT 10 (70) and the lowest for FCV AT 20 (37.5) with a mean of 53.38. The average number of leaflets at 120 DAP was 60.15 with the highest for FCV AT 14 (70.25) and the lowest for FCV AT 20 (38.25). At 150 DAP the mean number of leaflets was 56.36 with the highest for FCV AT 15 (76.25) and the lowest for FCV AT 8 (41.5).

Table 5. Variation in number of leaves of seedlings from different seed sources.

Seed sources	Number of Leaves				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	5.50	7.25	9.50	10.75^{abcd}	10.00
FCV AT 2	5.00	7.50	11.50	10.25^{abcd}	10.00
FCV AT 3	5.00	8.25	10.50	12.75^{ab}	11.00
FCV AT 4	5.00	6.75	11.25	12.25^{ab}	9.75
FCV AT 5	4.00	6.50	11.25	11.00^{abcd}	9.00
FCV AT 6	3.75	6.00	10.75	12.50^{ab}	11.75
FCV AT 7	3.25	7.00	10.00	8.25^{cd}	9.25
FCV AT 8	4.25	6.50	13.00	12.00^{ab}	7.75
FCV AT 9	5.75	6.50	11.25	11.75^{abc}	9.75
FCV AT 10	4.75	9.00	13.75	12.50^{ab}	10.50
FCV AT 11	4.00	7.00	10.25	12.25^{ab}	9.25
FCV AT 12	5.00	7.25	10.00	11.25^{abcd}	10.75
FCV AT 13	5.25	8.00	10.25	9.25^{bcd}	7.75
FCV AT 14	5.25	8.00	12.25	11.00^{abcd}	9.75
FCV AT 15	5.25	6.75	10.25	12.25^{ab}	13.00
FCV AT 16	5.25	5.00	9.50	12.50^{ab}	10.25
FCV AT 17	3.75	7.50	10.00	12.50^{ab}	9.25
FCV AT 18	5.00	8.00	13.00	13.50^{a}	11.50
FCV AT 18	4.25	7.00	9.50	7.75^{d}	10.50
FCV AT 20	4.75	6.50	8.50	8.25^{cd}	10.50
Mean	4.70	7.11	10.81	11.23	10.06
P	0.14^{ns}	0.097^{ns}	0.082^{ns}	0.006*	0.357^{ns}

**significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

Table 6. Variation in number of leaflets of seedlings from different seed sources.

Seed sources	Number of Leaflets				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	22.00	33.25^{abcd}	48.50	58.50^{abc}	53.75
FCV AT 2	20.25	28.00^{abcd}	56.50	56.25^{abcd}	62.25
FCV AT 3	20.00	36.50^{ab}	51.75	61.75^{abc}	61.25
FCV AT 4	20.75	31.75^{abcd}	50.25	66.00^{ab}	48.25
FCV AT 5	14.25	29.75^{abcd}	56.00	62.50^{abc}	56.00
FCV AT 6	17.00	27.25^{bcd}	58.00	66.25^{ab}	63.75
FCV AT 7	14.50	26.75^{bcd}	46.25	45.00^{cd}	51.50
FCV AT 8	16.50	25.25^{cd}	60.00	64.50^{abc}	41.50
FCV AT 9	17.50	28.00^{abcd}	56.50	64.75^{abc}	59.50
FCV AT 10	19.75	38.00^{a}	70.00	59.25^{abc}	57.75
FCV AT 11	17.00	27.50^{abcd}	48.75	63.25^{abc}	50.25
FCV AT 12	16.25	30.00^{abcd}	53.00	62.50^{abc}	58.00
FCV AT 13	20.25	33.50^{abc}	51.50	48.00^{bcd}	43.25
FCV AT 14	19.75	34.25^{abc}	63.00	70.25^{a}	60.75
FCV AT 15	21.25	30.75^{abcd}	52.25	64.25^{abc}	76.25
FCV AT 16	21.50	23.00^{d}	47.25	65.00^{ab}	57.75
FCV AT 17	16.00	35.00^{abc}	49.25	66.00^{ab}	52.25
FCV AT 18	19.75	36.50^{ab}	62.25	70.25^{a}	63.75
FCV AT 18	17.00	27.75^{abcd}	49.00	50.50^{abcd}	61.25
FCV AT 20	17.50	28.50^{abcd}	37.50	38.25^{d}	48.25
Mean	18.44	30.56	53.38	60.15	56.36
P	0.149^{ns}	0.043*	0.084^{ns}	0.014*	0.114^{ns}

** Significant at 5 per cent level and superscript* 'ns' *indicate not significant*
Values with the same superscript along the column are homogenous

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4.2.5 Taproot length

Taproot length of *Ailanthus triphysa* was analysed for variation among the different seed sources. The results revealed significant difference over time (Table 7). Variations in tap root length for the different seed sources were significant at 60 DAP and 120 DAP but did not show any significant difference at 30 DAP, 60 DAP and 150 DAP. At 30 DAP, the mean length of all the seedlings was 7.41 cm. The highest value (10.35 cm) was recorded for seedlings from FCV TP 12 seed source and least (5.55 cm) for FCV TP 3. At 60 DAP, the average length of taproot from all the sources was 9.58 cm. The highest (14.48 cm) tap root length was observed in FCV TP 2 and least (6.5 cm) in FCV TP 4. At 90 DAP the mean tap root length of the seedlings was 17.76 cm. FCV AT 17 was the longest (21.75 cm) among the progenies and FCV AT 20 (12.78 cm) was having the shortest tap root length at 90 DAP. At 120 DAP, FCV AT 4 (28.28 cm) was having the highest and FCV AT 13 (14.78 cm) the lowest taproot length. The overall mean for taproot length at 120 DAP was 21.18 cm. The mean taproot length at 150 was 21.40 cm with FCV AT 1 (36.23) being the longest and FCV AT 20 (14.65 cm) the shortest.

4.2.6 Number of lateral roots

Analysis of variance revealed significant difference in number of lateral roots due to different seed sources at 120 DAP and 150 DAP while there were no significant variations in number of lateral roots in 30 DAP, 60 DAP, and 90 DAP (Table 8). At 30 DAP, the highest (44.25) number of lateral roots was observed in FCV AT 7 and least (12) for FCV AT 5. The average number of lateral roots at 30 DAP was 17.75. At 60 DAP, the highest (28.25) number of lateral roots was observed in FCV AT 7 and least (11.75) for FCV AT 12. At 90 DAP, the average number of lateral roots were 25.15 with FCV AT 10 (33.75) and the lowest was for FCV AT 3 (18.75). At 120 DAP the highest number of lateral roots was found for FCV AT 18 (40.5) and the lowest value was for FCV AT 8 (15.75). The mean number of lateral roots at 120 DAP was 25.86. At 150 DAP, the average for all the seed sources was 30.94 with the highest value for FCV AT 1 (47.5) and the lowest for FCV AT 20 (21.75).

Table 7. Variation in tap root length (cm) of seedlings from different seed sources.

Seed sources	Tap Root Length (cm)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	8.38	10.10^{abcd}	21.40	19.48^{abc}	27.43
FCV AT 2	6.65	14.48^{a}	14.20	19.20^{abc}	20.88
FCV AT 3	5.55	7.78^{bcd}	14.88	26.53^{ab}	24.38
FCV AT 4	7.90	6.50^{d}	14.45	28.38^{a}	22.25
FCV AT 5	5.85	8.43^{bcd}	21.45	22.75^{abc}	22.20
FCV AT 6	6.88	9.60^{abcd}	16.23	20.40^{abc}	21.18
FCV AT 7	9.23	12.35^{abc}	16.50	26.30^{ab}	25.33
FCV AT 8	8.13	13.00^{ab}	16.25	20.35^{abc}	22.88
FCV AT 9	6.40	8.30^{bcd}	19.25	24.25^{abc}	23.28
FCV AT 10	7.25	9.73^{abcd}	20.15	25.35^{ab}	20.93
FCV AT 11	6.40	12.23^{abc}	12.78	23.95^{abc}	17.90
FCV AT 12	10.35	7.05^{cd}	20.20	19.53^{abc}	19.85
FCV AT 13	8.50	12.88^{ab}	18.73	14.78^{c}	25.40
FCV AT 14	8.80	12.98^{ab}	16.73	19.10^{abc}	20.03
FCV AT 15	6.45	9.20^{abcd}	14.18	17.70^{bc}	16.43
FCV AT 16	8.38	7.63^{bcd}	18.38	20.30^{abc}	20.35
FCV AT 17	7.25	7.93^{bcd}	21.75	20.18^{abc}	21.28
FCV AT 18	8.03	7.28^{cd}	18.48	18.30^{abc}	23.15
FCV AT 18	5.98	6.95^{cd}	20.15	19.73^{abc}	18.20
FCV AT 20	5.88	7.13^{cd}	19.10	17.05^{bc}	14.65
Mean	7.41	9.58	17.76	21.18	21.40
P	0.175^{ns}	0.004*	0.214^{ns}	0.135*	0.111^{ns}

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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Table 8. Variation in number of lateral roots of seedlings from different seed sources.

Seed sources	Number of Lateral Roots				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	24.00	22.25	26.75	29.75^{abc}	47.50^{a}
FCV AT 2	14.00	25.25	20.50	24.75^{bcd}	26.75^{cde}
FCV AT 3	15.00	19.25	18.75	24.00^{bcd}	34.75^{bcd}
FCV AT 4	17.50	18.00	22.75	30.00^{abc}	42.00^{ab}
FCV AT 5	12.00	12.00	27.25	26.00^{bcd}	30.50^{bcde}
FCV AT 6	16.00	17.25	21.00	21.25^{cd}	30.00^{bcde}
FCV AT 7	44.25	28.25	31.75	25.50^{bcd}	32.25^{bcde}
FCV AT 8	15.00	16.50	20.00	15.75^{cd}	22.50^{de}
FCV AT 9	15.75	18.25	23.25	21.25^{cd}	29.25^{cde}
FCV AT 10	18.25	17.50	33.75	33.50^{ab}	37.75^{abc}
FCV AT 11	15.50	18.25	20.25	24.00^{bcd}	29.00^{cde}
FCV AT 12	15.00	11.75	27.50	20.50^{cd}	29.00^{cde}
FCV AT 13	17.25	20.75	25.25	20.75^{cd}	33.25^{bcde}
FCV AT 14	13.50	20.00	24.25	29.50^{bc}	33.25^{bcde}
FCV AT 15	17.00	21.25	22.50	29.75^{abc}	24.00^{de}
FCV AT 16	18.25	14.25	19.00	29.75^{abc}	33.50^{bcde}
FCV AT 17	16.00	21.25	29.50	24.50^{bcd}	26.50^{cde}
FCV AT 18	17.25	14.00	31.50	40.50^{a}	30.00^{bcde}
FCV AT 18	15.25	16.50	28.00	24.50^{bcd}	25.25^{cde}
FCV AT 20	18.25	16.25	29.50	21.75^{cd}	21.75^{e}
Mean	17.75	18.44	25.15	25.86	30.94
P	0.294^{ns}	0.165^{ns}	0.50^{ns}	0.002*	0.001*

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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4.2.7 Fresh weight of stem

Analysis of variance revealed significant difference in fresh weight of stem at 60 DAP but the variations were not significant at 30 DAP, 90 DAP, 120 DAP and 150 DAP. (Table 9). At 30 DAP, the highest fresh weight of stem (0.36 g) was recorded for FCV AT 6 and least (0.22 g) for FCV AT 18. The average for all the seedlings at 30 DAP was 0.29 g. At 60 DAP, the highest (0.88 g) fresh weight of shoot was observed in FCV AT 7 and least (0.31 g) for FCV AT 20. At 90 DAP, the highest (2.17 g) fresh weight of shoot was observed in FCV AT 10 and least (0.67g) for FCV AT 20. The mean, highest and the lowest values for fresh weight of stem at 120 DAP was 3.04 g, 0.68 g and 4.63 g respectively. At 150 DAP the highest value was (4.52 g) for FCV AT 15 and the lowest for FCV AT 20 (1.26 g). The average value for fresh weight of stem was 3.41g.

4.2.8 Fresh weight of leaves

The fresh weight of leaves showed significant variations in *Ailanthus triphysa* seedling at 30 DAP, 120 DAP and 150 DAP whereas there was no significant difference at 60 DAP and 90 DAP (Table 10). At 30 DAP, the average fresh weight of leaves was found to be 0.35g with the highest value for FCV AT 1 (0.56 g) and the lowest was found to be FCV AT 9 (0.19 gm). At 60 DAP the average fresh weight of seedlings was 1.25 g with lowest for FCV AT 8 (0.7 g) and the highest for FCV AT 3(2.12 g). The average fresh weight of leaves was 4.4.g at 90 DAP. The highest and lowest values for fresh weight at 90 DAP were 6.48 g (FCV AT 10) and 1.79 g (FCV AT 20). At 120 DAP the fresh weight of leaves averaged to 8.05 g with FCV AT 14 (10.89 gm) having the highest and FCV AT 20 (1.85 g) the lowest. At 150 DAP the average, highest and lowest values for leaf fresh weight were 9.34 g, 13.9 g (FCV AT 15) and 3.79 gm (FCV AT 20) respectively.

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

Seed sources	Fresh Weight of Stem (g)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	0.35	0.72^{abc}	1.39	3.39	3.36
FCV AT 2	0.34	0.42^{cde}	1.84	3.11	3.71
FCV AT 3	0.24	0.83^{ab}	1.40	2.56	3.74
FCV AT 4	0.32	0.66^{abcd}	1.99	4.19	4.40
FCV AT 5	0.28	0.55^{abcde}	1.44	3.68	3.16
FCV AT 6	0.36	0.55^{abcde}	1.73	2.66	3.29
FCV AT 7	0.26	0.88^{a}	1.40	2.96	2.90
FCV AT 8	0.24	0.37^{de}	1.14	2.42	2.23
FCV AT 9	0.29	0.50^{bcde}	1.39	2.82	3.14
FCV AT 10	0.31	0.49^{bcde}	2.17	4.63	4.09
FCV AT 11	0.24	0.39^{cde}	0.93	2.99	4.07
FCV AT 12	0.27	0.37^{cde}	1.39	4.62	2.81
FCV AT 13	0.34	0.59^{abcde}	1.50	2.22	3.32
FCV AT 14	0.23	0.40^{cde}	1.94	3.34	3.77
FCV AT 15	0.33	0.78^{ab}	1.39	3.27	4.52
FCV AT 16	0.30	0.43^{cde}	2.06	3.64	3.84
FCV AT 17	0.28	0.59^{abcde}	1.77	3.01	3.98
FCV AT 18	0.22	0.54^{abcde}	1.90	3.37	3.78
FCV AT 18	0.23	0.43^{cde}	1.08	1.14	2.80
FCV AT 20	0.35	0.31^{e}	0.67	0.68	1.26
Mean	0.29	0.53	1.53	3.04	3.41
P	0.317^{ns}	0.003*	0.21^{ns}	0.108^{ns}	0.056^{ns}

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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

Seed sources	Fresh weight of Leaf (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	0.56^{a}	1.60	4.22	10.80^{a}	9.37^{bcd}
FCV AT 2	0.29^{cdef}	0.94	5.62	9.90^{a}	12.02^{ab}
FCV AT 3	0.43^{abc}	2.12	4.26	7.81^{ab}	9.57^{abcd}
FCV AT 4	0.43^{abcd}	1.33	5.65	10.12^{a}	10.28^{abc}
FCV AT 5	0.25^{dcf}	1.16	5.28	10.06^{a}	11.72^{abc}
FCV AT 6	0.36^{bcdef}	1.10	4.08	8.92^{ab}	10.07^{abcd}
FCV AT 7	0.19^{f}	1.76	4.68	7.28^{ab}	8.57^{bcd}
FCV AT 8	0.29^{cdef}	0.70	3.47	5.87^{abc}	5.75^{de}
FCV AT 9	0.28^{cdef}	1.19	4.05	7.63^{sb}	10.07^{abcd}
FCV AT 10	0.36^{bcdef}	1.45	6.48	10.52^{a}	10.49^{abc}
FCV AT 11	0.25^{cdef}	0.75	3.16	8.46^{ab}	10.09^{abcd}
FCV AT 12	0.24^{e}	0.74	4.42	5.65^{abc}	7.39^{cde}
FCV AT 13	0.36^{bcdef}	1.44	4.79	5.66^{abc}	7.71^{bcd}
FCV AT 14	0.38^{bcde}	1.28	5.80	10.89^{a}	10.70^{abc}
FCV AT 15	0.51^{ab}	1.79	4.35	9.86^{ab}	13.90^{a}
FCV AT 16	0.37^{bcdef}	0.86	4.02	7.23^{ab}	7.89^{bcd}
FCV AT 17	0.30^{cdef}	1.46	4.31	9.46^{ab}	9.12^{bcd}
FCV AT 18	0.33^{cdef}	1.31	4.77	8.46^{ab}	9.72^{abcd}
FCV AT 18	0.38^{bcde}	1.20	3.02	4.61^{bc}	8.53^{bcd}
FCV AT 20	0.34^{cdef}	0.77	1.79	1.85^{bd}	3.79^{e}
Mean	0.35	1.25	4.41	8.05	9.34
P	0.001*	0.054^{ns}	0.161^{ns}	0.006*	0.001*

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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4.2.9 Fresh weight of root

Analysis of variance revealed significant differences in fresh weight of roots at 30 DAP and 60 DAP, however, there were no significant variations at 90 DAP, 120 DAP and 150 DAP (Table 11). At 30 DAP, the highest (0.43 g) fresh weight of roots was observed in FCV AT1 and least (0.16 g) in FCV AT 5. The average root fresh weight at 30 DAP was 0.25 g. At 60 DAP, the highest (1.62 g) fresh weight of roots was observed in FCV AT 7, the least (0.47) for FCV AT 8 and the overall average was 0.89 g. At 90 DAP, the average root weight when measured fresh was 3.03 g with the highest (4.73 g) for FCV AT 13 and least (1.11 g) for FCV AT 9. At 120 DAP, the average fresh weight of roots was 4.29 g with the highest (6.31 g) for FCV AT 17 and least (1.14 g) for FCV AT 20. At 150 DAP, the average root weight when measured fresh was 5.93 gm with the highest value (8.4 g) for FCV AT 17 and the least value for fresh weight of roots in FCV AT 20 (3.06 g).

4.2.10 Dry weight of stem

Significant difference in dry weight of shoots was found during the analysis at 60 DAP and 120 DAP while the variations are not significant in 30 DAP, 90 DAP, and 150 DAP (Table 12). At 30 DAP, the average value for dry weight of stem was 0.096 g with values ranging from 0.05g to 0.25g. At 60 DAP, the average dry weight of stem was 0.14 g with the highest (0.23 g) for FCV AT 7 and least (0.09 g) for FCV AT 20. At 90 DAP, the average dry weight of stem was 0.49 g with values ranging from 0.24 g to 0.74 g. At 120 DAP, the average dry weight of stem was 0.88g with the highest (1.25 g) in FCV AT 10 and least (0.27 g) for FCV AT 20. At 150 DAP the overall average of dry weight of stem was 1.08 g with values ranging from 0.37 g to 1.52 g.

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

Seed sources	Fresh weight of Root (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	0.43^{a}	1.07^{abcde}	3.22	5.02	6.92
FCV AT 2	0.24^{bcd}	0.71^{de}	3.76	5.14	6.17
FCV AT 3	0.17^{d}	1.29^{abcd}	2.13	3.62	6.16
FCV AT 4	0.28^{bcd}	0.78^{cde}	2.14	4.18	5.18
FCV AT 5	0.16^{d}	0.67^{de}	2.21	4.67	5.21
FCV AT 6	0.30^{abcd}	0.68^{de}	2.49	2.32	4.65
FCV AT 7	0.28^{abcd}	1.62^{a}	4.40	4.69	5.68
FCV AT 8	0.23^{bcd}	0.47^{e}	1.76	4.52	5.31
FCV AT 9	0.23^{bcd}	0.89^{bcde}	1.11	4.70	5.54
FCV AT 10	0.22^{bcd}	0.75^{cde}	1.85	5.07	5.72
FCV AT 11	0.22^{bcd}	0.69^{de}	2.09	4.71	6.31
FCV AT 12	0.18^{cd}	0.57^{e}	3.90	4.52	5.46
FCV AT 13	0.22^{bcd}	1.55^{ab}	4.73	3.76	7.92
FCV AT 14	0.28^{bcd}	0.93^{bcde}	4.50	4.11	7.50
FCV AT 15	0.36^{ab}	1.43^{abc}	3.08	4.63	5.66
FCV AT 16	0.18^{cd}	0.50^{e}	4.16	5.38	6.54
FCV AT 17	0.25^{bcd}	0.92^{bcde}	4.04	6.31	8.40
FCV AT 18	0.18^{cd}	0.76^{cde}	4.38	4.86	6.66
FCV AT 18	0.24^{bcd}	0.92^{bcde}	2.61	2.41	4.48
FCV AT 20	0.33^{abc}	0.55^{e}	1.99	1.14	3.06
Mean	0.25	0.89	3.03	4.29	5.93
P	0.013*	0.002*	0.282^{ns}	0.204^{ns}	0.139^{ns}

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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Table 12. Variation in stem dry weight (g) of seedlings from different seed sources.

Seed sources	Dry weight of Stem (g)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	0.14	0.16^{abcd}	0.42	1.01^{ab}	1.07
FCV AT 2	0.25	0.09^{d}	0.54	1.00^{ab}	1.10
FCV AT 3	0.08	0.18^{abc}	0.39	0.68^{abc}	1.20
FCV AT 4	0.07	0.17^{abcd}	0.53	1.23^{a}	1.39
FCV AT 5	0.06	0.13^{bcd}	0.42	1.08^{ab}	0.94
FCV AT 6	0.09	0.15^{abcd}	0.40	0.8^{abc}	1.00
FCV AT 7	0.06	0.23^{a}	0.51	0.83^{abc}	0.94
FCV AT 8	0.06	0.09^{d}	0.35	0.69^{abc}	0.70
FCV AT 9	0.05	0.14^{d}	0.43	0.73^{abc}	1.06
FCV AT 10	0.06	0.13^{bcd}	0.59	1.25^{a}	1.30
FCV AT 11	0.06	0.10^{cd}	0.31	0.86^{ab}	1.28
FCV AT 12	0.20	0.10^{cd}	0.48	0.73^{abc}	1.10
FCV AT 13	0.09	0.15^{abcd}	0.57	0.68^{abc}	1.03
FCV AT 14	0.06	0.09^{d}	0.73	1.08^{ab}	1.09
FCV AT 15	0.08	0.20^{ab}	0.50	0.97^{ab}	1.52
FCV AT 16	0.07	0.13^{bcd}	0.74	1.11^{ab}	1.19
FCV AT 17	0.23	0.16^{abcd}	0.61	0.95^{ab}	1.21
FCV AT 18	0.07	0.15^{abcd}	0.69	1.06^{ab}	1.18
FCV AT 18	0.06	0.12^{cd}	0.36	0.62^{bc}	0.86
FCV AT 20	0.09	0.09^{d}	0.24	0.27^{d}	0.37
Mean	0.10	0.14	0.49	0.88	1.08
P	0.597^{ns}	0.004*	0.70^{ns}	0.037*	0.142^{ns}

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

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4.2.11 Dry weight of leaves

Analysis of variance revealed significant difference in dry weight of leaves between the progenies of the seed sources over time (Table 13). At 30 DAP, there was no significant difference in the dry weight of leaves and the average weight was 0.10 g with values ranging from 0.06 g to 0.16 g. At 60 DAP, there was no significant variation in dry weight of leaves. The average weight at 60 DAP was 0.30 g with values ranging from 0.18 g to 0.44 g. There were no significant variations at 90 DAP. At 120 DAP, there was significant variation in the dry weight of leaves. The highest (3.17 g) dry weight of leaves was observed for FCV AT10 and least (0.69 g) for FCV AT 20. At 150 DAP, significant difference was observed in the dry weight of leaves. At this stage, the highest value was (4.01 g) recorded for FCV AT 15 and the least (1.05 g) dry weight of leaves was observed for FCV AT 20.

4.2.12 Dry weight of root

Analysis of variance revealed significant difference in dry weight of roots of seedlings from different seed sources (Table 14). There was no significant variation in dry weight of root at 30 DAP. There was significant variation in dry weight of root at 60 DAP. The mean dry weight of root was 0.19 g with the highest (0.03 g) in FCV AT 7 and least (0.01 g) for FCV AT 8. At 90 DAP, there was no significant variation in dry weight of roots between Seed sources. At 120 DAP the variation in dry weight of root was significant. The average dry weight was 1.14 g with the highest (1.93 g) in FCV AT 17 and the least (0.49 g) for FCV AT 20. At 150 DAP, there was no significant difference in the dry weight of root.

Table 13. Variation in leaf dry weight (g) of seedlings from different seed sources.

Seed sources	Dry weight of Leaves (g)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	0.16	0.37	1.04	2.89^{ab}	2.89^{abc}
FCV AT 2	0.07	0.20	1.19	2.98^{ab}	3.17^{ab}
FCV AT 3	0.13	0.41	0.89	1.90^{abc}	2.84^{abc}
FCV AT 4	0.10	0.31	1.18	2.79^{ab}	2.74^{abc}
FCV AT 5	0.07	0.27	1.19	3.03^{ab}	3.32^{ab}
FCV AT 6	0.10	0.26	1.08	2.63^{ab}	2.93^{abc}
FCV AT 7	0.15	0.42	1.05	2.05^{abc}	2.52^{bc}
FCV AT 8	0.08	0.18	0.84	1.56^{bc}	1.76^{cd}
FCV AT 9	0.07	0.29	1.03	2.07^{abc}	2.88^{bc}
FCV AT 10	0.09	0.35	1.51	3.17^{a}	3.13^{ab}
FCV AT 11	0.10	0.20	0.75	2.39^{ab}	2.92^{abc}
FCV AT 12	0.07	0.20	1.19	2.11^{abc}	2.42^{bc}
FCV AT 13	0.11	0.35	1.34	1.63^{abc}	2.35^{bc}
FCV AT 14	0.12	0.32	1.71	3.05^{ab}	2.90^{abc}
FCV AT 15	0.13	0.44	1.23	2.87^{ab}	4.01^{a}
FCV AT 16	0.12	0.22	1.20	2.15^{ab}	2.25^{bc}
FCV AT 17	0.06	0.38	1.28	2.64^{ab}	2.59^{bc}
FCV AT 18	0.11	0.34	1.37	2.59^{abc}	2.67^{bc}
FCV AT 18	0.11	0.29	0.80	1.45^{bc}	2.36^{bc}
FCV AT 20	0.10	0.23	0.51	0.69^{d}	1.05^{d}
Mean	0.10	0.30	1.12	2.33	2.69
P	0.151^{ns}	0.122^{ns}	0.115^{ns}	0.022*	0.006*

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

Table 14. Variation in root dry weight (g) of seedlings from different seed sources.

Seed sources	Dry weight of root				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	0.10	0.20^{abcdef}	0.62	1.38^{ab}	1.55
FCV AT 2	0.05	0.11^{ef}	0.54	1.31^{ab}	1.27
FCV AT 3	0.07	0.18^{abcdef}	0.55	0.75^{bc}	1.45
FCV AT 4	0.05	0.18^{abcdef}	0.58	1.12^{bc}	1.18
FCV AT 5	0.04	0.12^{ef}	0.48	1.40^{ab}	1.28
FCV AT 6	0.15	0.13^{def}	0.44	0.84^{bc}	1.08
FCV AT 7	0.06	0.30^{a}	0.50	1.31^{ab}	1.43
FCV AT 8	0.06	0.10^{f}	0.50	0.95^{bc}	1.21
FCV AT 9	0.06	0.22^{abcdef}	0.49	1.14^{bc}	1.45
FCV AT 10	0.06	0.20^{abcdef}	0.63	1.27^{abc}	1.34
FCV AT 11	0.05	0.15^{cdef}	0.34	1.00^{bc}	1.36
FCV AT 12	0.05	0.11^{ef}	0.62	0.77^{bc}	1.12
FCV AT 13	0.06	0.27^{abc}	0.48	1.07^{bc}	1.68
FCV AT 14	0.08	0.19^{abcdef}	0.65	1.12^{bc}	1.44
FCV AT 15	0.28	0.28^{ab}	0.55	1.27^{abc}	1.34
FCV AT 16	0.07	0.17^{bcdef}	0.92	1.46^{ab}	1.42
FCV AT 17	0.06	0.23^{abcde}	0.9	1.93^{a}	1.84
FCV AT 18	0.07	0.26^{abcd}	0.92	1.42^{ab}	1.45
FCV AT 18	0.07	0.20^{abcdef}	0.67	0.80^{bc}	0.98
FCV AT 20	0.07	0.18^{abcdef}	0.42	0.49^{bc}	0.57
Mean	0.08	0.19	0.59	1.14	1.32
P	$.365^{ns}$	.005*	$.117^{ns}$	.034*	$.113^{ns}$

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

4.2.13 Leaf area

Analysis of variance revealed significant difference in leaf area of seedlings from different seed sources (Table 15). At 30 DAP, the average leaf area was 9.92 cm^2 with the highest value (28.13 cm^2) for FCV AT 1 and least (2.21 cm^2) for FCV AT12. There was no significant variation in leaf area at 60 DAP. At 90 DAP, the average leaf area was 251.60 cm^2 with the highest (406.17 cm^2) for FCV AT 10 and least (92.5 cm^2) for FCV AT 20. At 120 DAP, the average leaf area was 448.09 cm^2 with the highest (648.05 cm^2) for FCV AT 5 and least (95.3 cm^2) for FCV AT 20. At 150 DAP, the average leaf area was 429.32 cm^2 with highest value (716.33 cm^2) for FCV AT 15 and least (175.16 cm^2) for FCV AT 20.

4.2.14 Leaf area ratio

Analysis of variance revealed significant difference in leaf area ratio of seedlings from different seed sources over time (Table 16). There was significant difference at 30 DAP, 60 DAP, 90 DAP and 120 DAP. At 150 DAP, there was no significant variation in leaf area ratio due to various Seed sources. At 30 DAP, the average leaf area ratio was 37.87 cm^2g^{-1} with the highest (90.52 cm^2g^{-1}) for FCV AT 3 and least (9.41 cm^2g^{-1}) for FCV AT 4. At 60 DAP, the average leaf area ratio was 86.69 cm^2g^{-1} with the highest (129.1 cm^2g^{-1}) for FCV AT 3 and least (57.12 cm^2g^{-1}) for FCV AT 7. At 90 DAP, the average leaf area ratio was 115.52 cm^2g^{-1} with the highest (156.53 cm^2g^{-1}) for FCV AT 5 and least (69.76 cm^2g^{-1}) for FCV AT 19. At 120 DAP, the average leaf area ratio was 102.28 cm^2g^{-1} with the highest (152.26 cm^2g^{-1}) for FCV AT 3 and least (69.51 cm^2g^{-1}) for FCV AT 20.

Table 15. Variation in leaf area (cm^2) of seedlings from different seed sources.

Seed sources	Leaf Area				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	28.13^{a}	70.80	252.70^{abcde}	537.10^{ab}	331.28^{bcd}
FCV AT 2	5.71^{d}	36.17	292.46^{abcd}	554.89^{ab}	485.85^{bc}
FCV AT 3	25.2^{ab}	102.87	249.78^{abcde}	464.48^{ab}	474.26^{bc}
FCV AT 4	12.80^{cd}	61.55	334.17^{ab}	502.89^{ab}	465.20^{bc}
FCV AT 5	4.24^{d}	59.26	322.94^{abc}	648.05^{ab}	478.18^{bc}
FCV AT 6	6.91^{d}	45.66	294.86^{abcd}	544.55^{abc}	448.70^{bc}
FCV AT 7	3.07^{d}	59.85	202.81^{abcd}	364.62^{abc}	427.25^{bc}
FCV AT 8	6.62^{d}	26.95	202.46^{bcde}	339.80^{bc}	268.89^{cd}
FCV AT 9	4.59^{d}	56.64	247.44^{abcde}	458.39^{ab}	550.68^{ab}
FCV AT 10	6.33^{d}	70.25	406.17^{a}	571.24^{ab}	418.04^{bc}
FCV AT 11	4.42^{d}	27.77	127.21^{de}	417.10^{ab}	264.39^{cd}
FCV AT 12	2.21^{d}	28.50	250.11^{abcde}	388.27^{ab}	364.02^{bcd}
FCV AT 13	6.31^{d}	68.68	253.48^{abcde}	290.99^{bc}	366.19^{bcd}
FCV AT 14	8.74^{cd}	60.50	329.71^{ab}	641.80^{ab}	558.16^{ab}
FCV AT 15	17.95^{bc}	91.76	270.07^{abcde}	480.42^{ab}	716.33^{a}
FCV AT 16	10.24^{cd}	44.95	228.84^{abcde}	386.56^{ab}	409.62^{bc}
FCV AT 17	5.93^{d}	70.86	255.66^{abcde}	515.59^{ab}	378.69^{bcd}
FCV AT 18	9.38^{cd}	69.90	275.38^{abcd}	484.98^{ab}	533.94^{ab}
FCV AT 18	18.57^{abc}	70.82	143.38^{cde}	274.70^{bc}	471.53^{bc}
FCV AT 20	10.98^{cd}	35.09	92.50^{e}	95.30^{d}	175.16^{d}
Mean	9.92	57.94	251.61	448.09	429.32
P	$<0.001^{**}$	0.129^{ns}	0.027^{*}	0.007^{*}	0.001^{*}

**Significant at 5 per cent level, **Significant at 1 per cent level and superscript 'ns' indicate not significant*

Values with the same superscript along the column are homogenous

Table 16. Variation in leaf area ratio (cm^2g^{-1}) of seedlings from different seed sources.

Seed sources	Leaf Area Ratio				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	67.76^{abc}	69.52^{bc}	119.20^{bcdef}	101.83^{abc}	61.54
FCV AT 2	28.50^{def}	80.68^{bc}	139.71^{abcd}	103.56^{bcde}	87.75
FCV AT 3	90.52^{a}	129.10^{a}	142.97^{abcd}	152.26^{a}	89.32
FCV AT 4	58.38^{bcd}	91.38^{abc}	149.79^{abc}	100.08^{bcde}	88.06
FCV AT 5	24.90^{def}	113.65^{ab}	156.53^{a}	117.49^{abcd}	88.17
FCV AT 6	24.77^{def}	84.80^{abc}	155.91^{a}	127.32^{ab}	101.77
FCV AT 7	14.30^{ef}	57.12^{c}	101.36^{efgh}	88.52^{bcde}	99.30
FCV AT 8	34.77^{cdef}	66.27^{bc}	122.35^{abcde}	108.48^{bcde}	75.24
FCV AT 9	20.58^{ef}	83.62^{abc}	126.18^{abcde}	119.08^{abcd}	102.32
FCV AT 10	29.92^{def}	98.48^{abc}	153.07^{ab}	100.35^{bcde}	72.16
FCV AT 11	21.10^{ef}	62.57^{c}	91.71^{efgh}	105.97^{bcde}	50.14
FCV AT 12	9.41^{f}	66.38^{bc}	110.91^{defg}	80.08^{de}	81.73
FCV AT 13	23.86^{def}	88.35^{abc}	109.56^{defg}	87.55^{cde}	73.71
FCV AT 14	30.64^{def}	104.60^{abc}	106.57^{defg}	121.09^{abc}	102.75
FCV AT 15	49.05^{bcde}	97.22^{abc}	115.46^{cdefg}	92.89^{bcde}	104.70
FCV AT 16	40.11^{cdef}	76.80^{bc}	80.10^{gh}	83.92^{cde}	92.12
FCV AT 17	28.78^{def}	89.27^{abc}	91.72^{efgh}	96.57^{bcde}	67.64
FCV AT 18	38.59^{cdef}	92.82^{abc}	83.54^{fgh}	95.78^{bcde}	100.31
FCV AT 18	78.02^{ab}	112.67^{ab}	69.76^{h}	93.23^{bcde}	106.99
FCV AT 20	43.48^{cdef}	68.55^{bc}	84.03^{fgh}	69.51^{e}	88.32
Mean	37.87	86.69	115.52	102.28	86.70
P	0.00*	0.035*	<0.001**	<0.001**	0.05^{ns}

**Significant at 5 per cent level and **indicate significant at 1 per cent level 'ns' indicate not significant. Values with the same superscript along the column are homogenous*

4.2.15 Specific Leaf area

Analysis of variance revealed significant difference in specific leaf area in seedlings from different seed sources (Table 17). Variations were not significat at 30 DAP and 150 DAP but significant variations was observed at 60 DAP, 90 DAP and 120 DAP. At 60 DAP, average specific leaf area was found to be 179.83

cm^2g^{-1} with highest (245.67 cm^2g^{-1}) for FCV AT 3 and least (126.7 cm^2g^{-1}) FCV AT 7. At 90 DAP, average specific leaf area was found to be 224.70 cm^2g^{-1} with highest (292.86 cm^2g^{-1}) for FCV AT 4 and least (160.43 cm^2g^{-1}) FCV AT 19. At 120 DAP, average specific leaf area was found to be 194.13 cm^2g^{-1} with highest (268.58 cm^2g^{-1}) for FCV AT 3 and least (144.94 cm^2g^{-1}) FCV AT 20.

Table 17. Variation in Specific Leaf Area (cm^2g^{-1}) of seedlings from different seed sources.

Seed sources	**Specific Leaf Area**				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	145.26	138.30^{cd}	240.75^{abcde}	189.67^{bcd}	118.11
FCV AT 2	77.79	161.07^{bcd}	260.25^{abcd}	183.43^{bcd}	156.87
FCV AT 3	193.51	245.67^{a}	285.84^{a}	268.58^{a}	170.26
FCV AT 4	124.90	197.24^{abcd}	292.86^{a}	183.38^{bcd}	171.53
FCV AT 5	60.87	216.85^{abc}	278.20^{ab}	214.27^{bc}	146.16
FCV AT 6	67.07	173.43^{abcd}	279.21^{ab}	207.20^{bc}	165.28
FCV AT 7	39.16	126.70^{d}	204.36^{cdefg}	177.22^{bcd}	197.77
FCV AT 8	84.04	139.04^{cd}	242.64^{abcde}	220.64^{bc}	154.99
FCV AT 9	57.36	192.06^{abcd}	239.2^{abcdef}	223.93^{ab}	191.09
FCV AT 10	69.83	190.61^{abcd}	271.23^{abc}	180.99^{bcd}	132.75
FCV AT 11	44.47	139.91^{cd}	169.75^{fg}	182.25^{bcd}	97.32
FCV AT 12	29.57	138.48^{cd}	213.25^{bcdef}	188.64^{bcd}	154.47
FCV AT 13	56.82	195.12^{abcd}	191.84^{defg}	179.66^{bcd}	162.23
FCV AT 14	69.62	193.78^{abcd}	192.10^{defg}	212.05^{bc}	192.89
FCV AT 15	137.59	204.53^{abcd}	215.73^{bcdef}	166.71^{cd}	180.97
FCV AT 16	83.33	175.51^{abcd}	189.51^{efg}	182.87^{bcd}	190.62
FCV AT 17	236.97	180.52^{abcd}	200.52^{defg}	197.98^{bcd}	146.65
FCV AT 18	88.70	204.48^{abcd}	181.62^{efg}	189.62^{bcd}	200.97
FCV AT 18	171.29	235.00^{ab}	160.43^{g}	188.51^{bcd}	193.37
FCV AT 20	113.42	148.22^{cd}	184.70^{efg}	144.94^{d}	168.19
Mean	97.58	179.83	224.70	194.13	164.63
P	0.053^{ns}	0.012*	<0.001**	0.921^{ns}	0.088^{ns}

**Significant at 5 per cent level, **indicate significant at 1 per cent level and superscript 'ns' indicate not significant. Values with the same superscript along the column are homogenous*

4.2.16 Absolute growth rate

Analysis of variance revealed no significant difference in absolute growth rate in seedlings from different seed sources (Table 18).

Table 18. Variation in Absolute Growth Rate (cm day^{-1}) of seedlings from different seed sources.

Seed sources	Absolute growth rate				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1		0.01	0.04	0.11	0.01
FCV AT 2		0.01	0.06	0.10	0.01
FCV AT 3		0.02	0.03	0.05	0.07
FCV AT 4		0.01	0.05	0.09	0.01
FCV AT 5		0.01	0.05	0.11	0.00
FCV AT 6		0.01	0.05	0.08	0.02
FCV AT 7		0.02	0.04	0.07	0.02
FCV AT 8		0.01	0.04	0.05	0.02
FCV AT 9		0.02	0.04	0.07	0.05
FCV AT 10		0.02	0.07	0.10	0.00
FCV AT 11		0.01	0.03	0.10	0.04
FCV AT 12		0.00	0.06	0.04	0.03
FCV AT 13		0.02	0.05	0.03	0.06
FCV AT 14		0.01	0.08	0.07	0.01
FCV AT 15		0.01	0.05	0.09	0.06
FCV AT 16		0.01	0.08	0.06	0.00
FCV AT 17		0.01	0.07	0.09	0.00
FCV AT 18		0.02	0.07	0.07	0.01
FCV AT 18		0.01	0.04	0.03	0.04
FCV AT 20		0.01	0.02	0.01	0.02
Mean		0.01	0.05	0.07	0.02
P		0.711^{ns}	0.215^{ns}	$.308^{ns}$	0.971^{ns}

Superscript 'ns' indicate not significant

4.2.17 Relative Growth Rate

Analysis of variance revealed no significant difference in relative growth rate of seedlings from different seed sources (Table 19).

Table 19. Variation in Relative Growth Rate (g $g^{-1}day^{-1}$) of seedlings from different seed sources.

Seed sources	Relative Growth Rate				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1		0.01	0.04	0.03	0.01
FCV AT 2		0.02	0.06	0.03	0.00
FCV AT 3		0.03	0.03	0.02	0.02
FCV AT 4		0.04	0.04	0.03	0.00
FCV AT 5		0.04	0.04	0.04	0.00
FCV AT 6		0.02	0.04	0.03	0.00
FCV AT 7		0.04	0.03	0.03	0.00
FCV AT 8		0.02	0.05	0.02	0.01
FCV AT 9		0.04	0.04	0.02	0.01
FCV AT 10		0.04	0.05	0.03	0.00
FCV AT 11		0.03	0.04	0.03	0.01
FCV AT 12		0.01	0.06	0.01	0.01
FCV AT 13		0.04	0.04	0.01	0.01
FCV AT 14		0.03	0.06	0.02	0.00
FCV AT 15		0.02	0.03	0.03	0.01
FCV AT 16		0.02	0.06	0.01	0.00
FCV AT 17		0.03	0.04	0.02	0.00
FCV AT 18		0.04	0.04	0.02	0.00
FCV AT 18		0.03	0.04	0.02	0.01
FCV AT 20		0.02	0.03	0.01	0.01
Mean		0.03	0.04	0.02	0.01
P		0.756^{ns}	0.140^{ns}	0.327^{ns}	0.919^{ns}

Superscript 'ns' indicate not significant

4.2.18 Net Assimilation Rate

Analysis of variance revealed no significant difference in net assimilation rate of seedlings from different seed sources (Table 20).

Table 20. Variation in Net Assimilation Rate (g $g^{-1}day^{-1}$) of seedlings from different seed sources.

Seed sources	Net Assimilation Rate (g $g^{-1}day^{-1}$)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1		0.05	0.08	0.05	0.02
FCV AT 2		0.07	0.11	0.06	0.00
FCV AT 3		0.08	0.05	0.03	0.04
FCV AT 4		0.08	0.08	0.05	0.00
FCV AT 5		0.04	0.08	0.06	0.00
FCV AT 6		0.10	0.08	0.05	0.01
FCV AT 7		0.04	0.05	0.05	0.01
FCV AT 8		0.10	0.11	0.04	0.01
FCV AT 9		0.08	0.08	0.04	0.02
FCV AT 10		0.06	0.09	0.05	0.00
FCV AT 11		0.00	0.08	0.06	0.02
FCV AT 12		0.09	0.12	0.02	0.03
FCV AT 13		0.06	0.07	0.03	0.03
FCV AT 14		0.04	0.11	0.03	0.00
FCV AT 15		0.05	0.06	0.05	0.02
FCV AT 16		0.09	0.15	0.03	0.00
FCV AT 17		0.08	0.09	0.05	0.00
FCV AT 18		0.07	0.10	0.04	0.00
FCV AT 18		0.05	0.08	0.03	0.02
FCV AT 20		0.06	0.07	0.01	0.02
Mean		0.06	0.09	0.04	0.01
P		0.673^{ns}	0.115^{ns}	0.519^{ns}	0.943^{ns}

Superscript 'ns' indicate not significant

4.3.1 Variation in vessel and fibre morphology

The parameters like fibre length, vessel length, fibre lumen diameter, fibre diameter and fibre wall thickness found to be significantly different among seed sources (Table 21).

The average fibre length was 1696.05 μm with values ranging from 1344.10 μm to 1696.05 μm, the longest (2027.17 μm) was for FCV AT 3. The

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average vessel length was found to be 635.09 μm with values ranging from 541.23 μm to 724.52 μm, the longest was FCV AT 3. The fibre lumen dimeter had an average value of 33.29 μm with values ranging from 27.45 μm to 39.29 μm and the largest value was for FCV AT 2. Fibre diameter had an average value of 42.97 μm with values ranging from 35.91 μm to 50.05 μm, the largest was from FCV AT 10. Fibre wall thickness had an average value of 4.85 μm with values ranging from 4.17 μm to 6.01 μm, the largest was from FCV AT 10.

4.3.2 Variation fibre indices.

The parameters like Runkel ratio, Slenderness ratio, Rigidity coefficient and Flexibility coefficient was found to vary significantly among the seed sources (Table 22).

Runkel ratio had an average value of 0.30 with values ranging from 0.25 to 0.36, the largest was from FCV AT 12. Slenderness ratio had an average value of 40.34 with values ranging from 29.69 to 48.59, the largest was from FCV AT 18. Rigidity coefficient had an average value of 22.77 with values ranging from 19.96 to 26.29, the largest was from FCV AT 12. Flexibility coefficient had an average value of 77.23 with values ranging from 73.71 μm to 80.04 μm, the largest was from FCV AT 2.

Table 21. Variation in Vessel and Fibre morphology of different seed sources.

Seed sources	Vessel and Fibre Traits				
	FL	VL	FLD	FD	FWT
FCV AT 1	1729.93^{cdef}	648.51^{abcd}	36.68^{abc}	46.09^{abcd}	4.71^{cdefgh}
FCV AT 2	1638.02^{def}	635.64^{abcde}	39.29^{a}	48.92^{a}	4.82^{cdefg}
FCV AT 3	2027.17^{a}	724.52^{a}	37.10^{abc}	46.48^{abc}	4.69^{cdefgh}
FCV AT 4	1959.00^{ab}	649.52^{abcd}	31.47^{defg}	40.94^{efghi}	4.74^{cdefgh}
FCV AT 5	1711.08^{cdef}	587.25^{cde}	33.49^{cde}	42.60^{cdefg}	4.55^{defgh}
FCV AT 6	1482.62^{g}	597.98^{bcde}	28.85^{fgh}	38.07^{hij}	4.61^{defgh}
FCV AT 7	1627.55^{def}	605.83^{bcde}	36.91^{abc}	46.89^{ab}	4.99^{bcdef}
FCV AT 8	1609.98^{fg}	696.42^{ab}	34.42^{bcd}	44.24^{bcde}	4.91^{cdef}
FCV AT 9	1344.10^{h}	541.23^{e}	33.63^{cde}	43.74^{bcdef}	5.06^{bcde}
FCV AT 10	1479.38^{g}	606.03^{bcde}	38.04^{ab}	50.05^{a}	6.01^{a}
FCV AT 11	1839.83^{bc}	667.92^{abcd}	32.55^{def}	42.09^{defgh}	4.77^{cdefgh}
FCV AT 12	1621.17^{ef}	605.00^{bcde}	28.94^{fgh}	39.15^{ghij}	5.11^{bcd}
FCV AT 13	1635.33^{def}	573.50^{de}	30.46^{defgh}	40.97^{efghi}	5.25^{ab}
FCV AT 14	1845.61^{bc}	637.97^{abcde}	29.75^{efgh}	38.59^{ghij}	4.42^{fgh}
FCV AT 15	1740.80^{cdef}	635.41^{abcde}	37.84^{ab}	48.92^{a}	5.54^{ab}
FCV AT 16	1763.24^{cde}	631.92^{abcde}	37.09^{abc}	46.66^{abc}	4.78^{cdefgh}
FCV AT 17	1772.07^{cd}	651.00^{abcd}	31.24^{defgh}	39.58^{fghij}	4.17^{h}
FCV AT 18	1635.67^{def}	604.22^{bcde}	28.27^{gh}	37.13^{ij}	4.43^{efgh}
FCV AT 18	1710.00^{cdef}	718.06^{a}	27.45^{h}	35.91^{j}	4.23^{gh}
FCV AT 20	1748.39^{cdef}	683.93^{abc}	32.29^{def}	42.44^{cdefg}	5.08^{bcd}
Mean	1696.05	635.09	33.29	42.97	4.84
P	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

FL=Fibre Length; VL=Vessel Length; LD= Lumen Diameter; FD= Fibre Diameter; FWT=Fibre Wall Thickness.

***Significant at 1 per cent level*

Values with the same superscript along the column are homogenous

Table 22. Variation in Fibre indices of different seed sources.

Seed sources	Fibre Indices			
	RR	SR	RC	FC
FCV AT 1	0.26^{ef}	38.2^{defg}	20.71^{ef}	79.29^{ab}
FCV AT 2	0.25^{f}	34.28^{ghi}	19.96^{f}	80.04^{a}
FCV AT 3	0.26^{ef}	44.16^{abc}	20.26^{ef}	79.74^{ab}
FCV AT 4	0.30^{bcde}	48.41^{a}	23.17^{bcde}	76.83^{bcde}
FCV AT 5	0.28^{def}	40.66^{bcde}	21.46^{cdef}	78.54^{abcd}
FCV AT 6	0.33^{abc}	39.49^{cdef}	24.43^{abc}	75.57^{def}
FCV AT 7	0.28^{def}	34.95^{fgh}	21.44^{cdef}	78.56^{abcd}
FCV AT 8	0.29^{cdefg}	36.83^{defg}	22.35^{cdef}	77.65^{abcd}
FCV AT 9	0.30^{bcde}	31.23^{hi}	23.25^{bcde}	76.75^{bcde}
FCV AT 10	0.32^{abcd}	29.69^{i}	24.12^{abcd}	75.88^{cdef}
FCV AT 11	0.29^{cdefg}	44.37^{abc}	22.64^{cdef}	77.36^{abcd}
FCV AT 12	0.36^{a}	41.74^{bcd}	26.29^{a}	73.71^{ef}
FCV AT 13	0.35^{ab}	40.35^{bcde}	25.73^{ab}	74.27^{ef}
FCV AT 14	0.30^{bcdef}	48.28^{a}	22.92^{bcdef}	77.08^{abcde}
FCV AT 15	0.30^{bcdef}	35.84^{efgh}	22.77^{bcdef}	77.23^{abcde}
FCV AT 16	0.26^{ef}	38.21^{defg}	20.64^{ef}	79.36^{ab}
FCV AT 17	0.27^{def}	45.19^{ab}	21.19^{def}	78.81^{abc}
FCV AT 18	0.32^{abcd}	44.69^{ab}	24.05^{abcd}	75.95^{cdef}
FCV AT 18	0.32^{abcd}	48.59^{a}	24.04^{abcd}	75.96^{cdef}
FCV AT 20	0.32^{abcd}	41.66^{bcd}	24.08^{abcd}	75.92^{cdef}
Mean	0.30	40.63	23.05	76.95
P	<0.001**	<0.001**	<0.001**	<0.001**

RR= Runkel Ratio; SR= Slenderness Ratio; RC=Rigidity Coefficient; FC=Flexibility Coefficient

***Significant at 1 per cent level, Values with same superscript along the column are homogenous*

4.4 FIELD TRIAL

The parameters like seedling height and collar diameter were measured in the field for 150 days. The seedling height was found to vary significantly among the different seed sources (Table 23). Whereas the collar diameter did not show significant variation among the seed sources (Table 24).

4.4.1 Height

Significant variation were present for the seedling height 30 DAP. The average height was 47.96 cm with values ranging from 29.31 cm to 59.84 cm FCV AT 1 being the tallest. At 60 DAP, the seedling height was found to be significantly different. The average height was 51.73 cm with values ranging from 37.88 cm to 64.69 cm and FCV AT 1 having the highest value. At 90 DAP, the seedling height was found to be significantly different. The average height was 54.65 cm with values ranging from 45.94 cm to 68.28 cm and FCV AT 1 was the tallest. At 120 DAP, the seedling height was found to be significantly different. The average height was 58.61 cm with values ranging from 49.75 cm to 68.91 cm and FCV AT 1 was the highest value. At 150 DAP, the seedling height was found to be significantly different. The average height was 66.81 cm with values ranging from 59.19 cm to 76.69 cm and FCV AT 1 was the tallest at 150 DAP.

4.4.2 Collar Diameter

Collar diameter showed significant variation at 30 DAP. The average collar diameter was 9.88 mm with values ranging from 7.79 mm to 12.02 mm and FCV AT 10 having highest collar diameter. At 60 DAP, the collar diameter was found to be significantly different. The average height was 12.41 mm with values ranging from 14.24 mm to 11.4 mm with FCV AT 2 having the highest and FCV AT 14 having the lowest. The collar diameter was not found to vary significantly among the seed sources at 90 DAP, 120 DAP and 150 DAP.

Table 23. Variation in seedling height (cm) of different seed sources.

Seed sources	Seedling Height(cm)				
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
FCV AT 1	59.84^{a}	64.69^{a}	68.28^{a}	68.91^{a}	76.69^{a}
FCV AT 2	56.81^{abc}	59.13^{bc}	60.50^{bcd}	64.81^{abc}	72.50^{ab}
FCV AT 3	44.41^{ef}	49.72^{fgh}	52.97^{efgh}	56.84^{defg}	66.38^{bcd}
FCV AT 4	44.78^{ef}	48.69^{fghi}	51.41^{fghi}	55.56^{defg}	63.88^{bcd}
FCV AT 5	44.16^{ef}	46.25^{hij}	50.31^{ghi}	55.25^{defg}	67.69^{abcd}
FCV AT 6	44.94^{ef}	46.81^{ghij}	49.56^{hi}	55.22^{defg}	64.94^{bcd}
FCV AT 7	57.66^{ab}	60.47^{ab}	61.78^{bc}	64.94^{abc}	70.38^{abc}
FCV AT 8	51.78^{cd}	56.76^{bcd}	58.59^{bcde}	61.91^{bcd}	68.50^{abcd}
FCV AT 9	45.56^{def}	49.59^{fgh}	53.13^{efgh}	56.41^{defg}	64.88^{bcd}
FCV AT 10	48.72^{def}	53.06^{def}	56.00^{cdefg}	59.41^{bcdef}	67.69^{abcd}
FCV AT 11	53.38^{bcd}	55.93^{bcde}	57.22^{bcdef}	60.88^{bcde}	68.94^{abcd}
FCV AT 12	39.00^{f}	42.88^{j}	46.09^{i}	49.75^{g}	59.19^{d}
FCV AT 13	49.34^{def}	52.44^{defg}	56.69^{bcdef}	59.63^{bcdef}	68.81^{abcd}
FCV AT 14	47.34^{def}	50.22^{efgh}	52.00^{fghi}	55.31^{defg}	62.06^{cd}
FCV AT 15	45.38^{def}	48.91^{fghi}	51.59^{fghi}	55.06^{defg}	61.56^{cd}
FCV AT 16	58.91^{ab}	61.44^{ab}	62.31^{b}	65.50^{ab}	70.33^{abc}
FCV AT 17	51.41^{cde}	54.06^{cdef}	57.31^{bcdef}	61.58^{bcd}	68.40^{abcd}
FCV AT 18	47.44^{def}	52.41^{defg}	54.56^{defgh}	58.00^{cdef}	65.81^{bcd}
FCV AT 18	39.03^{f}	43.78^{ij}	46.69^{i}	53.41^{fg}	64.79^{bcd}
FCV AT 20	29.31^{g}	37.38^{k}	45.94^{i}	53.78^{efg}	62.75^{bcd}
Mean	47.96	51.73	54.65	58.61	66.81
P	<0.001**	<0.001**	<0.001**	<0.001**	0.023*

**Significant at 5 per cent level; **Significant at 1 per cent level.*
Values with the same superscript along the column are homogenous

Table 24. Variation in seedling collar diameter (mm) of different seed sources.

Seed sources	Collar Diameter (mm)				
	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP
FCV AT 1	11.09^{b}	13.85^{ab}	16.14	18.50	22.15
FCV AT 2	10.76^{abc}	14.24^{a}	16.93	19.69	24.66
FCV AT 3	9.69^{bcd}	12.84^{abc}	15.44	18.95	22.58
FCV AT 4	9.82^{bcd}	12.31^{bc}	15.26	17.30	23.72
FCV AT 5	9.03^{de}	11.81^{c}	14.40	16.73	23.14
FCV AT 6	10.07^{bcd}	12.48^{bc}	14.92	17.63	23.10
FCV AT 7	9.96^{bcd}	12.66^{bc}	14.25	16.77	19.83
FCV AT 8	9.86^{bcd}	12.64^{bc}	14.70	19.21	23.21
FCV AT 9	9.68^{bcd}	12.35^{bc}	14.76	15.88	22.44
FCV AT 10	12.02^{a}	12.60^{bc}	14.88	17.68	23.28
FCV AT 11	10.02^{bcd}	12.89^{abc}	15.21	18.46	23.51
FCV AT 12	9.09^{cde}	11.55^{c}	13.56	17.22	21.56
FCV AT 13	9.96^{bcd}	12.33^{bc}	15.55	18.46	23.92
FCV AT 14	9.99^{bcd}	11.40^{c}	13.43	15.83	19.63
FCV AT 15	9.44^{bcd}	11.81^{c}	13.33	16.05	20.59
FCV AT 16	10.39^{bcd}	12.19^{c}	14.77	17.10	21.25
FCV AT 17	10.07^{bcd}	11.88^{c}	14.80	18.25	23.14
FCV AT 18	9.84^{bcd}	12.77^{abc}	14.94	18.35	23.78
FCV AT 18	9.01^{de}	11.98^{c}	14.81	17.51	22.87
FCV AT 20	7.79^{e}	11.60^{c}	14.63	18.99	25.71
Mean	9.88	12.41	14.83	17.73	22.70
P	0.001*	0.009*	0.557^{ns}	0.278^{ns}	0.864^{ns}

**Significant at 5 per cent level and superscript 'ns' indicate not significant*
Values with the same superscript along the column are homogenous

4.4.3 Survival Percentage

The survival percentage did not vary significantly at 150 DAP in the field. The mean survival percentage was 98.44 per cent while the least survival per cent was for FCV AT 15 having 87.5 per cent.

4.5 Questionnaire survey

A Questionnaire survey was conducted to study the general perceptions of farmers towards tree farming.

4.5.2 Statements supporting short rotation trees

Four statements which indicate the reasons for growing short rotation trees were ranked based on the responses of the people surveyed. The statements are;

i. Fetches more price

ii. More yield

iii. More number of fellings can be made

iv. More compatible for Agroforestry/Farm forestry practices

In Palakkad district the highest ranked statement was iii. (More number of fellings can be made), followed by ii. (More yield), i. (Fetches more price) with least ranking for iv. (More compatible for Agroforestry/Farm forestry practices) (Figure 1).

In Thrissur district the highest ranked statement was iii. (More number of fellings can be made) followed by iv. (More compatible for Agroforestry/Farm forestry practices), i. (Fetches more price), with least ranking for ii. (More yield) (Figure 2).

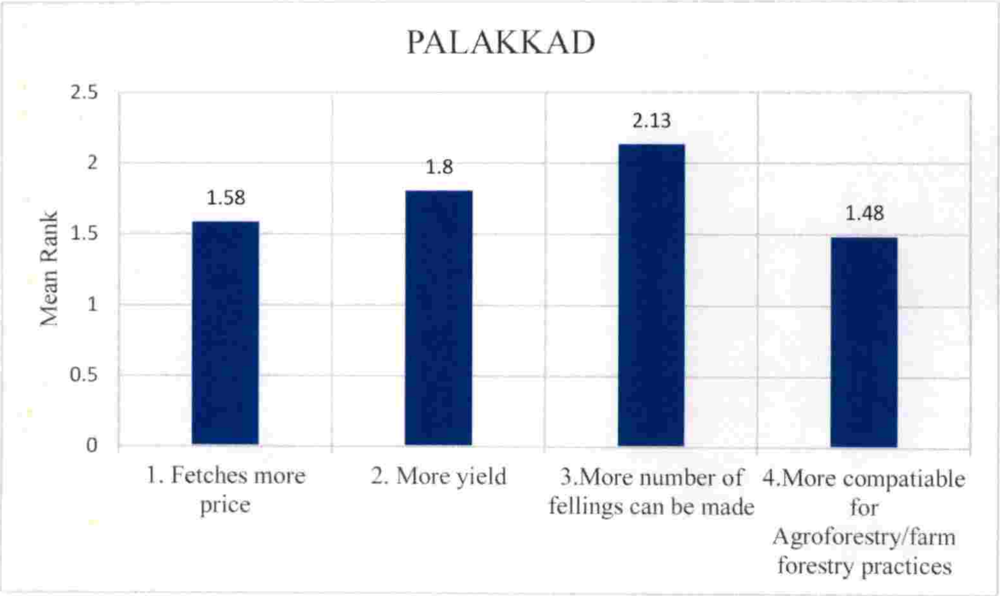

Figure 1. Mean ranking of incentives for planting short rotation trees in Palakkad district.

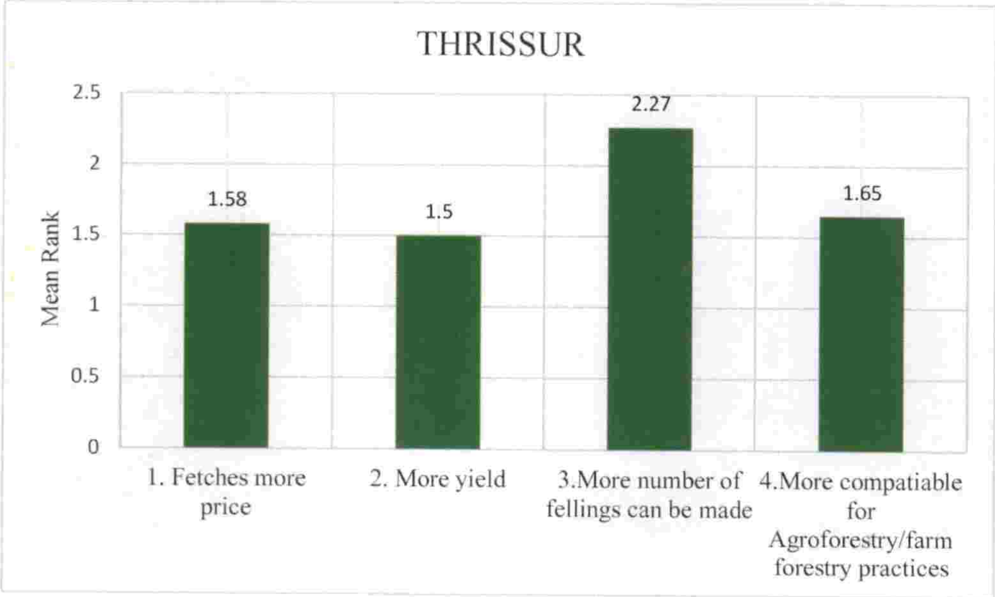

Figure 2. Mean ranking of incentives for planting short rotation trees in Thrissur.

4.5.2 Statements supporting Long rotation trees

Five statements which indicate the reasons for growing long rotation trees were ranked based on the responses of the people surveyed. The statements are;

i. Good quality timber than short rotation trees
ii. More number of benefits-timber, fuel wood, fodder, fruits, shade etc.
iii. Fetches more price than short rotation trees
iv. More ecofriendly than short rotation trees
v. An asset for future generations

In Palakkad district, the highest ranked statement was i. (Good quality timber than short rotation trees) followed by iii. (Fetches more price than short rotation trees), ii. (More number of benefits-timber, fuel wood, fodder, fruits, shade etc.), v. (An asset for future generations) with statement iv. (More ecofriendly than short rotation trees) having the least rank. (Figure 3)

In Thrissur district the highest ranked statement was i (Good quality timber than short rotation trees) followed by iii (Fetches more price than short rotation trees), ii (More number of benefits-timber, fuel wood, fodder, fruits, shade etc.), v (An asset for future generations) with statement iv (More ecofriendly than short rotation trees) having the least rank (Figure 4).

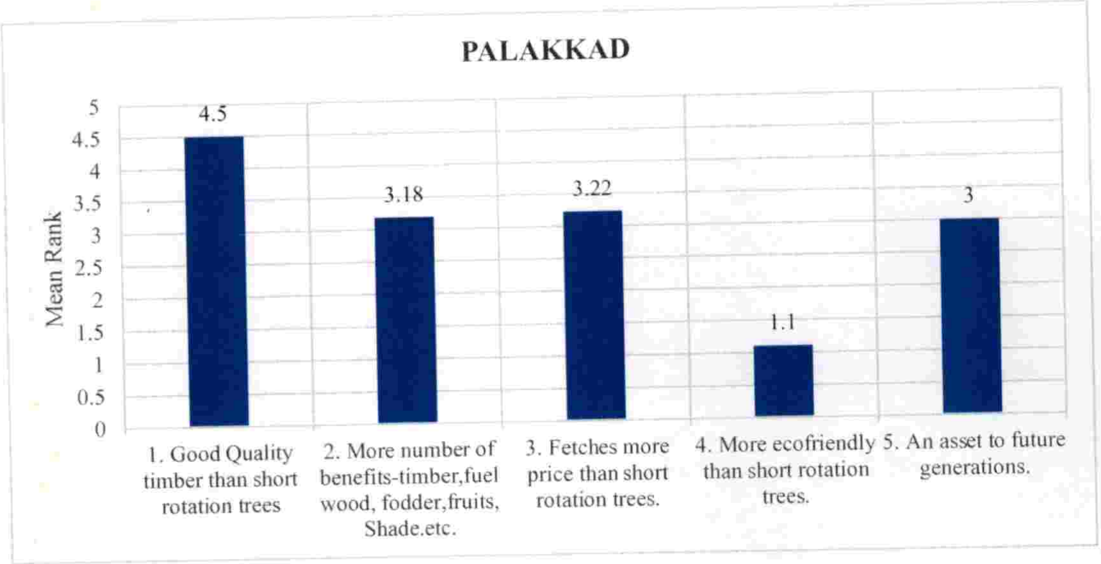

Figure 3. Mean ranking of incentives for planting Long rotation trees in Palakkad district.

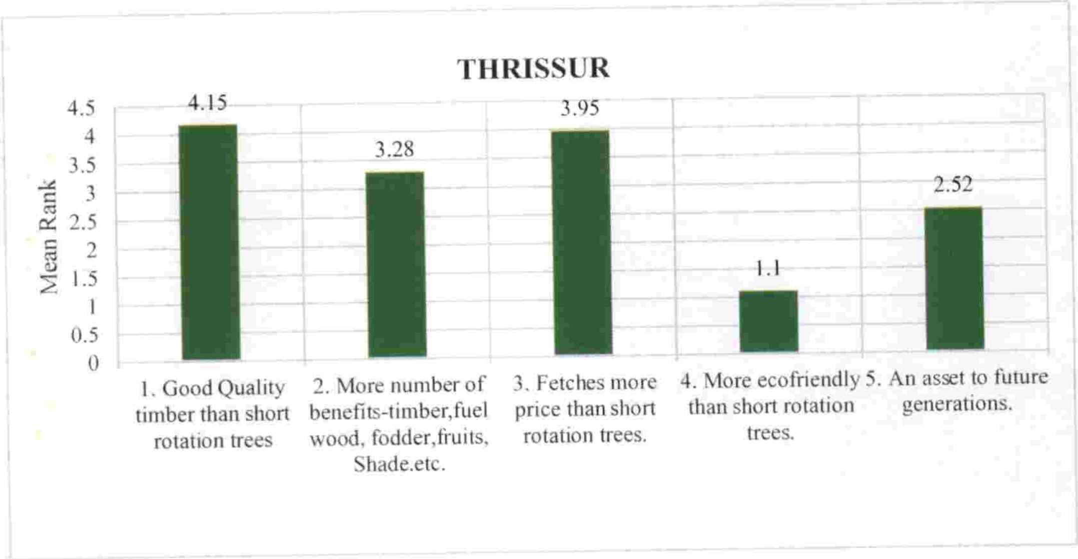

Figure 4. Mean ranking of incentives for planting Long rotation trees in Thrissur district.

4.5.3 Attitude towards tree farming in Thrissur and Palakkad

People's opinion towards tree farming in Thrissur and Palakkad districts was looked into with the help of six statements and the farmer's opinion was noted with a three point lickert scale showing Agree, neutral and disagree

. The statements are;

i. Tree farming with the help of scientific guidance will help in increasing the yield
ii. Seminars/workshops based on tree farming will help to improve the efficiency
iii. Tie-up programmes with any scientific institutions like agri-universities/match industries will help the farmers to fetch more income
iv. New alternate species other than matti (*Ailanthus triphysa*) should be promoted
v. Lack of awareness regarding forest legislation restrict farmers from going in for large scale plantations
vi. Lack of awareness regarding the current market trends of matchwood species restrict farmers from going in for matchwood plantations

In Thrissur district, 53.33 per cent of the respondents agreed with the statements. 43.33 per cent of the responses were neutral for the statements but 3.33 per cent of the responses were negative. (Figure 5)

In Palakkad district, 48.33 per cent of the responses were positive for the statements. 45 per cent of the responses were neutral for the statements, but 6.67 per cent of the respondents did not agree with the statements. (Figure 6)

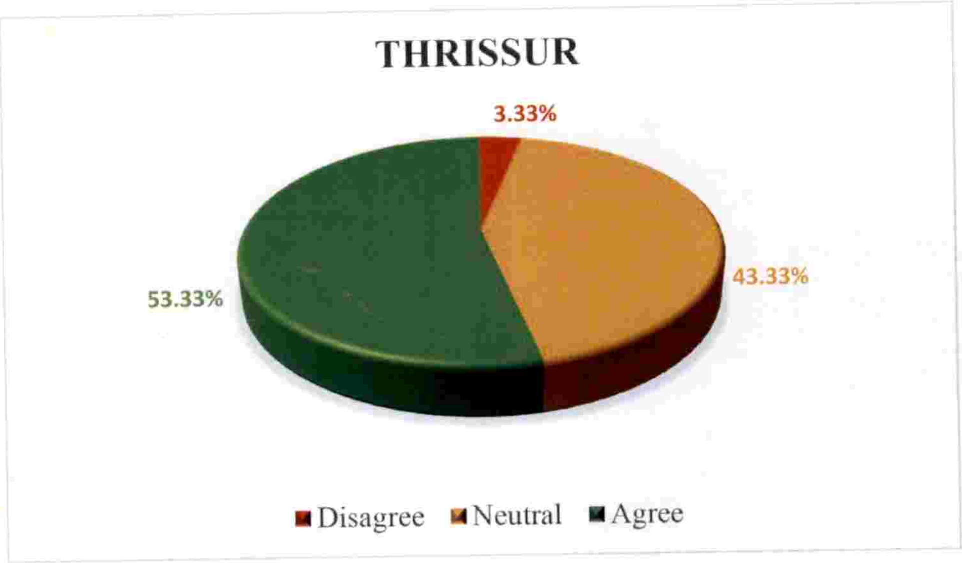

Figure 5. General perception of people towards tree farming in Thrissur district.

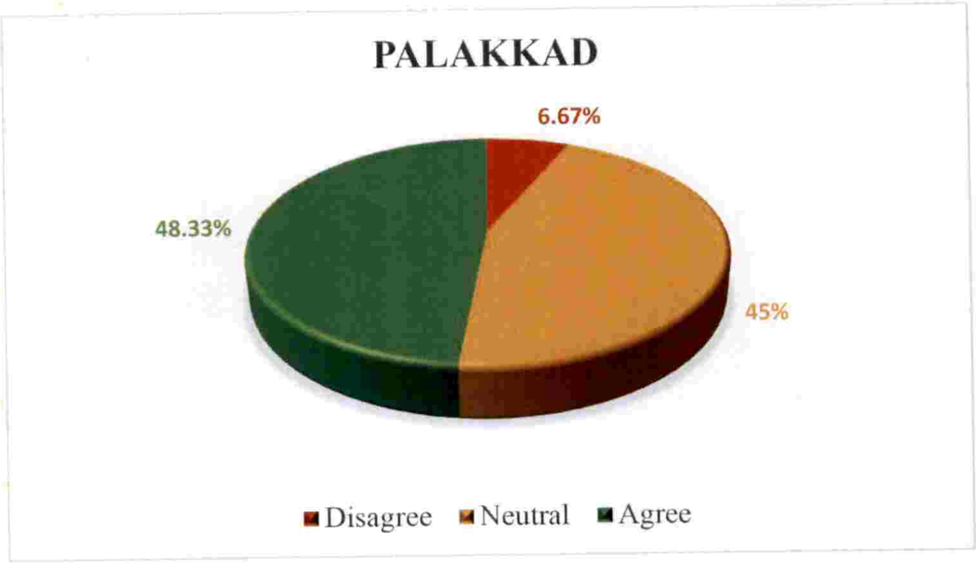

Figure 6. General perception of people towards tree farming in Palakkad district.

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Table 25. Approval rate of statements regarding tree farming in Thrissur and Palakkad districts.

Sl.no	Statements	Palakkad			Thrissur		
		Agree %	Neutral %	Disagree %	Agree %	Neutral %	Disagree %
1.	Tree farming with the help of scientific guidance will help in increasing the yield	71.67	25.00	3.33	78.33	20.00	1.67
2.	Seminars/workshops based on tree farming will help to improve the efficiency	51.67	40.00	6.67	73.33	25.00	1.67
3.	Tie-up programmes with any scientific institutions like agri- universities/match industries will help the farmers to fetch more income	53.33	36.67	10.00	65.00	33.33	1.67
4.	New alternate species other than matti (*Ailanthus triphysa*) should be promoted	55.00	31.67	13.33	33.33	65.00	1.67
5.	Lack of awareness regarding forest legislation restrict farmers from going in for large scale plantations	41.67	38.33	20.00	36.67	48.33	15.00
6.	Lack of awareness regarding the current market trends of matchwood species restrict farmers from going in for matchwood plantations	33.33	51.67	15.00	20.00	68.33	11.67

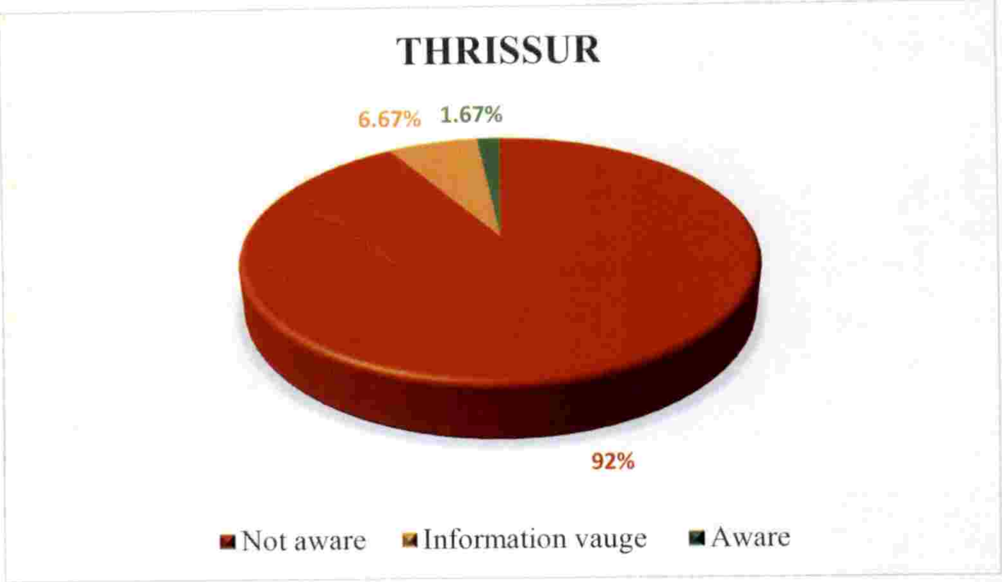

Figure 7. Knowledge of policies/acts regarding tree farming in Thrissur district.

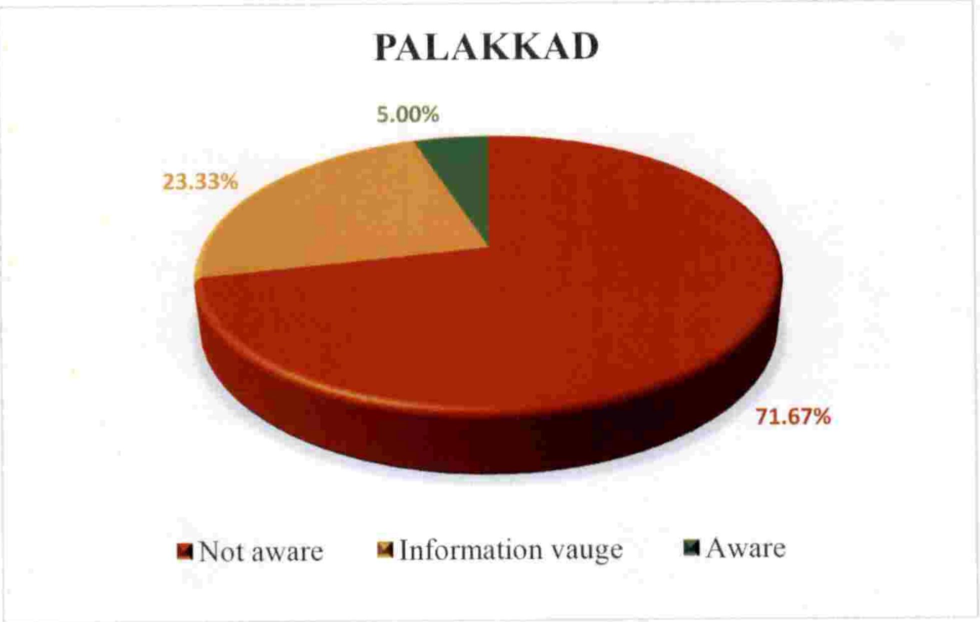

Figure 8. Knowledge of policies/acts regarding tree farming in Palakkad district.

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The statement 'Tree farming with the help of scientific guidance will help in increasing the yield' was the most agreeable statement for Thrissur (78.33 %) and Palakkad (71.67 %) (Table 25). The statement 'Seminars/workshops based on tree farming will help to improve the efficiency' also had a high degree of approval (73.33 %) in Thrissur. The statement 'Lack of awareness regarding the current market trends of matchwood species restrict farmers from going in for matchwood plantations' had the lowest approval among the statements with 33.33 per cent for Palakkad and 20 per cent for Thrissur. The statement 'Lack of awareness regarding forest legislation restrict farmers from going in for large scale plantations' was highly disapproved both in Thrissur (15%) and Palakkad (20%).

4.5.3 Knowledge of Legislation in Thrissur and Palakkad

The Knowledge on Legislation in Thrissur and Palakkad was surveyed based on Knowhow of four policies/acts related to trees in Kerala and the responses were collected using a three point lickert scale showing Not aware, Information vague and Aware. The policies/acts are;

i. Kerala Land Reforms Act, 1963
ii. Kerala Restriction on cutting and destruction of Valuable Trees Act, 1974
iii. Kerala Preservation of Trees Amendment Act, 2003
iv. Kerala Promotion of Tree Growth in Non-Forest Areas Act, 2005

Only 1.67 per cent were aware of these legislations in Thrissur while 6.67 per cent had vague information. Not having any knowledge about these legislations accounted for 92 per cent of the total responses in Thrissur. (Figure 7)

In Palakkad, five per cent of the people who participated in the survey were aware of these legislations with 23.33 per cent having vague information, whereas 71.67 per cent of the people were not aware of these legislations (Figure 8).

3.6 Cluster analysis

The relatedness and distance of a sample can be assessed using cluster analysis. In order to provide relatedness between the half-sib progenies of the selected seed sources, hierarchical cluster analysis was done using two traits in the field Collar diameter and height. Dendrogram of the analysis is presented in (Figure 9).

The progenies formed two clusters at a rescaled distance of 25 units with FCV AT 1 forming 1 cluster and the rest of the seed sources forming another cluster. FCV AT 8, FCV AT 17, FCV AT 11, FCV AT 13, FCV AT 10 and FCV AT 5 were closely related. FCV AT 3, FCV AT 18, FCV AT 6, FCV AT 19, FCV AT 4, FCV AT 9 were also found to be closely related. FCV AT 7 and FCV AT 14 was closely related to FCV AT 16 and FCV AT 15 respectively.

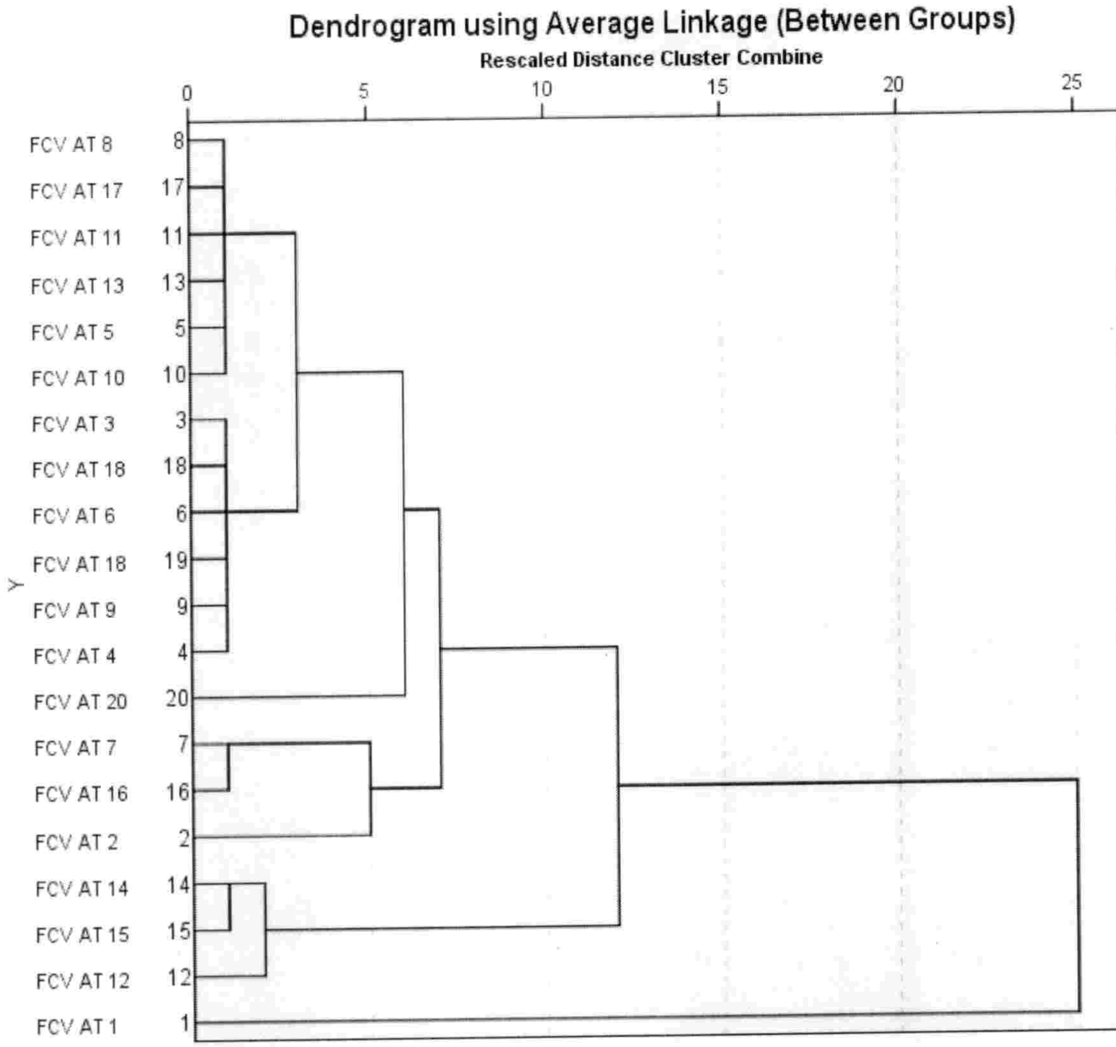

Figure 9. Dendrogram of hierarchical cluster analysis of seedlings of *Ailanthus triphysa* based on two variates.

DISCUSSION

5. DISCUSSION

In the present study, twenty seed sources and their half-sib progenies from five panchayats each of Thrissur and Palakkad districts were examined to identify the variations that exist in growth attributes and wood traits of *Ailanthus triphysa*. The study also focusses on the general perception of farmers to growing forest trees in their homesteads.

5.1 Germination Studies

During analysis, significant variations were found in germination percentage. The germination percentage averaged to about 48.82 per cent for all the seed sources and ranged from 72.08 per cent to 21.67 per cent among the different seed sources. Similar variations with the germination percentages of seeds from different seed sources were reported by Indira (1996). Variation in germination percentage and seed weight were high for *Ailanthus triphysa* seeds were found to be ranging from zero per cent to 69.20 per cent (Indira, 1996). Rawat *et al.* (2006) in *Pinus wallichiana* and Mahto *et al.* (2006) in *Azadirachta indica* corroborated the present study.

Significant variations were found in the Peak value of germination. The peak value of germination was highest for FCV AT 17 (3.60) and the lowest was for FCV AT 4 (1.08). Reddy *et al.* (2007) also reported the presence of significant variations in the Peak value of germination and Mean daily germination of *Pongamia pinnata* from different seed sources. Significant variations were found in was found in the present study. The mean daily germination ranged from 7.23 (FCV AT 7) to 1.80 (FCV AT 4) among the different seed sources. Germination value also varied significantly in the present study similar to the report by Singh and Sofi (2011) in *Dalbergia sissoo*. The germination value was highest for FCV AT 7 (25.28) and the lowest was for FCV AT 4 (2.03). The germination rate was also found to vary significantly among the different seed sources with FCV AT 7 (5.37) having the highest and FCV AT 4 (1.55) having the lowest value. The germination characteristics showed consistent differences among the seed sources and this might reflect genetic variation. The variations in all germination derived parameters may be due to fact that the external and internal seed morphological features or due to genetic variations present in the population.

5.2 Nursery performance

Statistical analysis shows significant differences in seedling height due to different seed sources over time in the nursery (Table 3). At 120 DAP, significant variation was found between the shoot height of *Ailanthus triphysa* seedlings with values ranging from 37.55 cm to 5.93 cm. This was higher than the values observed in *Ailanthus triphysa* in same time period in the study by Indira (1996). A similar trend in variation of seedling height was observed in different seed sources by Lester, (1970) in balsam fir and Singh and Bhatt (2008) in *Acacia mangium*. Variations in collar diameter among seedlings from different seed source sources were reported by Salazar (1989) in *Acacia mangium* and Singh and. At 150 DAP, collar diameter ranged from 6.12 mm (FCV AT 15) to 5.17 mm (FCV AT 20).

There was a significant difference in the number of leaves at 120 DAP but the differences were not pronounced in observations taken at 30,60,90 and 150 DAP. The number of leaves at 120 DAP ranged from7.75 (FCV AT 19) to 13.5 (FCV AT 18). Sekar (2003) in *Simarouba glauca* and Shu *et al.* (2012) in *Magnolia officinalis* found significant variation in number of leaves of progenies from different seed sources. The variations in the number of leaflets were significant at some months and not significant at other months with an irregular pattern like the number of leaves.

The success of a plant is highly depended on the root system. Taproot length of *Ailanthus triphysa* showed significant variation between the different seed sources in the present study however the differences were not significant at all times during the study (Table 7). Significant difference in number of lateral roots among seedling from different seed sources was also found. These variations were not profound in the initial stages of growth, but the differences became significant from

120 DAP (Table 8). At 150 DAP, the number of lateral roots ranged from 47.5 (FCV AT 1) to 21.75 (FCV AT 20). The variation in root parameters was also reported by Ghildiyal *et al.* (2009) in *Pinus roxburghii*, Kumar et al. (2008) in *Pongamia pinnata* and Shu *et al.* (2012) in *Magnolia officinalis.*

5.3 Biomass and growth

Plant biomass is a much better parameter in representing the growth of seedling in the nursery than collar diameter or seedling height 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. The present study revealed significant differences in fresh weights and dry weights of stem, root and leaves among the progenies of the seed sources during different times after planting. (Table 9, Table 10, Table 11, Table 12, Table13 and Table 14). At 150 DAP FCV AT 20 had the least value in all the parameters observed while FCV AT 15 had the highest values fresh and dry weight in stem and leaves. The highest root biomass was observed in FCV AT 17. The variations at 150 DAP were significant only for fresh weight and dry weight of leaf. Studies by Kumar et al. (2008) in *Pongamia pinnata,* Shu *et al.* (2012) in *Magnolia officinalis* and Liu (2002) in *Camptotheca acuminata*, shows the variation in biomass of seedlings from different seed sources.

Analysis of variance revealed significant differences in leaf area, Leaf area ratio, and specific leaf area of seedlings from different seed sources (Table 15, Table 16 and Table 17). Leaf area of the seedlings increased throughout the study period. The variations in leaf area were significant except for observations taken at 60 DAP. Jayasankar *et al.* (1999) in *Tectona grandis,* (Ramesh and Khurana, 2003) in *Populus alba* and Oyebade *et al.* (2012) in *Chrysophyllum albidum* reported significant variations in leaf area in seedlings from different seed sources. At 150 DAP the highest value for leaf area (716.33 cm$^{2)}$ was for FCV AT 15 and least (175.16 cm^{2}) for FCV AT 20 showing a similar pattern to the weight of leaves (fresh and dry). This is due to the increase in weight associated with the area. The Leaf area ratio and Specific leaf area increase till 90 DAP and then decreased. Variations in Leaf area were only significant during the early growth periods (30 to 120 DAP) in the plant while Specific leaf area showed no significant variations even at 30. The disproportionate increase in leaf biomass and plant biomass as a whole is responsible for the reduction in Leaf area ratio and Specific Leaf area after 90 DAP.

The growth and assimilatory parameters of the seedlings like absolute growth rate (Table 18), relative growth rate (Table 19) and Net assimilation rate (Table 20) showed no significant variation among the progenies from seed sources. This was similar to the report by Shu *et al.* (2012) in *Magnolia officinalis* seedlings from different seed sources.

5.4 Variation in vessel and fibre morphology

The variability in anatomical characteristics has a profound influence on properties of wood strength, specific gravity, flexibility and hardness (Burley and Palmer 1979). In the present study, the parameters like fibre length, vessel length, fibre lumen diameter, fibre diameter and fibre wall thickness found to be significantly different among mother trees (Table 21). The wood properties of *Ailanthus triphysa* were not studied much, especially anatomical properties, as it is not among the commercially important timber or pulpwood species.

The average fibre length was 1696.05 μm with values ranging from 1344.10 μm to 1696.05 μm, the longest (2027.17 μm) was for FCV AT 3. The fibre length of *Ailanthus triphysa* from this study was higher than that of *Ailanthus excels*a which was reported by Mohammed, and Nasroun (2012). The fibre lumen diameter had an average value of 33.29 μm with values ranging from 27.45 μm to 39.29 μm and the largest value was for FCV AT 2. Fibre diameter had an average value of 42.97 μm with values ranging from 35.91 μm to 50.05 μm, the largest was from FCV AT 10. Fibre wall thickness had an average value of 4.85 μm with values ranging from 4.17 μm to 6.01 μm, the largest was from FCV AT 10. Significant variation for fibre properties *Eucalyptus tereticornis* was reported by Shashikala and Rao (2005) and in *Populus deltoides* by Chauhan et al. (2001). Vessels are unique features of hardwoods which designed to perform the function of conduction of water and mineral nutrients in the trees (Carlquist, 1988). The average vessel length was found to be 635.09 μm with values ranging from 541.23 μm to 724.52 μm, the longest was FCV AT 3. Significant intra- and inter-clonal variations in vessel element dimensions were found in *Populus deltoides* (Pande and Dhiman, 2010). Pande and Singh (2009) had also reported significant variations in *Eucalyptus tereticornis* for vessel length.

5.5 Variation fibre indices.

The parameters like Runkel ratio, Slenderness ratio, Rigidity coefficient and Flexibility coefficient were found to vary significantly among the seed sources (Table 22). Runkel ratio which refers to the ratio between double the wall thicknesses and lumen diameter is a commonly used indicator of the collapsibility of tracheids (Evans *et al*., 1997). In the present study, Runkel ratio had an average value of 0.30 with values ranging from 0.25 to 0.36, the largest was from FCV AT 12. Slenderness ratio is directly proportional to fibre length and inversely proportional to fibre cell wall thickness. Fibres having longer and thinner cell walls are producing a good slenderness ratio. Higher the slenderness ratio, greater will be the expected flexibility that will give better tensile and tear property. Ogbonnaya *et al*. (1997) stated that fibres of poor slenderness ratio do not produce good surface contact and fibre to fibre bonding which reduces its mechanical strength properties. If the slenderness ratio of a fibrous material is lower than 70, it is not valuable for quality pulp and paper production (Young, 1981; Bektas *et al*., 1999). Slenderness ratio had an average value of 40.34 with values ranging from 29.69 to 48.59, the largest was from FCV AT 18.) Rigidity coefficient is a measure of physical resistance properties of paper. Higher values for this coefficient is not desirable. In the present study, Rigidity coefficient had an average value of 22.77 with values ranging from 19.96 to 26.29, the largest was from FCV AT 12. Flexibility coefficient is also referred as Istas coefficient or elasticity coefficient is related to individual elasticity of fibres. Bektas *et al*. (1999) classified fibres into four groups based on its elasticity rate.

- Highly elastic fibres having elasticity coefficient greater than 75
- Elastic fibres having elasticity ratio 50 to 75
- Rigidity fibres having elasticity ratio 30 to 50
- Highly rigid fibres having elasticity less than 30

Fibres with high elasticity coefficient are flexible, collapse readily and produce good surface contact and fibre-to-fibre bonding. They yield low bulk paper with excellent physical characteristics. In the present study flexibility coefficient had an average value of 77.23 with values ranging from 73.71 μm to 80.04 μm, the largest was from FCV AT 2. The fibre indices obtained from this study shows *Ailanthus triphysa* is not suitable for pulp production

5.6 Field Trial

The parameters like seedling height and collar diameter were measured in the field for 150 days. The seedling height was found to vary significantly among the different seed sources (Table 23). Whereas the collar diameter among the seed sources did show significant variation only till 60 DAP (Table 24). At 150 DAP, the seedling height was found to be significantly different. The average height was 66.81 cm with values ranging from 59.19 cm to 76.69 cm and FCV AT 1 was the tallest. *Ailanthus triphysa* performed equally well in degraded soils and in fertile land, whereas *Ailanthus integrifolia* failed to survive in such degraded areas. Pliura *et al.* (2007), in hybrid poplar and Indira (1996), in *Ailanthus triphysa* reported significant variation in height of progenies from different sources. The survival percentage did not vary significantly at 150 DAP in the field. The mean survival percentage was 98.44% while the least survival percentage was for FCV AT 15 having 87.5%. Collar diameter showed significant variation at 30 DAP and at 60 DAP. Indira (1996) had reported that girth difference was not significant and found no significant difference between plus trees and average trees. Brodie and Debell (2004) also reported significant difference in height in poplar clones but the differences were not significant in girth.

5.7 Questionnaire survey

A Questionnaire survey was conducted to study the general perceptions of farmers towards tree farming. Statements supporting long rotation trees had a similar response from Thrissur and Palakkad. Home gardens constitute the predominant farming systems of Kerala (Guillerme, 1999). Despite food, home gardens provide about 80 per cent of the total wood consumption in the state predominantly firewood (Krishnankutty, 1990). The results of the present study show people from Thrissur and Palakkad preferred good quality timber trees when considering long rotation trees to be planted in their field. This might be due to the general consensus that long rotation trees are better timber species than short rotation trees. The environmental factors are given least priority in favouring long rotation over short rotation trees which is probably due to a general view of the people that all trees are environmentally friendly. The comparatively higher number of harvest in short rotation trees to long rotation trees was the major incentive for people of Thrissur and Palakkad districts for growing short rotation trees. Respondents in Palakkad district were least bothered about the compatibility of the short rotation trees with agroforestry practices, while yield was the least of their concern for respondents in Thrissur district.

The Knowledge on Legislation related to trees in Kerala was analysed in a representative population from Thrissur and Palakkad districts. More than 70 per cent of the population surveyed had no knowledge on these legislations. This was as high as 92 per cent in Thrissur. Only five per cent of the respondents in Palakkad district and nearly 2 per cent in Thrissur were aware of the land and forest legislations. This might be due to the fact that knowledge on these legislations is not indispensable for small-scale farmers growing trees in their homesteads.

While analysing the farmers' perception towards tree farming, in Thrissur and Palakkad districts suggest the requirement of scientific guidance for increasing yield in tree farming. Over 70 per cent of the respondents from Thrissur were in the opinion that seminars and workshops will improve the efficiency in tree farming. Lack of awareness regarding forest legislations was high in both districts but fewer than half of the respondents believed that it had any effect on restricting farmers from growing large scale plantations. The respondents from both districts were largely impartial on the effect of market awareness in the Matchwood business on farmer's decision to start match wood plantations.

The importance of selection and screening of fast growing species like *Ailanthus triphysa* is reiterated by the increasing demand for its wood in the match industry. The present study evaluates the growth and wood property variations in 20 plus trees from two districts and their progenies to provide a basis for future improvement programme.

SUMMARY

6. SUMMARY

A study titled "Screening of *Ailanthus triphysa* (Dennst.) Alston. for preferred match wood qualities." was carried out at the College of Forestry, Kerala Agricultural University, Vellanikkara, Kerala during 2013-2016. The salient findings of the study are as follows:

- In the present study, significant variations were found in germination percentage, Peak value of germination, Mean daily germination, germination value and germination rate among the seed sources.
- The germination percentage averaged to about 48.82 per cent for all the seed sources. The highest value was for FCV AT 17 at 72.08 per cent and the lowest was for FCV AT 4 (21.67%).
- The peak value of germination was highest for FCV AT 17 and the lowest was for FCV AT 4. The mean Peak Value of Germination was 2.43 for all the seed sources.
- The Mean Daily Germination for all the seed sources was 4.42 with FCV AT 7 having the highest and FCV AT 4 having the lowest.
- Germination Value was highest for FCV AT 7 and the lowest was for FCV AT 4 with a mean of 11.80.
- Germination Rate for all the seed sources averaged to 3.41, with FCV AT 7 having the highest and FCV AT 4 having the lowest value.
- Significant difference in seedling height due to different seed sources was observed. The observations taken at 150 DAP showed significant variation in shoot height with 27.65 cm as mean. The tallest one was FCV AT 4 (36.23 cm) and the shortest one was FCV AT 20 at 16.98 cm.
- Collar diameter varied significantly with FCV AT 15 (6.12 mm) having the highest and FCV AT 20 (3.75 mm), the lowest value.

- The variations in number of leaves and taproot length were significant only at 120 DAP while the variation in number of leaflets was significant at 60 and 120 DAP.
- Number of lateral roots varied significantly at 150 DAP, with the highest value for FCV AT 1 and the lowest was for FCV AT 20.
- Fresh weight of stem and root showed significant variation only during initial months whereas fresh weight of leaves was showing significant variations at 150 DAP with FCV AT 15 having the highest and FCV AT 20 having the lowest.
- Dry weight of root and stem were not significant at 150 DAP while dry weight of leaves showed significant difference among the seed sources at 150 DAP, with FCV AT 15 having the highest and FCV AT 20 having the lowest.
- Leaf area showed significant difference among the seed sources with FCV AT 15 having the highest and FCV AT 20 having the lowest at 150 DAP. Whereas leaf area ratio had significant differences at all observations except at 150 DAP
- Specific Leaf area varied significantly only at 60, 90 and 120 DAP with highest values at 90 DAP after which it decreases.
- Absolute Growth Rate, Relative Growth Rate, Net Assimilation Rate had no significant differences ant any point during the study.
- Fibres and vessel dimensions were found to be significant at 1 per cent among the seed sources. FCV AT 3 had the highest fibre and vessel length. The highest value for fibre wall thickness and fibre diameter was for FCV AT 10.
- Fibre indices were observed to be significant at 1 percent. Only flexibility coefficient met the required standard for pulping.
- In the field, only height was found to have significant differences till 150 DAP while collar diameter had significant differences till 60 DAP. Tallest plants were from FCV AT 1. Survival percentage showed no significant difference at 150 DAP.

- The questionnaire survey conducted in Thrissur and Palakkad districts revealed 'more number of harvests' was the main incentive for planting short rotation trees. Whereas 'good quality timber' was the main incentive for planting long rotation trees while the ecological aspects were least of their concern.
- Both Thrissur and Palakkad districts had high positive responses for statements provided with respect to tree farming. The majority of respondents agreed that allocation of scientific guidance will help increase the yield. More than 70 percent of the respondents from Thrissur district believed that workshops and seminars will improve the efficiency of tree farming.
- The statement 'Lack of awareness regarding forest legislation restrict farmers from going in for large scale plantations' showed the highest degree of disapproval among the statements but it was comparatively low when compared to the percentage of respondents agreeing to it.
- This study shows that the people's knowledge on forest and land legislations are pretty low in Thrissur and Palakkad districts with Thrissur district faring worse.
- The cluster analysis shows FCV AT 1 is different from all the other seed sources. FCV AT 8, FCV AT 17, FCV AT 11, FCV AT 13, FCV AT 10 and FCV AT 5 were closely found to be related. FCV AT 3, FCV AT 18, FCV AT 6, FCV AT 19, FCV AT 4, FCV AT 9 were also found to be closely related. FCV AT 7 and FCV AT 14 was closely related to FCV AT 16 and FCV AT 15 respectively.

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SCREENING OF *Ailanthus triphysa* (Dennst.) Alston. FOR PREFERRED MATCH WOOD QUALITIES

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ABSTRACT

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8. ABSTRACT

Ailanthus triphysa, a member of the family Simarubaceae is an important tree with regard to match manufacture. Twenty Candidate plus trees (CPTs) were selected from 10 panchayats across two districts (Thrissur and Palakkad) in Kerala to study the variation in wood properties and the growth parameters of their half-sib progenies during 2013-2017. Core samples were collected to analyse the anatomical properties and fibre indices between the CPTs, which was later found to vary significantly at one percent level. Morphological and growth parameters were observed in the half-sib progenies of the selected trees both in nursery and field condition for 150 days each. The morphological parameters like height, collar diameter, root length, leaf area, number of leaves etc. were found to vary significantly at nursery but not throughout the study period. Relative Growth Rate, Absolute Growth Rate and Net Assimilation Rate did not show significant variation among the seed sources. Field performance of the progenies was evaluated at Aaramkal, Vellanikkara, Thrissur, Kerala in RBD. Height and collar diameter varied significantly initially but the differences were not significant for collar diameter from 90 days after planting. However, survival percentage did not show any significant difference between the progenies. FCV AT 1 showed the maximum height growth at 150 days after planting. A questionnaire survey was conducted to access farmers' perception towards growing raw materials for match manufacture. The respondents had an overall positive approach toward tree farming. The majority of the respondents were confident that scientific guidance will help them in increasing the yield.

APPENDIX

APPENDIX I

STRUCTURED QUESTIONNAIRE FOR SOCIOECONOMIC SURVEY

FARMERS' PERCEPTION FOR TREE PLANTING IN HOMESTEADS

District:
Panchayath:
Ward:
Name of Farmer & Address:

Interviewer's Name:
Date:

Respondent No.

1. Basic Details

Family Details

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

g) Size of holding (Farm size)

Area

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

h) Soil Type

i) Source of Irrigation (Rainfed/Irrigated)

2. Agroforestry practices

a. Agricultural Crops

Sl. No.	Crop	Area (acres)	Cost of production	Gross income	Net income
1	Cereals				
2	Pulses				
3	Oil seeds				

b. Tree Crops

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

3) Income from tree crops if any (timber, pulpwood, matchwood etc.) during 2011-13

Sl. No.	Species Name	Year	Rate (Rs.) per m^3 or ft^3	Total No. of Trees felled	Price(Rs.)

4) Attitude towards tree farming

a) Whether taken up by own interest/others' guidance?

b) Source of seedlings for planting?

c) Preference for source of planting materials

d) Reasons for cultivation of trees (Short/Long rotation)

Sl. No.	Short Rotation	Rank**	Sl. No.	Long Rotation	Rank**
1	Fetches more price		1	Good quality timber than short rotation trees	
2	More yield		2	More number of benefits-timber, fuel wood, fodder, fruits, shade etc.	
3	More number of fellings can be made		3	Fetches more price than short rotation trees	
4	More compatible for Agroforestry/Farm forestry practices		4	More ecofriendly than short rotation trees	
			5	An asset for future generations	

****Rank: 1-4** ****Rank: 1-5**

e) Species preference for match making, if any? (Yes/No)

f) General Perceptions regarding Tree Farming

Sl. No.	Statements	Opinion**
1	Tree farming with the help of scientific guidance will help in increasing the yield	
2	Seminars / workshops based on tree farming will help to improve the efficiency	
3	Tie-up programmes with any scientific institutions like agri universities/match industries will help the farmers to fetch more income	
4	New alternate species other than matti (*Ailanthus triphysa*) should be promoted	
5	Lack of awareness regarding forest legislation restrict farmers from going in for large scale plantations	
6	Lack of awareness regarding the current market trends of matchwood species restrict farmers from going in for matchwood plantations	

****3-agree, 1- disagree, 2- neutral**

g) What are the constraints faced in tree farming?

h) Policy and legal framework acting as incentive/disincentive

Sl. No.	Legislations	Response #
1.	Kerala Land Reforms Act, 1963	
2.	Kerala Restriction on cutting and destruction of Valuable Trees Act, 1974	
3.	Kerala Preservation of Trees Amendment Act, 2003	
4.	Kerala Promotion of Tree Growth in Non-Forest Areas Act, 2005	

 # 3- aware, 1- not aware, 2- information vague

i) Suggestions if any for improving current policy and legal support for tree farming