DIVERSITY ASSESSMENT AND SELECTION OF CANDIDATE PLUS TREES OF *Ailanthus triphysa* (Dennst.) Alston IN SELECTED DISTRICTS OF NORTHERN KERALA

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled, **"Diversity assessment and selection of candidate plus trees of *Ailanthus triphysa* (Dennst.) Alston in selected districts of Northern Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikara **Jes Lalnunpuia**

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C E R T I F I C A T E

Certified that this thesis, entitled **"Diversity assessment and selection of candidate plus trees of *Ailanthus triphysa* (Dennst.) Alston in selected districts of Northern Kerala"** is a record of research work done independently by **Mr. Jes Lalnunpuia (2018-17-015)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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C E R T I F I C A T E

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Place: Vellanikkara **Jes Lalnunpuia**

Date:

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Abbreviation	**Explanation**
ANOVA	Analysis of variance
C.V	Coefficient of variation
C.D	Critical difference
SEM	Standard error of mean
SD	Standard deviation
Df	Degrees of freedom
R	Replication
Cl	Cluster
viz.	Namely
i,e.	That is
etc.	Etcetera
Cm	Centimeter
cm^2	Centimeter square
cm^3	Cubic centimeter
M	Meter
Fig.	Figure
^oC	Degree Celsius
RWC	Relative water content
et al.	And co-workers
A	Anthikad
M	Manalur
P	Pudukkad
C	Chalakudy
W	Wadakkanchery
V	Vengara
PA	Parappur
T	Thrikkadeeri
AN	Ananganadi
U	Urakam

INTRODUCTION

1. INTRODUCTION

Matti *(Ailanthus triphysa* [Dennst.] Alston) belonging to the family Simaroubaceae is a medium to tall evergreen rainforest tree. It is one of the most important and extensively used trees for making match splints in India. The tree is used as a multipurpose tree in the mixed plantation in most parts of Kerala. In Kerala, *Ailanthus triphysa* occurs in all areas except in the high hills and grows in a wide range of soils (Kumar, 2000). It is an early flowering, short-rotation species, dioecious, and cross-breeding in nature. Flowers are small, drooping, greenish-yellow, polygamous. The inflorescence is terminal or axillary, panicles 20-50 cm long, small bracts, pedicels 4 mm long. The calyx lobes are 1 mm long and triangular and the petals 3-5 x 1-1.5 mm in size, oblong and lanceolate. Stamens 3.5 mm long in male flowers. The ovary is 2- 2.5 x 1-1.5 mm, glabrous, styles free or united at the base, connate above, and stigmas 3-4 lobed, peltate. Samara type has membraneous wings. Fruits are reddish-brown, rounded at both ends 5.5-8.5 x 1.5-3 cm size (Basak, 1980). It is commonly known as halmaddi in India and often called as pongalyam in Malayalam.

Different plant parts are used as medicine for a variety of diseases. The woods contain various alkaloids and quassinoids and beta-carboline and it has been used for the treatment of various diseases like dyspepsia, bronchitis, dysentery; bark decoction used in typhoid and constipation; root bark is used for cobra poisoning and it is also used in asthma (Ali *et al*., 2018). The plant roots, leaves, bark and gum are used as medicine in India. When the bark is cut, a sticky resin is excreted, and it became brittle on drying and the resins are used in medicinal purposes. The timber is used in the manufacturing of a matchbox. This plant is aromatic, so it is widely used in the manufacturing of incense and the wood is of high demand for match splints and is considered as the best Indian tree species for match splints along with *Evodia lunu-ankenda* (Nair, 1961).

A. triphysa has a faster growth rate, straight, clean bole and can yield good size of merchantable girth in 6-8 yrs. It is easily marketable and fetches a good amount of money. In match industries, branches greater than 35 cm in size with bark are even accepted. The cost of the timber at the standing site is Rs. 5000 per cubic meter and Rs.

6900 per cubic meter ex-depot (GoK, 2016). It is thought to be less competitive with associated field crops due to its lesser requirement for space, compact crown, moderate root spread and deep-rooted nature (Jamaludheen, 1994). It predominates in the ginger-based agroforestry systems of Kerala.

Eventhough there are multiple uses, the genetic variability of the trees is still very less known. The gene pool of the species still exists, but it could face serious erosion in the future due to over harvest. So, breeding programmes are needed to improve the wood quality and growth traits of *Ailanthus triphysa*. To perform effective breeding and gene conservation strategies, a better understanding of the pattern of level, structure and genetic variation within and between these populations is essential (Muona, 1990).

Industries in Kerala are now facing a shortage of raw materials like *A. triphysa* which led to an increase in demand of the species resulting in over-exploitation of superior trees in the natural forest. In this regard, scientific study on genetic diversity is very much essential for the conservation and improvement of this species. For any improvement programme in trees, variability study is a basic requirement. Hence, this present study is to assess the variability in matti trees among the Tree outside Forests (TOF) in selected districts of Kerala.

The study was carried out with the following objectives.

1. To analyse diversity in *Ailanthus triphysa* and
2. To select candidate plus trees from North Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Review of literature on the thesis entitled, "Diversity assessment and selection of candidate plus trees of *Ailanthus triphysa* (Dennst.) Alston in selected districts of Northern Kerala" is presented in this chapter.

2. 1. AILANTHUS GENUS

The genus *Ailanthus* belonging to the family Simaroubaceae is native to Southern Asia, Malaysia, China and Australia. Out of the five species belonging to this genus, four species are present in India, *Ailanthus excelsa* Roxb., is common in drier parts of Bihar, Gujarat, Chhotanagpur, Ganjam forests and Southern parts of India, *Ailanthus integrifolia* Lam. occurs in North-Eastern parts of India, *Ailanthus triphysa* (Dennst.) found in the evergreen forest of Andaman and Western Ghats upto an elevation of 1500 m above MSL and *Ailanthus altissima* (Mill.) is an exotic species planted to Northern India. The other species, *Ailanthus fordii* from Malaysia has not yet been introduced to India (Basak, 1980).

2. 2. AILANTHUS TRIPHYSA, GENERAL DESCRIPTION AND GROWTH

In India, *Ailanthus triphysa* is distributed in the evergreen forests up to 1500 m of Western Ghats, from Konkan southwards to Kerala. It is also found in Myanmar (Troup, 1921). This indigenous tree is widely planted in Kerala and is a prominent multipurpose tree. It is a large, fast-growing evergreen tree having of 30-40 m height and a 95 cm DBH. Leaves are 20-70 cm long, mostly paripinnate, leaflets 6-10 pairs, 9-12 x 2.5-5.5 cm, opposite, obliquely ovate-lanceolate to oblong-lanceolate, entire, wavy along the margin, unequal at the base, acute or acuminate at apex, coriaceous, glabrous, petioles about 5 mm long. According to Indira (1996), the flowering of *Ailanthus triphysa* begins from December and flowers profusely from January to February. Floral buds emerge along with the start of flushing. Male and female have a different flowering pattern. Normally, the flowers of male trees last for two weeks, then inactive for a few days and then continue blooming. Blooming lasts for 2 to 3 days in the male inflorescence. While in female trees flowering lasts for 1 to $1^{1}/_{2}$ months. The length of inflorescence varies from 30 to 45 cm generally. Small, off white flowers occur on large inflorescence. A sterile carpellode, ten stamens and five petals present in male flowers while five petals, sterile stamen (staminoides) and a trilocular ovary and large, showy and three ridged stigmas are characteristics of the female flower. Stigma, bigger as compared to the flower is directly attached to the ovary and present in such a position to easily receive pollen grains from outside. Stamens in the male flower are twice in size as compared to sterile stamens in female flowers. The nectariferous disc presents in both male and female flowers, leading to visits by insects due to sweat fragrance. Since the flowers are very small and bird pollination is rarely found, insect is considered as the main pollinators as anthers dehisce longitudinally with very little sticky pollen. The fruits mature during March-April after flowering (Rai, 1999). Since the seeds are dispersed by wind, fruits are collected normally from the tree by lopping off the branches (Luna, 1996).

Wood is used for match splints and boxes. The bark, the gum that exudates from the trunk, leaves and roots are used in medicine. The tree is also used as a support for growing black pepper vines. The wood is light and soft. Thus, it is used in the application of packing cases, catamarans, toys, drums and most importantly used in the match industry. The tree also possesses aromatic resin that is used as incense and in indigenous medicines (Kumar, 2000). It is also often planted as an ornament as well as a shade tree.

The growth, production and yield capacity of *Ailanthus triphysa* under different stockings and fertilizer treatments was assessed by Shujauddin and Kumar (2003). The analysis revealed that the height growth, stand LAI, diameter, biomass production and volume yield increased with planting density. The continuous fertilizer application in 1.2, 2.25 and 5.25 years after plantation had less impact on the production of biomass and volume, possibly due to competition of weeds (despite periodic weed management), a higher occurrence of pests (in highly fertilized plots) and/or fertile soils. The stem wood was the main component in the division of tree biomass (> 70%), while foliar was the least contributor (< 7%). While the highest concentrations of nitrogen, phosphorus and potassium were in foliar, followed by the stem, branch and course root. The denser stand had higher nitrogen, phosphorus and potassium accumulation and thus higher potential for export of nutrients through harvesting.

Isaac and Nair (2006) conducted a study on litter composition of six valuable MPTs (*Mangifera indica, Artocarpus heterophyllus, Anacardium occidentale*, *Ailanthus triphysa*, *Artocarpus hirsutus* and *Swietenia macrophylla*) in homegardens of Kerala. Litter fall and nutrient additions in the 6 MPTs were observed to vary from 383 to 868 $gm^{-2}\ y^{-1}$, N ranged from 6.4 to 8.8, P ranged from 0.17 to 0.42 and K ranged from 1.1 to 2.8 $g\ m^{-2}\ y^{-1}$. The decomposition rate and nutrient turnover were higher in *Mangifera indica, Artocarpus heterophyllus,* and *Anacardium occidentale*, while *Ailanthus triphysa*, *Artocarpus hirsutus* and *Swietenia macrophylla* take a longer time for decomposition and release of nutrient. Hence the latter three are much preferred as an organic mulch.

2.3. VARIABILITY IN TREES

Genetic variability is the basic requirement for tree breeding programs and nature has provided variation that could be applied in tree improvement. The role of tree breeders in the improvement of tree crops is achieved through the creation of a reservoir of variability through different breeding methods and then isolating the desirable genotypes through selection. The variability is imperative for designing different methods. Therefore, the evaluation of germplasm to determine the range of variation and its systematic exploitation and utilization for improvement of the tree is important and necessary. A wide range of variation is pre-requisite for tree improvement. It helps in selecting superior trees possessing desired characters or in choosing suitable parents for hybridization. Usually, variability in a mono-specific stand is often attributed to stand dynamics but still has a remarkable genetic control. It is, therefore, necessary to analyze, quantify and utilize the variation in tree improvement. Additive genes are considered to control traits that have high genetic variance and heritability. The presence of additive genes emphasizes the importance of the selection of plants based on phenotypic performance (Ghosh and Gulati, 2001). Heritability indicates the relative strength of heredity versus environment and thus plays an important role in improving tree genotypes (Dorman 1976). Genetic gain is influenced by the extent and type of genetic variation. It was reported that heritability estimates combined with genetic advance are more important than heritability alone to predict the selection of individuals based on phenotypes (Johnson *et al.*, 1955).

Kumar (2000) studied the variability among standing stock of *Ailanthus triphysa* trees in Kerala from 31 thaluks by selecting 737 home gardens. He found that *Ailanthus triphysa* in Kunnathunad and Thrissur thaluks was having the highest basal area and standing stock. He also concluded that *Ailanthus* was more abundant in the midlands of central and southern Kerala, and it comes well in very deep, well-drained, clayey soils on gentle slopes.

Indira (1996) studied the genetic improvement of *Ailanthus triphysa.* She found that the family heritability of *Ailanthus triphysa* in early years for the height was high and decreased to moderately high at the age of $3\frac{1}{2}$ years, whereas for basal girth the family heritability was moderate. Heritability for an individual tree was observed to be moderately high in height. The phenotypic and genotypic variability estimates were low for both height and basal girth. A significant positive relationship between height and basal girth enhanced the breeding programme. The genetic relationships between the height and the basal girth were 1.0, while the phenotypic relationship was 0.69 at $3\frac{1}{2}$ years of age. The study also revealed significant variations existed between the plus trees.

Das (2018) assessed the genetic variability of *Ailanthus triphysa* preference for matchwood. The analysis revealed that the candidate plus trees showed greater variation in anatomical features such as fiber, vessel and ray. The mean CPTs wood density was 0.37 g cm^{-3}. The fiber length recorded varied from 1076.48 µm to 1269.16 µm. The mean fiber width was found to be 29.84 µm and varied from 26.46 µm to 36.15 µm. The highest fiber thickness (4.88 µm) was recorded for the plus trees FCV AT 1 and the lowest (3.77 µm) for the plus trees FCV AT 3. The mean vessel length was 618.9 µm. The highest vessel area (62419.82 μm^2) and vessel frequency ($3/mm^2$) was recorded for the plus trees FCV AT 17 and FCV AT 02.

Abhijith (2018) conducted a nursery and field experiment to evaluate the superiority performance of candidate plus trees of *Ailanthus triphysa* from the Thrissur District, Kerala. The analysis revealed there was a significant difference between the progenies of the selected CPTs in their initial growth parameters. The highest germination per cent of 83.50 was exhibited by CPT-11 and the lowest of 67 per cent by CPT-1. After the six months of observation in the nursery, CPT-11 attained the maximum height of 88.67 cm and the lowest height was CPT-5 (76.33 cm). The maximum plant height (99 cm) and girth (21.04 cm) in the field were also exhibited by CPT-11. The CPT-11, CPT-10 and CPT-9 were the top performers compared to other selections. The CPT-1 was inferior in the nursery and also in the field. The CPTs that exhibited superiority in germination percentage, germination value and mean daily germination also exhibited distinctively superior growth in the nursery and the field.

Paul (2017) studied the variation in wood properties and the growth parameters of half-sib progenies of *Ailanthus triphysa* from Thrissur and Palakkad for preferred matchwood qualities. The analysis showed the anatomical properties and fiber indices between the CPTs varied significantly. The highest fiber and vessel length was observed on FCV AT 3. The highest value for fiber wall thickness and fiber diameter was observed on FCV AT 10. The analysis also revealed there was a significant difference in germination performance and morphological characters at nursery but not throughout the study period. The average germination per cent was 48.82 among the selected CPTs. The highest value was for the plus trees FCV AT 17 at 72.08 per cent and the lowest was for FCV AT 4 which was 21.67 per cent and the peak value of germination was highest for FCV AT 17 (3.60). The mean daily germination for all the CPTs averaged to 4.42 and germination value was highest for FCV AT 7 (25.28). From the field analysis, the plant height and collar diameter showed a significant difference among the selections. In field condition, the FCV AT 1 performed the best.

Kaushik *et al.*, (2017) assessed the genetic improvement of *Ailanthus excelsa* and concluded that the yield of leaf fodder had high heritability with high genetic advance followed by volume index, plant height and basal diameter suggesting a vast scope for genetic improvement. Plant height after six months was positively correlated with diameter and height at genotypic as well as phenotypic levels.

Hedge *et al.*, (2018) studied the genetic diversity of Mahua (*Madhuca longifolia var. latifolia*) from 13 populations in Gujarat based on seed oil yielding potential. They concluded that there is a wide variation in the oil content of the seed. The seed oil content along with oil yield per kg exhibited significant difference and ranged from 29.40 to 32.35 % and 115.04 g to 283.84 g.

Ghildiyal *et al*., (2009) studied variability in the growth of seedlings and production of biomass from 14 provenances of *Pinus roxburghii* from Garhwal Himalaya based on variable traits. After 18 months of seedling growth, the root length ranged from 47.60 cm to 73.73 cm. The broad sense heritability for height was 83.54 %. For root length, root-biomass, root-to-shoot ratio, seedling height and shoot biomass, both phenotypic and genotypic coefficients of variance were evaluated. The root length recorded the maximum coefficient of variation for the environment and collar diameter as the lowest.

Loha *et al*., (2006) evaluated the genetic diversity of the seeds of *Cordia africana* collected from six natural populations in Ethiopia. The results concluded that there was a significant difference in all the seed characters studied such as seed morphology, seed germination and seedling growth except in the root collar diameter after four months. The heritability of broad sense for seed morphological characters, germination capacity, germination energy, seedling height and root collar diameter were 71-98 %, 80 %, 42 %, 57-58 % and 3-13 % respectively.

2.4. SELECTION OF TREES

The first step in tree improvement programmes is the identification of candidate plus trees (CPTs). The plus tree selection is to increase the quality and yield of forest trees (Cornelius, 1994). The growth of trees is influenced by many characters and thus these characters are mostly suited for selection. Single trait selection is not very effective to screen elite genotypes as compared to the multi-trait selection method in many tree species. Each trait plays an important role and all the individuals are ranked according to one scoring system in the multi-trait selection method. The phenotypes selected through the multi-trait selection method are expected to have desired qualities as well as provide a genetically divergent base for future genetic and breeding programs (Bedell, 1980). Phenotypically superior and healthy trees are selected based on certain characters like tree height, diameter at breast height, clear bole height, stem straightness, self-pruning capability, free from insect and disease incidences and higher growth rate (Venkatesh, et al. 1986). The preliminary step in tree improvement programme of any species is the selection of CPT, which is considered as a guideline.

There are several methods for selection in natural stands for single traits and multiple traits. Trees that are superior in growth and form is compared with the adjacent trees growing on the same site (Zobel and Talbert, 1984). Single traits selection includes mass selection, family selection, sib selection, progeny testing, within family selection, and family plus within family selection. Tandem selection, independent culling, selection index and recurrent selection are the methods for multiple traits selection.

There are two major kinds of forests stands which are even-aged and uneven-aged forests. For this comparison tree method, individual tree selection was mostly used in even-aged forests while baseline and regression methods are commonly used for uneven-aged forests (ICAR, 2003).

The comparison tree method of selection has been widely accepted and applied in plantations and even-aged stands. Here, the candidate tree is first selected, once selected, they are screened for desired traits with the surrounding trees called comparison tree or check tree. This environmental check is believed to increase the accuracy of the identification of individuals with good genotypes. If the candidate tree surpasses the comparison tree, it is selected as a plus tree (Bedell, 1980).

In the natural forests, the methods commonly used are base value and the regression methods. Here, the base value for those characters such as bole straightness, wood density, branching habits and disease resistance are observed by adopting suitable sampling methods (5-10 %) from base populations and superiority for the candidate tree is worked out and trees are selected (Zobel and Talbert, 1984). This method was reported in *Melia dubia* (Binu, 2019) and *Dalbergia sissoo* (Sidhu, 1997).

In the regression methods, observations are taken on the traits of interest from the sample plots marked in the base populations. After plotting the observations against the age of the tree, the regression lines are prepared for the population. The position of the trees on the regression line will determine the superiority of the tree.

Abhijith (2018) selected 12 Candidates Plus Trees (CPTs) of *Ailanthus triphysa* from three agroecological zones of Thrissur, Kerala. The results showed there were significant differences in the plus trees selected. The variation in height of plus trees was in the range of 19 m to 24 m. The average height measured for the plus trees was 21.92 m. A total number of seven trees had height above the mean value. The standard deviation from the mean value was 1.56 and the coefficient of variation was 7.14 %. The average girth at breast height (GBH) estimated was 134.17 cm. The variation in GBH ranged from 120 cm to 143 cm. The standard variation and coefficient of variation were 6.39 and 4.77 % respectively.

Paul (2017) selected 20 CPTs of *Ailanthus triphysa* from Thrissur and Palakkad, Kerala. A significant variation was observed in the selected CPTs. The average height measured for the plus trees was 20.4 m. The variation in height of plus trees and GBH ranged from 16 m to 26 m and 102 cm to 153 cm. A total number of ten trees had height above the mean value. The average girth at breast height (GBH) estimated was 122.4 cm. The standard deviation of height and GBH from the mean values was 2.8 and 13.8 per cent and 13.4 and 10.9 per cent respectively.

Paray *et al.,* (2017) conducted a selection of CPT's of *Salix alba* from Kashmir valley using a comparison tree method. They determined that the superiority percentage over the comparison trees of these candidate plus trees was 28.9%, 43.1%, and 163.6% in height, DBH and volume respectively. They also found that the tree height, DBH, volume, bole height and crown diameter was in the range of 9.9 m - 14.8 m, 20.5 cm - 37.2 cm, 0.24 m^3 - 0.98 m^3, 4.3 m - 5.4 m and 2.5 m-4.5 m respectively. Sahoo *et al.,* (2011) identified 53 CPTs of karanj (*Pongamia pinnata)* from various localities in Orissa, India, based on the seeds and pods characters to determine suitable seed source having higher oil content producing quality planting stocks for afforestation. Fifty CPTs of *Pongamia pinnata* from different agro- climatic zones of Punjab, Haryana and Rajasthan were identified based on their morphological traits to characterize suitable seed sources with high oil content (Deswal *et al*., 2015).

Kumar *et al*., (2003) examined genetic improvement of *Gmelina arborea* by selecting 60 plus trees from the states of Assam, Arunachal Pradesh and Mizoram using point grading method of selection. The superiority percentage of these selected CPTs over their respective comparison trees was 18.77 %, 20.68 % and 46.48 % for height, GBH and clear bole height (cbh) respectively. Arunachal Pradesh Plus trees had the highest response for girth at breast height (31.52 %) and clean bole height (67.28 %) while Mizoram plus trees had 25.22 % improvement in height.

Chauhan *et al.,* (2018) studied twenty CPTs of *Melia dubia* from South Gujarat, India using the individual selection method. Among 20 plus trees selected, NAU-20 was showing the highest GBH of 170.2 cm and the lowest of 101.80 cm was recorded in NAU-12. These CPTs chosen were to be used in a future tree improvement programme to generate superior quality of the plant material.

Daneva *et al*., (2018) selected twenty-one plus trees of mahaneem (*Ailanthus excelsa* Roxb.) from Haryana, Rajasthan and Gujarat. The selection was based on phenotypic assessment of desirable traits and the genetic variability observed on the nursery performance. Among the progeny, the progeny A19 had the highest seedling height, shoot length and seedling dry weight. However, the progeny AE08 had maximum field emergence.

Navhale *et al*., (2011) conducted a selection of CPTs of Chebulic myrobalan (*Terminalia chebula*) from 40 genotypes for its genetic diversity. The analysis was done on its morphological traits and 12 parameters from fruits. The results showed significant variation for all the characters studied. Compared to the genotypic variances, phenotypic variances had higher variability for all characters indicating a higher environmental impact. Morphological traits like height, canopy diameter, diameter at the base, diameter at breast height, girth at base and girth at breast height exhibited greater variability.

2.5. EVALUATION OF PROGENIES

Progeny testing aims at the selection of superior parents based on the performance of the offspring. It can easily distinguish the superior and the poor parents based on the observations taken on progeny.

Das (2018) assessed the growth characters of *Ailanthus triphysa* for genetic improvement. The analysis revealed among the progenies observed for height and collar diameter, the progenies FCV AT 11 and FCV AT 20 had better performance. The highest average volume of the stem (0.006 m^3) was also recorded by the progenies FCV AT 11. Bole straightness revealed that there was a significant difference among the progenies of CPTs. The branching habit for all the progenies was similar except the progeny FCV AT 3. The mean survival percentage of the progenies was 94.98 %.

Kanna *et al*., (2019) analyzed the growth performance of *Ailanthus excelsa* from 30 progenies. The results concluded that there is huge diversity among the progenies and the three progenies FCRI AE-6, FCRI AE 16 and FCRI AE 26 shows significant superiority as compared to other progenies. Several other similar studies also report progeny testing in various tree species like *Terminalia arjuna* (Srivastava *et al.*, 1993), *Melia dubia* (Saravanan, 2012), Willow tree (Sharma *et al.*, 2011), *Acacia nilotica (*Padmini and Banerjee, 1986), red gum tree (Otegbeye, 1990), sandalwood (Bagchi and Veerendra, 1991), *Tecomella undulata* (Jindal *et al*., 1991), *Lagerstroemia* spp. (Jamaludheen *et al*., 1995), *Albizia lebbeck* (Radhakrishnan, 2001), *Pinus elliottii* var. *elliottii* (Vergara *et al.*, 2011), *Acacia catechu* (Nautiyal *et al.*, 2006), *Eucalyptus* (Vennila, 2009) and *Leucaena leucocephala* (Sangram and Keerthika, 2013).

Kumar (2005) experimented 70 clones of *Gmelina arborea* from 10 geographical locations in northeast India and reported that there was a significant difference between the clones and the broad sense heritability for height, diameter at ground level and DBH was 0.31, 0.44, and 0.31 with 18.1%, 24.6% and 30.1% genetic gain after 24 months. The DBH was found to be the most important character out of all the characters.

Meena *et al*., (2014) evaluated 54 progenies of *Melia azedarach* from different geographical locations in Punjab, India. They concluded that there was a significant difference between the progenies for all the characters studied. The 54 progenies were clustered into 8 based on Euclidean distance. Among the progeny, progeny number 10 had the highest values for all the characters studied and the genetic gain was found to be higher within the progeny selection.

Parthiban *et al.*, (2019) assessed 20 progenies of kadam to improve the yield and growth for agroforestry system and concluded that among the progeny studied, the progeny FCRIK17 was superior in all the characters and as the right choice to be adopted in the system. High heritability was recorded for volume followed by height and girth at breast height. The progenies were clustered into five, among them, cluster 3 had higher intracluster distance.

Jayasankar *et al.*, (1998) experimented provenance trial in teak from seven provenances in different locations of Kerala. They concluded that among the provenances, better shoot and root growth rates in seedlings were observed in the provenances of Parambikulam, Nilambur and Malayattur while poor growth was seen in Trichur. Among the fast-growing provenances, there was a close similarity between the provenances based on Mahalanobis D^2 test.

Abarquez *et al*., (2015) experimented with progeny trials of Mahogany at Butuan and Cagayan de Oro in Mindanao (Philippines) from 73 families of six plantation seed sources. They found that among the seed sources Lianga and Bislig were observed to be better in growth as compared to others. The mean diameters for progenies at Butuan and Cagayan de Oro after 50 months were 12.1 cm and 4.5 cm while the mean height was 9.4m to 3.8 m.

2.6. PHYSIOLOGICAL STUDIES OF PROGENY OF PLUS TREES

Tree physiology plays a major role in the growth of the plants and is greatly influenced by both heredity and environment. Understanding these mechanisms/behavior will help us in the scientific management of the trees. For an early selection, the rate of photosynthesis and gas exchange has been reported to enhance the efficacy of tree breeding (Ledig and Botkin, 1974). However, studies reported that the correlation between plant growth and the rate of carbon dioxide exchange maybe strongly positive or negative (Ceulemans *et al*., 1987). This in turn may affect growth rates such as height or biomass growth (Mahon *et al*., 1977).

Photosynthetic characteristics play an important role in the trees in case of environment adaptability. The evolutionary patterns in land plants have been discussed for characters like photosynthetic type, leaf shape, stomatal type and functions (Keeley *et al*., 2012). A better understanding of these traits will help us to explore the characters' involvement in the land plants. Seed plants as compared to ferns have much higher photosynthetic capacity (Brodribb *et al*., 2007). However, the exact mechanisms involving photosynthetic differences have not yet been unravelled.

Mebrahtu and Hanover (1991) study the variations of black locust (*Robinia pseudoacacia* L.) for its growth, gas exchange and leaf characters from 11 half sib families. They concluded that there was significant family variation among the characters of seedlings studied. Three weeks after seedlings germination, the slowest growing family and fastest growing family of the seedlings had a growth ranged from a minimum of 1 cm diameter and a maximum of 3 cm diameter. Photosynthetic rates declined due to the age of the seedling.

Ginwal and Mandal (2004) assessed the provenance trial of *Acacia nilotica* from 19 provenances from Pakistan, India, Sudan, Senegal and Yemen. Among the provenance studied, the provenance from Gujrat (Punjab) and Pakistan showed superiority in height, GBH and survival. There are significant trait differences in all the provenances studied and the heritability was recorded to be good for height, GBH and number of branches as compared to inter-nodal length.

Huang *et al*., 2019 reported that clones of *Tectona grandis* had wide variability and high heritability (h^2) for growth and physiological traits such as gases exchange, chlorophyll fluorescence and growth parameters. These characters were mostly genetically controlled especially for the actual quantum yield. They concluded that such characters are practically important for enhancing efficiency in teak breeding effectively. Similar findings also reported in *Populus trichocarpa* (McKown, 2014).

Rawat and Nautiyal (2006) evaluated the genotype-site interactions in growth, physiological and biochemicals parameters of *Dalbergia sissoo* and concluded that there is significant interaction in the genotype – site for collar diameter increment, photosynthetic rate, transpiration rate, stomatal conductance, total soluble proteins and starch content. These characters were greatly influenced by genetic causes and can be recommended for further improvement of this species.

Kundu and Tigerstedt (1999) concluded that neem (*Azadirachta indica*) from 10 provenances had genetic variation in the physiological traits such as net photosynthesis, CO_2 exchange, stomatal conductance, leaf area and seedlings dry weight. They also reported that photosynthesis and stomatal conductance was responsible during the early growth of seedlings. Similar work is done on black spruce by Johnsen and Major (1995). They reported that higher CO_2 assimilation rates are due to stomatal density. According to Salisbury and Ross (1992), net photosynthesis and stomatal conductance are often related to each other. Generally, stomatal regulation affects photosynthesis rates (Meng and Arp, 1992) as well as growth and productivity (Walton, 1974). Matsumoto *et al*., (2005) in their study suggested that the leaf physiology of *Quercus serrata* was having an impact on stomatal conductance and gaseous exchange. They concluded that leaf physiology has more effective in evaluating seasonal change in stomatal conductance.

Plant growth and yield greatly influenced photosynthesis. Environmental factors are not only responsible for plant photosynthesis but also affected by genetic factors. The role of plant genetic and environmental factors relation in photosynthetic activity is complicated. The present study will help to understand the physiological traits, growth, and improvement of *Ailanthus triphysa* resources in a future breeding program.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study attempted to determine the genetic diversity and selection of candidate plus trees from different panchayat from selected districts of Northern Kerala and to evaluate their progeny. Thirty plus trees were selected based on the regression baseline method and progeny evaluation was performed by raising seedlings from the fruit collected from plus trees. The details regarding the materials and methods used for the study are detailed below.

3.1. EXPERIMENTAL LOCATION

A reconnaissance survey was done in the selected districts of Kerala for assessing the population of *Ailanthus triphysa*. The trees of *Ailanthus triphysa* from farmer's field in different districts were located after a reconnaissance survey.

3.2. GENERAL DESCRIPTION AND CLIMATE OF THE STUDY AREA

The study was carried out in selected districts of Northern Kerala and the study area maps are presented in Figures 6 to 10.

3.2.1. Kasaragod

Kasaragod is Kerala's northernmost district, which borders the state of Karnataka. The district is drained by nine rivers; all rivers draining to the Arabian Sea. The climate here is generally mild hot and humid. The area receives an annual rainfall of 3500 mm. The maximum temperature recorded varies from 29.2°C to 33.4°C, while the minimum varies from 19.7°C to 25°C (Fig. 1). Wind velocity is much stronger in March to June ranging from 2.1 to 3.3 km/h (Central Ground Water Board, 2013).

Four main soil types, viz, lateritic soil, brown hydromorphic soil, alluvial and forest loam are found in this district. The most dominant soil found here is the lateritic soil and is formed from laterites, occurring in the midland and hilly areas.

3.2.2. Wayanad

Wayanad is located in the northern parts of Kerala, spanning about 2131 km^2 area. It lies on the Deccan plateau's southern end, which covers most of the Western Ghats. The district has a typical tropical climate monsoon with a mean rainfall of 2786 mm. The average maximum temperature is 29°C and the average minimum temperature is 18°C. The maximum temperature reported during the summer season is 34°C and the minimum temperature is 29°C (Fig. 2).

Lateritic soils, brown hydromorphic, forest loam and river alluvium are the most commonly found soils. The predominant soil found in this place is lateritic (Central Ground Water Board, 2013).

3.2.3. Malappuram

Malappuram district is located in the southern part of the former Malabar district, Kerala, having an area of 3554 km^2. The climate is hot and humid with a mean annual rainfall of 2793.3 mm. The highest temperatures recorded varies from 28.9°C to 36.2°C and minimum from 17°C to 23.4°C (Fig. 3). Especially between December and February the wind velocity is very high. In the morning, relative humidity is higher and varies from 84 to 94 % (Central Ground Water Board, 2013).

Based on the topographical configuration, this area has three physiographic regions, i.e., low land (<7.5 m), mid land (7.5 m – 75 m) and high lands (>75 m). The soils are alluvial soil, lateritic soil, hydromorphic soil and loamy forest soil. Alluvial soils are primarily seen in lowlands, coastal plains and valleys. Laterite soil has been found abundant in midland areas. Hydromorphic soils are dark in colour, clayey texture containing more gravel. Forest loamy soil is dark brown, clayey to loamy textures with a massive abundance of gravels.

3.2.4. Palakkad

Palakkad is a district in the central region of Kerala. The vegetation of the district is mostly moist and dry deciduous forest. The climate is tropical humid monsoon, experiencing annual rainfall of 2362 mm. The mean annual temperature is

27.8°C. The maximum temperature recorded is 32.3°C and the lowest temperature is 23.4 °C (Fig. 4). Throughout the year, the humidity and wind velocity are high during morning and evening hours. The average wind velocity is 13.6 km/hr (Central Ground Water Board, 2013).

The soils mostly found here are lateritic, virgin forests soil, black cotton soil and alluvial soil. The most predominant soil in this place is lateritic soil which is seen in the central regions.

3.2.5. Thrissur

Thrissur district is located in the central part of the state and has a total area of 3032 km^2. The average annual rainfall in the district is between 2310.1 mm and 3955.3 mm with a mean annual rainfall of 3198.133 mm. The highest rainfall occurs between June and September. The wettest month is July. The mean annual temperature is 32.3°C and the average maximum temperature recorded to vary from 29.3°C to 36.2°C and minimum from 22.1°C to 24.9°C (Fig. 5). A laterites soil, covering almost the entire central area of the district, is the dominant soil type observed (Central Ground Water Board, 2013).

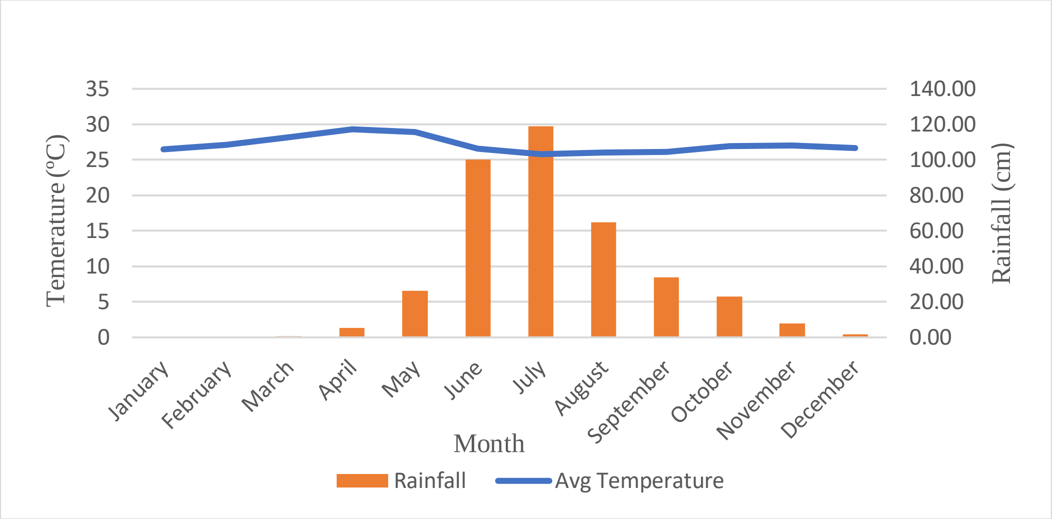

Fig. 1. Climate graph of Kasargod district

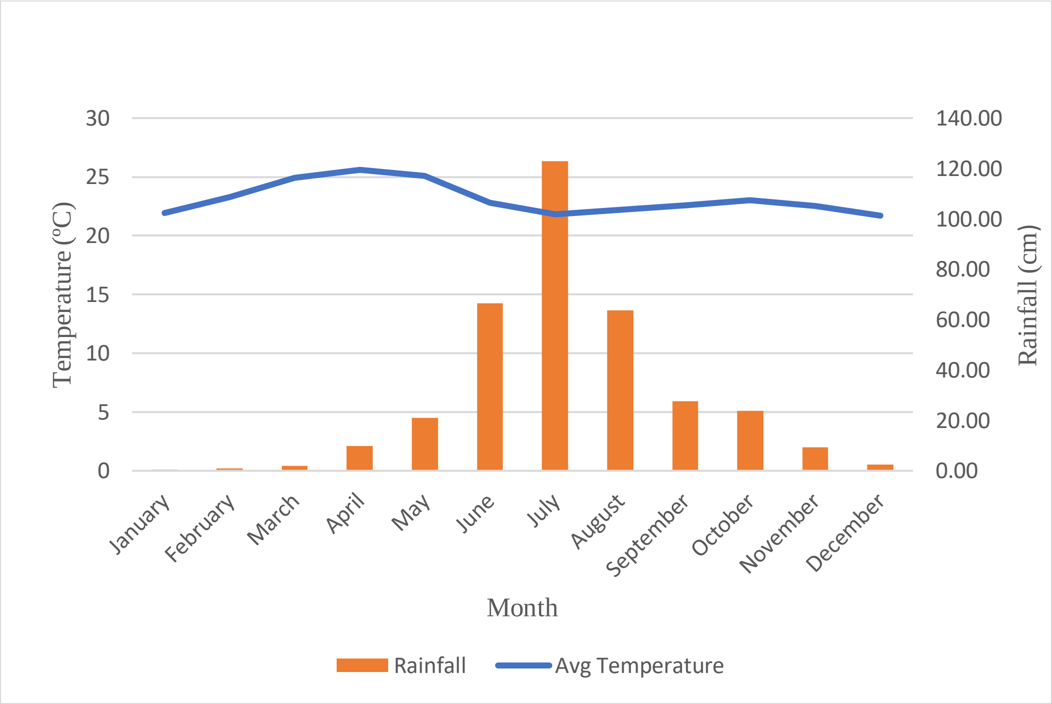

Fig. 2. Climate graph of Wayanad district

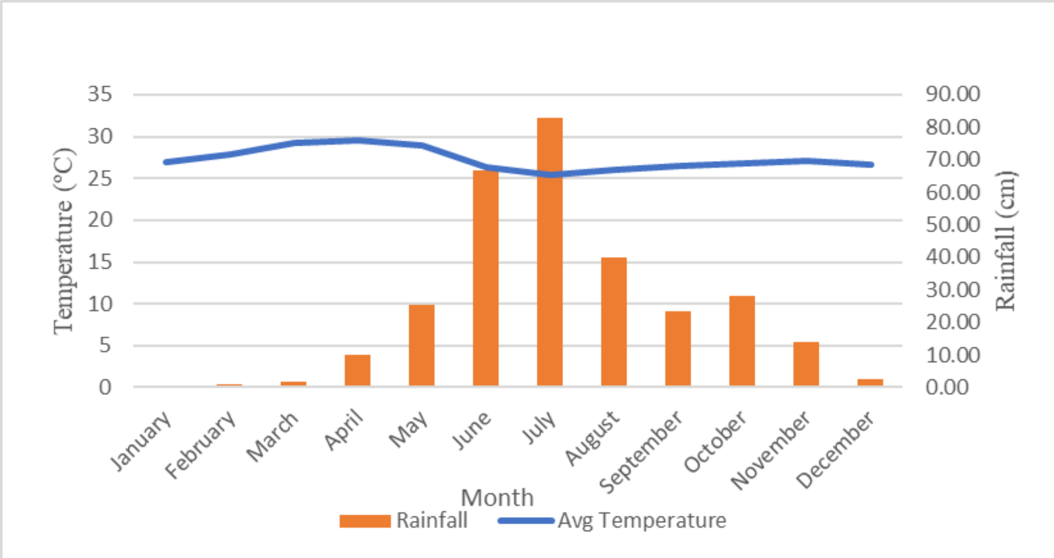

Fig. 3. Climate graph of Malappuram district

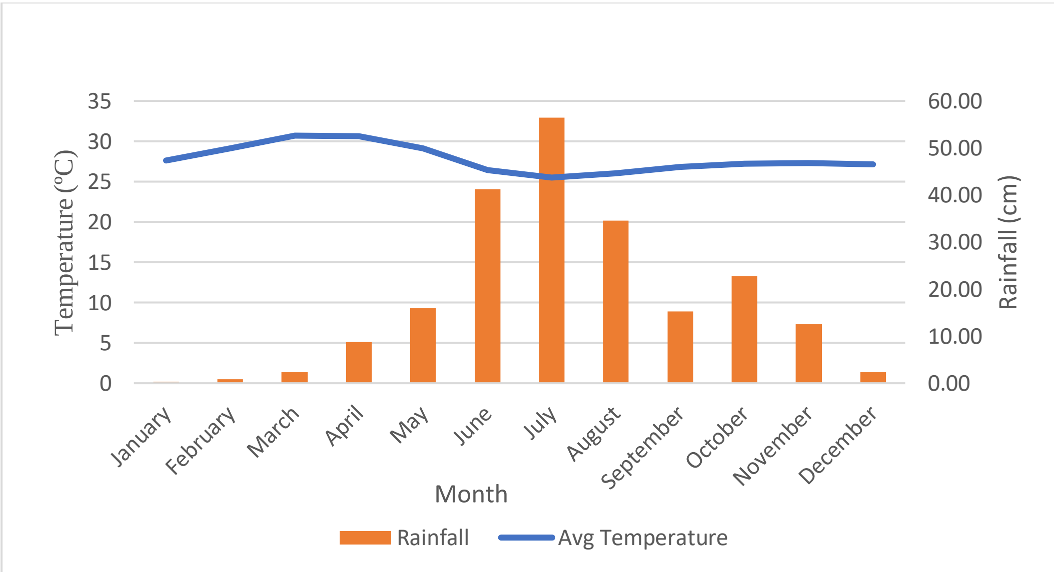

Fig. 4. Climate graph of Palakkad district

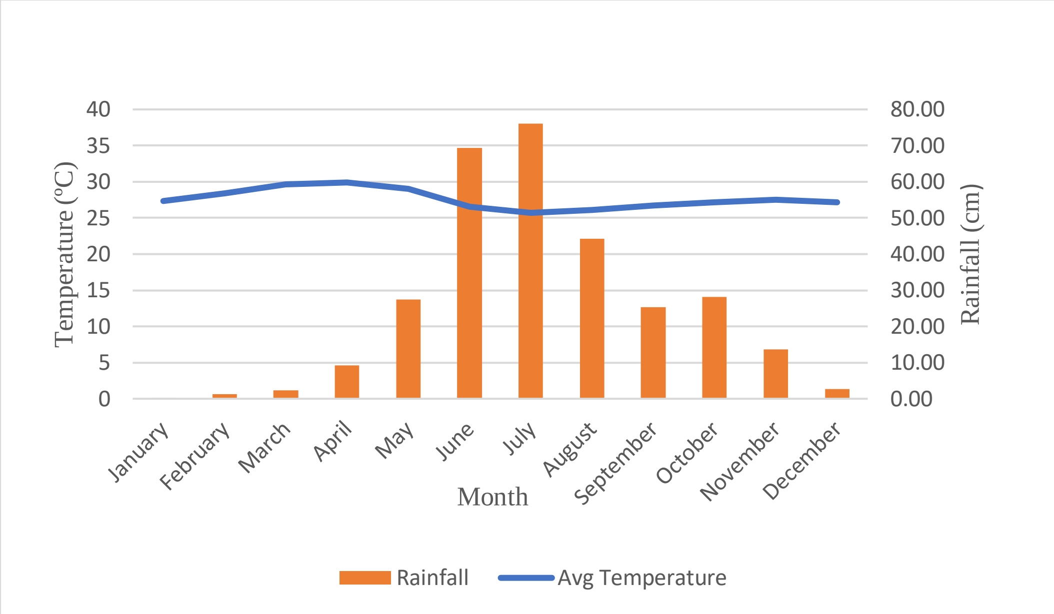

Fig. 5. Climate graph of Thrissur district

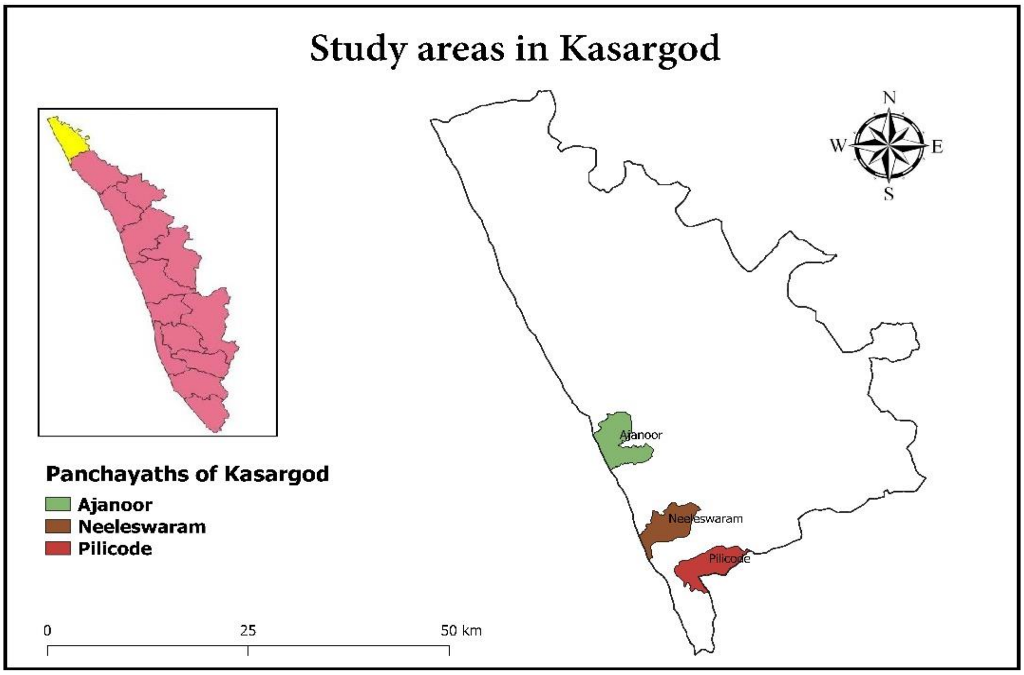

Fig. 6. Selected panchayaths for enumeration of *Ailanthus triphysa* trees in Kasaragod district

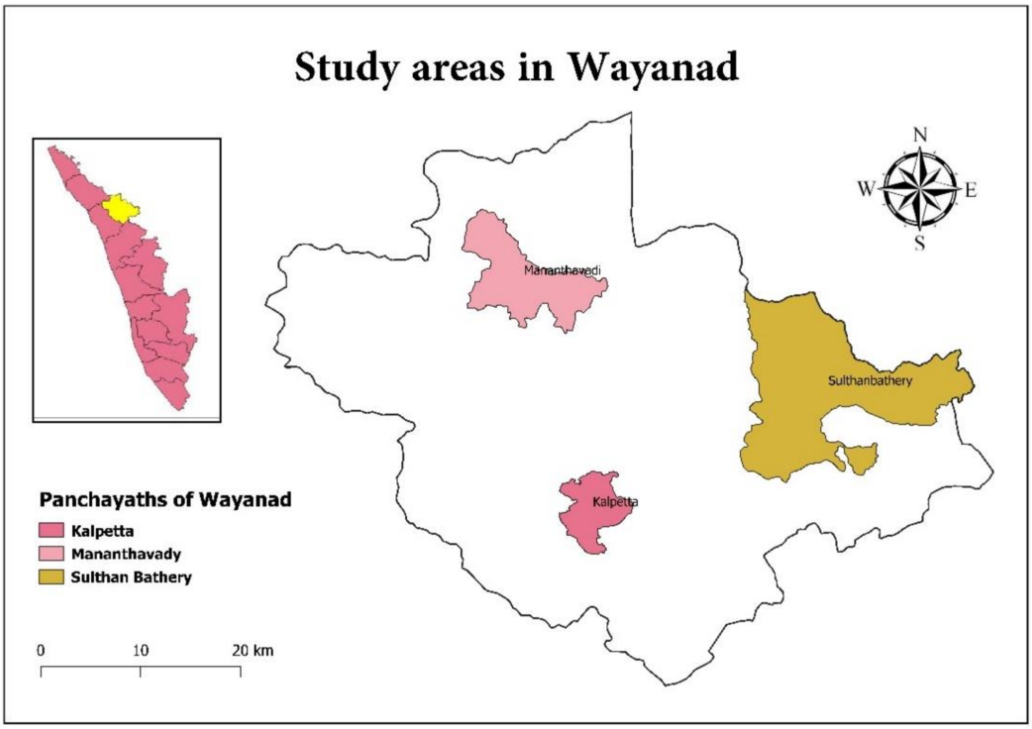

Fig. 7. Selected panchayaths for enumeration of *Ailanthus triphysa* trees in Wayanad district

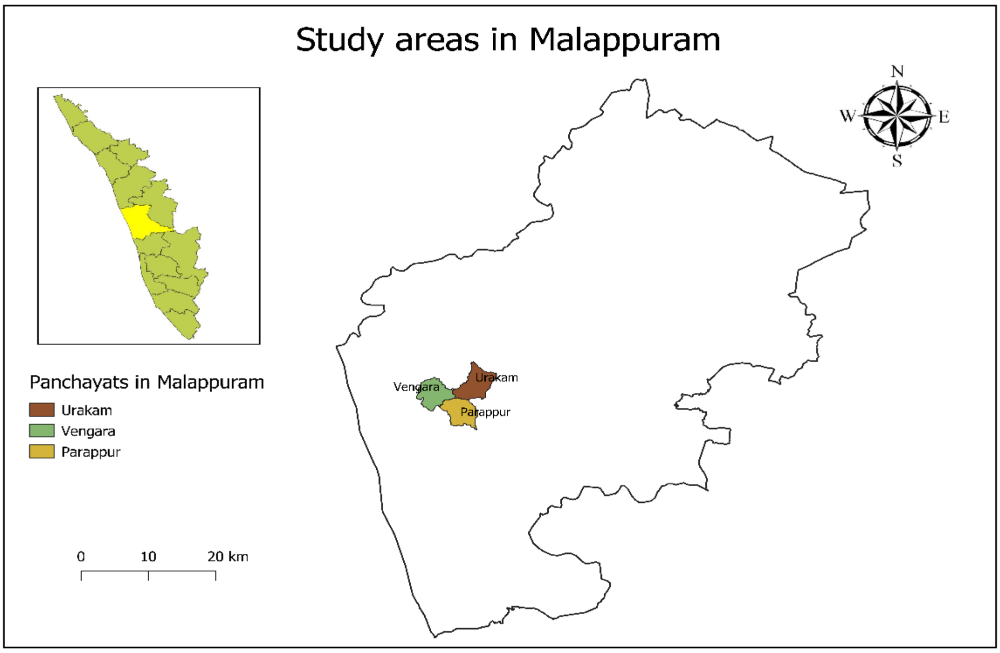

Fig. 8. Selected panchayaths for enumeration of *Ailanthus triphysa* trees in Malappuram district

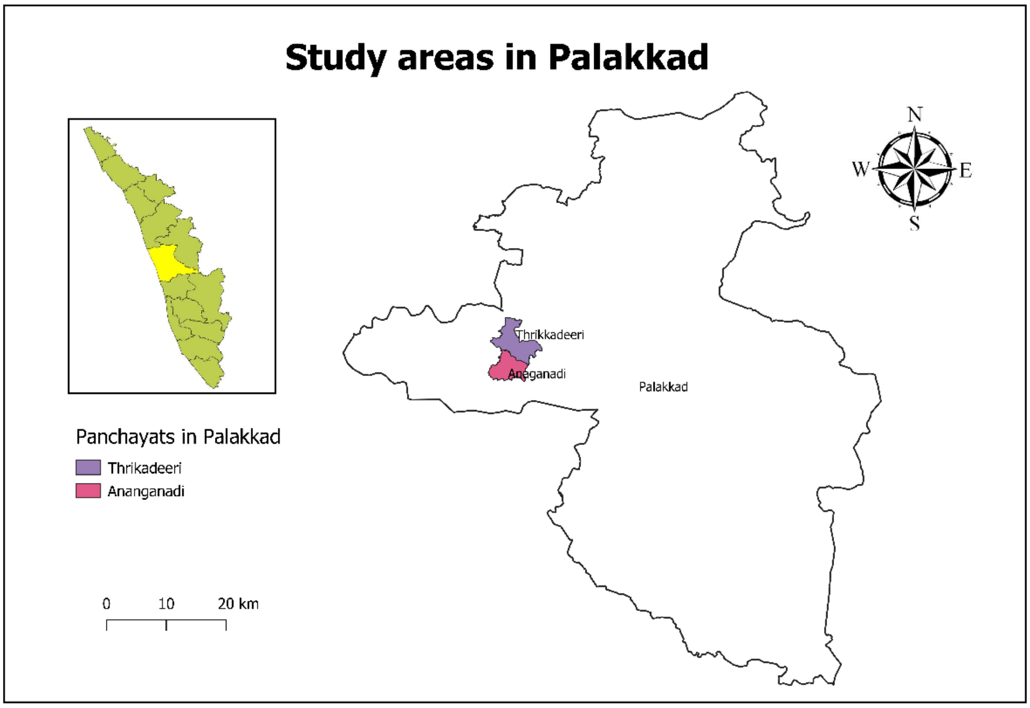

Fig. 9. Selected panchayaths for enumeration of *Ailanthus triphysa* trees in Thrissur district

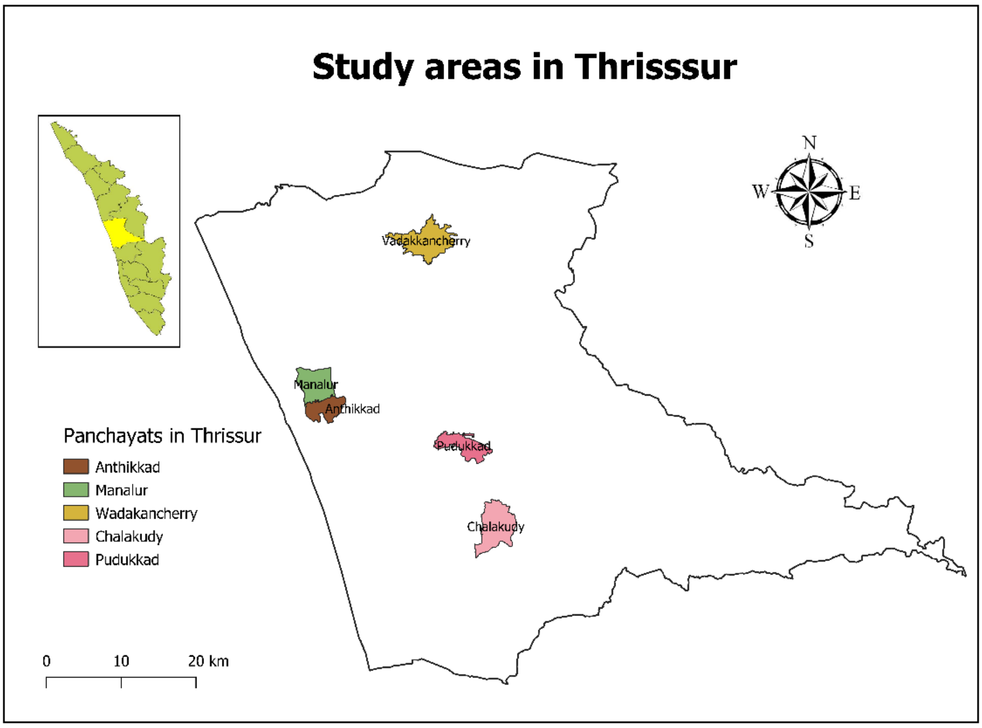

Fig. 10. Selected panchayaths for enumeration of *Ailanthus triphysa* trees in Thrissur district

3.3. EXPERIMENTAL METHODS

According to Kerala State of Environment Report (2007), Kerala is classified into 3 physiographic regions, viz., low land (an altitude less than 7.5 m above mean sea level) mid land (an altitude between 7.5 m to 75 m above mean sea level) and high land (an altitude more than 75 m above mean sea level). Based on this classification, panchayats were selected at random.

3.3.1. Plus Tree Selection

Trees above 45 cm girth at breast height were surveyed at the selected panchayats. The trees were enumerated and location was identified using Global Positioning System (GPS). The following observations for each tree were taken.

3.3.2. Quantitative traits

3.3.2.1. Total height (m)

The tree height was measured using Laser Hypsometer and expressed in meter (m). The height was taken from the foot of the tree to the topmost leading shoot.

3.3.2.2. Girth at Breast Height (m)

The girth at breast height was measured using tape at 1.37 m.

3.3.2.3. Crown diameter

The diameter of the crown was measured as the average of the two diameters. The first axis was measured at the widest portion of the crown and the diameter perpendicular to the widest area was measured as the second axis. The average diameter of the crown two axis was then computed.

3.3.2.4. Bole length

The length of the bole was measured from the ground level to the point of first branching, *i.e.*, the first living branch that forms part of the crown of the tree.

3.3.2.5. Crown length

Crown length is the measurement of the crown of the tree from the tip to the point half way between the lowest green branches forming green crown all round and the lowest green branch on the bole.

Crown length = Total height of the tree - Crown base height.

3.3.2.6. Crown volume

The product of squared of crown diameter with crown length is defined as crown volume.

3.3.2.7. Trunk volume

Trunk volume is the measurement of wood quantity. It was calculated using quarter girth's formula;

$$V = (g/4)^2 \times l$$

Where, g = girth of the tree at breast height

l = height of the tree

Plate 1. Crown width measurement

Plate 2. Girth at breast height measurement

3.3.3. Qualitative traits

3.3.3.1. Bole form

Clean bole straightness, cross section, swellings, etc., were recorded. The branching habit of the trees based on the height of the first branch, apical dominance, forking, branch angle, self-pruning ability, etc., also were recorded. The variations in the qualitative traits were determined using the scoring method developed by Jayaraj (1997). The format of the score is shown in Appendix I.

3.3.3.2. Health status

The foliar and stem damage of the trees were recorded.

3.3.3.3. Selection of candidate plus trees

From different locations 30 plus trees were selected using the baseline regression method (Rudolf, 1956). For this, the regression of trunk volume Vs crown volume was determined. Trees above the regression lines were initially selected as plus trees and below were rejected. If more trees are falling above the regression line, then trees which has the highest scoring of qualitative characteristics were selected.

3.4. PROGENY EVALUATION

Fruits were collected from the 30 selected plus trees from different locations. Reddish-brown ripened fruits were collected either directly from the trees or ground. They were immediately transported to the nursery in gunny bags.

3.4.1. Sowing of Seeds

The seeds were directly sowed into the nursery bed in February, 2019. Daily watering was done in the morning and evening. After germination, when the cotyledons were fallen off or atleast two leaves were developed, transplanting was done into polybag of size (25 x 15 cm) containing soil, sand and FYM in the ratio of 2:1:1 and then transferred to the greenhouse. The experiment was laid out in a completely randomized block design with three replications. Five seedlings formed one replication and a total of 450 seedlings were maintained as part of the evaluation.

3.4.2. Biometric observations of progenies

3.4.2.1. Seedlings height

The seedlings height was measured from the collar to the tip of the terminal bud using a meter scale.

3.4.2.2. Collar diameter

Seedlings collar diameter was measured along two opposite directions. This was done using Vernier calipers (least count = 0.02 mm) and was expressed in millimeters (mm).

3.4.2.3. Number of leaves

The total number of leaves in the seedlings were counted.

3.4.2.4. Biovolume index

The biovolume index is a rapid method to determine the above ground portion of the seedlings. This was done using the formula

Biovolume index = Stem diameter (mm) x Plant height (cm) (Hatchell, 1985).

3.4.3. Physiological observations

3.4.3.1. Photosynthetic rate

Infra-Red Gas Analyzer (LI 6400 LI-COR, USA)) was used to measure the seedlings photosynthetic rate at a light intensity of 1000 µmol. The amount of photosynthesis was expressed in µmol CO_2 $m^{-2}s^{-1}$.

3.4.3.2. Transpiration rate

Infra-Red Gas Analyser (LI 6400 (LI-COR, USA)) was used to measure the transpiration rate of seedlings. The light intensity was fixed at 1000 µmol and the amount of H_2O expressed in mmol H_2O cm^{-2} s^{-1}.

3.4.3.3. Leaf temperature

The leaf temperature of the seedlings was recorded using IRGA and expressed in °C.

3.4.3.4. Stomatal conductance

The stomatal conductance of the leaves of seedlings was measured using IRGA and the light intensity was fixed at 1000 µmol and the stomatal conductance was expressed in mmol H_2O cm^{-2} s^{-1}.

3.4.3.5. Relative water content (RWC)

For estimating relative water content, the leaf was cut into one cm square. Fresh weight was taken. It was then put in distilled water for 24 hours. After removal from distilled water, leaf samples were dried using blotting paper, and turgid weight was measured. The samples were then dried in a hot air oven at 70°C till constant weight was achieved. The RWC was calculated based on the formula

Relative water content = Fresh weight – Dry weight / Turgid weight –Dry weight

All the observations of physiological data were taken in the morning hours between 9 A.M. to 11 A.M.

Plate 3. Seedlings germination in the nursery bed

Plate 4. Seedlings transplanted to polybag

Plate 5. Collar girth measurement

Plate 6. Seedlings height measurement

Plate 7. Readings taken by Infrared Gas Analyser (IRGA)

3.5. Estimation of genetic parameters

3.5.1. Variability studies

These parameters were estimated from the ANOVA table by the method developed by Johnson *et al.*, (1955),

3.5.1.1. Genotypic variance (G.V),

$$(G.V)\ \ (\sigma^2 g) = (MS_1 - MS_2)/r$$

$$\text{Error variance } (\sigma^2 e) = MS_2$$

Where,

MS_1 = Genotypic mean square

MS_2 = Error mean square

r = number of replications

3.5.1.2. Phenotypic variance (PV)

$$(P.V)\ (\sigma^2 p) = (\sigma^2 g + \sigma^2 e)$$

Where,

$\sigma^2 g$ = Genotypic variance

$\sigma^2 e$ = Error variance

Phenotypic and genotypic coefficients of variability were computed using the following equations suggested by Burton (1952)

3.5.1.3. Phenotypic coefficients of variability

Phenotypic coefficients of variability were measured as

$$PCV\ (\%) = \sqrt{\sigma^2 p} / \text{Mean} \times 100$$

3.5.1.4. Genotypic coefficients of variability

Genotypic coefficients of variability were calculated as

$$GCV (\%) = \sqrt{\sigma^2 g} / Mean \times 100$$

3.5.1.5. Environmental coefficients of variations

It is an estimate of the total environmental variation present for a character.

$$ECV (\%) = \sqrt{\sigma^2 e} / Mean \times 100$$

3.5.2. Heritability

3.5.2.1. Broad sense heritability (H^2)

Broad sense heritability which is a measure of the amount of phenotypic variance contributed by genetic factor was estimated as,

$$H^2 = \sigma^2 g / \sigma^2 p$$

Heritability percentage = $H^2 \times 100$

3.5.2.2. Genetic advance

Genetic advance is the increase in the magnitude of a specific character which is expected when a selection pressure of a chosen intensity is applied. The expected genetic advance at 5% selection intensity was calculated as

$$\text{Genetic advance} = H^2 \times \sigma p \times k$$

Where,

H^2 = Broad sense heritability

σp = Phenotypic standard deviation of the original population

k = selection intensity presumed to be 2.06 in case of 5% selection in the sample which is large and is from a normally distributed population (Allard, 1960).

Genetic gain as a percentage of mean was calculated using the formula given by Burton and Devane (1953)

Genetic gain = GA/Grand Mean x 100.

3.6. STATISTICAL ANALYSIS

For progenies evaluation, the data recorded were analyzed statistically by applying the techniques of Analysis of Variance. Statistical analysis was carried out using SPSS and R-Packages.

3.6.1. Cluster analysis

Information on morphological characters of different plus trees was subjected to hierarchical clustering analysis. Cluster analysis was conducted using Minitab software based on squared Euclidean distance.

3.6.2. Principal component analysis

The principal component analysis was carried out on morphological characters of different plus trees using Minitab software.

RESULTS

4. RESULTS

The results obtained in the present investigation entitled "Genetic diversity and selection of candidate plus trees of *Ailanthus triphysa* (Dennst.) Alston in selected districts of Northern Kerala" is presented in this chapter.

4. 1. SELECTION OF PLUS TREES

As part of the study a total of 255 trees were enumerated. Details of enumerated trees for selection of candidate plus trees of *Ailanthus triphysa* are presented in table 1.

In Anthikad panchayath, 24 trees were enumerated. The maximum height, GBH, crown width and clean bole height recorded were 26 m, 1.1 m, 8 m and 17 m respectively, while the minimum height, GBH, crown width and clean bole height were 14 m, 0.5 m, 2 m and 4 m respectively. The respective mean height, GBH, crown width and clean bole height of all the trees located were 20.5 m, 0.7 m, 4.9 m and 10.6 m. Twenty-five trees were identified in Manalur panchayath. The variation in height, GBH, crown width and clean bole height ranged from 16 m to 28 m, 0.6 m to 0.9 m, 2.5 m to 8.5 and 8 m to 18 m respectively. The average height, GBH, crown width and clean bole height of all the trees identified were 21 m, 0.6 m, 4.3 m and 13.3 m.

In Pudukkad panchayath, 26 trees were identified. The average height, GBH, crown width and clean bole height of all the trees located were 26.5 m, 0.9 m, 6 m and 16.7 m respectively. The variation in height, GBH, crown width and clean bole height ranged from 16 m to 37 m, 0.5 m to 1.3 m, 3.5 m to 8.5 m and 7 m to 24 m respectively. In Chalakudy panchayath, 30 trees were enumerated. The maximum height, GBH, crown width and clean bole height were 37 m, 2 m, 11 m and 24 m respectively, while the minimum height, GBH, crown width and clean bole height were 13 m, 0.5 m, 2.5 m and 6 m respectively. The respective mean height, GBH, crown width and clean bole height of all the trees located were 28.7 m, 1 m, 6.6 m and 15.2 m. Twenty-five trees were identified in Wadakkanchery panchayath. The variation in height, GBH, crown width and clean bole height vary from 15 m to 33 mm, 0.5 m to 1.7 m, 2.5 m to 9.5 m and 4 m to 21 m respectively. The average height, GBH, crown width and clean bole height of all the trees located in Wadakkanchery were 25.2 m, 1 m, 5.1 m and 14.2 m.

In Vengara panchayath, 26 trees were assessed. The variation in height was 15 m to 28 m. Girth at breast height (GBH) ranged from 0.5 m to 1.3 m. The crown width varies from 1.8 m to 9.9 m. The variation in clean bole height ranged from 3 m to 18 m. The respective mean height, GBH, crown width and clean bole height of all the trees located were 20.2 m, 0.7 m, 3.7 m and 8.1 m respectively. The twenty-two trees enumerated in Parappur panchayath showed that the maximum height, GBH, crown width and clean bole height were 27 m, 1.1 m, 7.5 m and 19 m respectively, while the minimum height, GBH, crown width and clean bole height were 17 m, 0.5 m, 2.2 m and 6 m respectively. The average height, GBH, crown width and clean bole height of all trees located were 23.1 m, 0.8 m, 4.2 m and 13 m.

In Thrikadeeri panchayath, 25 trees were enumerated. The variation in height, GBH, crown width and clean bole height ranged from 16 m to 35 m, 0.5 m to 1.1 m, 2.5 m to 7.5 m and 7 m to 24 m respectively. The mean height, GBH, crown width and clean bole height of all the trees located were 25.3 m, 0.8 m, 4.5 m and 16.4 m. A total of 26 trees was identified in Ananganadi. The average height, GBH, crown width and clean bole height of all trees located were 20.5 m, 0.7 m, 4.9 m and 10.6 m respectively. The variation in height, GBH, crown width and clean bole height were 14 m to 26 m, 0.5 m to 1.1 m, 2 m to 8 m and 4 m to 17 m.

Of all the 26 trees located in Urakam panchayath, the maximum height recorded was 23 m and the minimum height was 10 m. The maximum GBH was 2.2 m and the minimum was 0.48 m. The maximum crown width was 10.5 m and the lowest was 1.5 m. The highest clean bole height was 18 m and the least was 3 m. The average height, GBH, crown width and clean bole height of all trees located were 17.9 m, 0.9 m, 4.7 m and 10.2 m.

The result of the regression analysis (Figure 11) for the trees in Anthikad panchayath showed that the regression ($R^2 = 0.73$) was significant ($p < 0.05$). It was observed that among the twenty-four trees located (Table 1), ten trees (A-01, A-02, A-04, A-10, A-11, A-12, A-13, A-18, A-19 and A-20) fell above the regression line. Three trees were selected as plus trees (A-10, A-12 and A-19), as the total score for the qualitative characters of the selected trees was 45, 42 and 46 respectively (Appendix

III). The trees A-01, A-02, A-04, A-10, A-11, A-12, A-13, A-18, A-19 and A-20 had scores 31, 30, 33, 36, 28, 32 and 32 respectively and thus they were rejected. In Manalur panchayath, the regression analysis showed that the regression is significant ($R^2 = 0.47$, $p < 0.01$). The graph (Figure 12) showed that eleven trees M-01, M-03, M-05, M-09, M-10, M-14, M-17, M-18, M-21, M-22 and M-24 were above the regression line. The total score for the qualitative characters of trees M-05, M-10, M-21 had a higher value of 48, 45 and 48 respectively and the trees were selected as plus trees. The trees numbered M-01, M-03, M-09, M-14, M-17, M-18, M-22 and M-24 had a lower value of 36, 36, 29, 33, 23, 26, 35 and 27 respectively, hence were rejected.

Similarly, the trees in Pudukkad panchayath showed significant variation ($R^2 = 0.43$, $p < 0.01$) and the thirteen trees (Figure 13) fell above the regression line (P-02, P-12, P-13, P-14, P-15, P-16, P-17, P-18, P-19, P-20, P-23, P-25 and P-26). Three trees P-13, P-16 and P-23 had a score of 48, 45 and 42 for the qualitative characters and were selected. As the score for the qualitative characters of the tree numbered P-02, P-12, P-14, P-15, P-17, P-18, P-19, P-20, P-25 and P-26 were found to be lower 37, 26, 39, 35, 29, 33, 21, 34, 31 and 29 respectively and they were not selected. Regression was significant ($R^2 = 0.78$, $p < 0.01$) for the trees in the Chalakudy municipalities. Ten trees (Figure 14) C-04, C-05, C-07, C-11, C-12, C-15, C-21, C-25, C-27 and C-30 fell above the regression lines. Three trees C-07, C-12, C-25 having a higher score for qualitative characters (44, 47 and 43) were selected as plus trees. The trees C-04, C-05, C-11, C-15, C-21, C-27 and C-30 had a score of 38, 39, 29, 33, 25, 26 and 28 respectively, so they were rejected. For the trees in Wadakkanchery panchayath, it was observed that regression was significant ($R^2 = 0.51$, $p < 0.01$) and Figure 15 showed that ten trees W-01, W-02, W-04, W-05, W-06, W-14, W-15, W-16, W-20 and W-21 were above the regression line. The score for the qualitative characters for three trees W-06, W-16 and W-20 was 44, 45 and 48 respectively and were selected as plus trees. The trees W-01, W-02, W-04, W-05, W-14, W-15 and W-21 (28, 30, 31, 35, 23, 34 and 30) had lower qualitative characteristics and hence were rejected. The regression was significant for trees located in the Vengara panchayath ($R^2 = 0.69$, $p<0.01$). The regression graph (Figure 16) showed that ten trees (V-02, V-04, V-06, V-09, V-10, V-18, V-20, V-21, V-24 and V-26) fell above the regression line. Trees V-10, V-18, and V-24 were selected as the score for the qualitative characters was higher 43, 46 and 45 respectively. The scores for the trees V-02, V-04, V-06, V-09, V-20, V-21 and V-26 were 18, 27, 37, 38, 29, 27 and 22 respectively and hence were not selected. The regression coefficient value (0.45) was significant ($p<0.01$) for the trees located in the Parappur panchayath. Eleven trees PA-02, PA-03, PA-04, PA-06, PA-07, PA-12, PA-13, PA-15, PA-16, PA-20 and PA-21 were found above the regression line (Figure 17). Trees numbered PA-07, PA-16 and PA-20 were selected based on the total score for the qualitative tree characteristics. The values were 43, 45 and 48 respectively. The other trees PA-02, PA-03, PA-04, PA-06, PA-12, PA-13, PA-15 and PA-21 had a score of 23, 28, 32, 34, 31, 26, 37 and 37 respectively. As the values for the qualitative characters were lower for these trees they were not selected as plus trees.

Similarly, for the trees in the Thrikadeeeri panchayath, among the twenty-five trees enumerated, the R^2 value was 0.58, $p < 0.01$ and therefore significant. The graph (Figure 18) showed that eight trees T-05, T-07, T-08, T-09, T-11, T-12, T-24 and T-25 were above the regression line. T-05, T-11 and T-25 were selected as plus trees as their qualitative score was 48, 44 and 47 which is higher as compared to the other trees. The scores for the trees T-07, T-08, T-09, T-12 and T-24 were 23, 29, 35, 29 and 25 respectively so they were rejected. The regression coefficient value was high ($R^2 = 0.46$, $p<0.01$)), for the trees located in Ananganadi panchayath. The regression graph of the trees from different forest areas in Ananganadi panchayath showed (Figure 19) that thirteen trees AN-01, AN-04, AN-05, AN-06, AN-09, AN-10, AN-11, AN-12, AN-14, AN-17, AN-18, AN-23 and AN-26 fell above the regression line. The score for the qualitative characters for the three trees AN-10, AN-12 and AN-17 were 45, 48 and 43 and hence, it was selected. The score for the trees AN-01, AN-04, AN-05, AN-06, AN-09, AN-11, AN-14, AN-18, AN-23 and AN-26 was 27, 40, 34, 32, 31, 28, 40, 39, 40 and 32 respectively and were not selected. For the trees in Urakam panchayath, regression was significant, $R^2 = 0.70$, $p<0.01$. Twelve trees U-01, U-02, U-07, U-08, U-09, U-11, U-13, U-17, U-19, U-20, U-21 and U-26 were above the regression line (Figure 20). Trees U-01, U-09 and U-26 had a higher score of 45, 43 and 45 respectively and selected as plus trees, whereas the scores for the qualitative characters of trees U-

02, U-07, U-08, U-11, U-13, U-17, U-19, U-20 and U-21 was 35, 38, 31, 31, 26, 30, 31, 28 and 32 respectively so they were not selected.

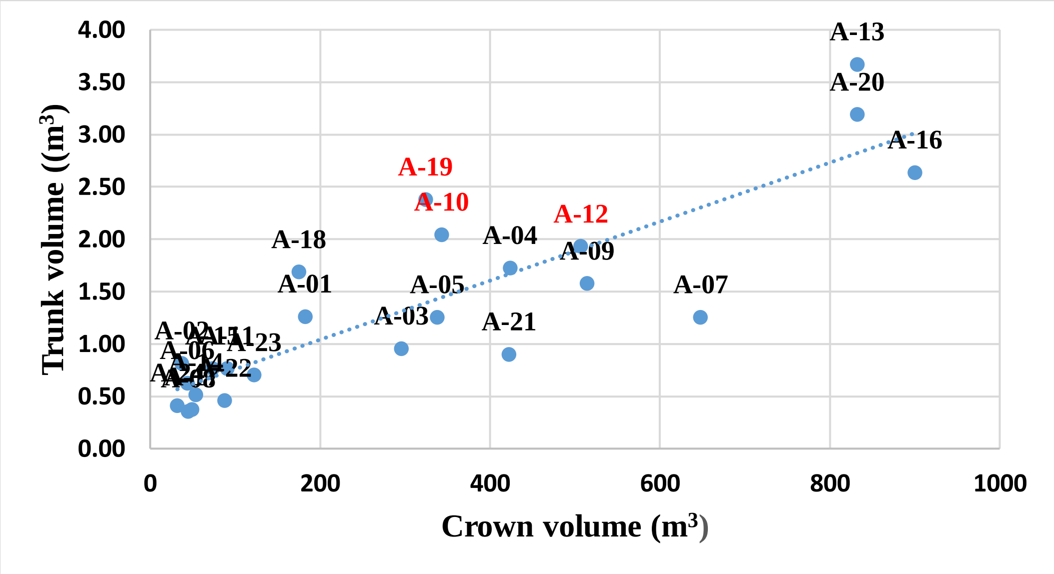

Fig. 11. Regression graph of trees located at Anthikad showing the CPTs selected

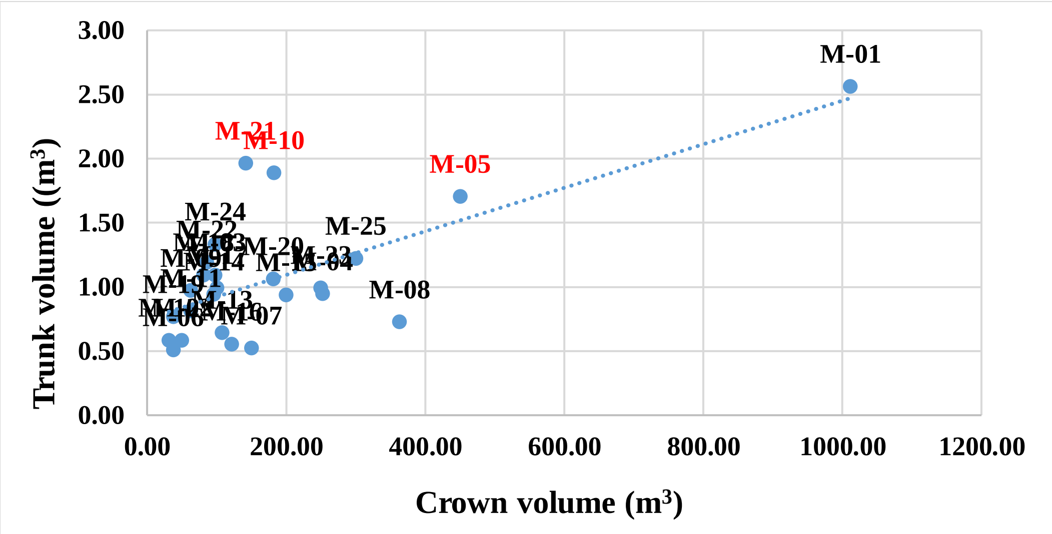

Fig. 12. Regression graph of trees located at Manalur showing the CPTs selected+

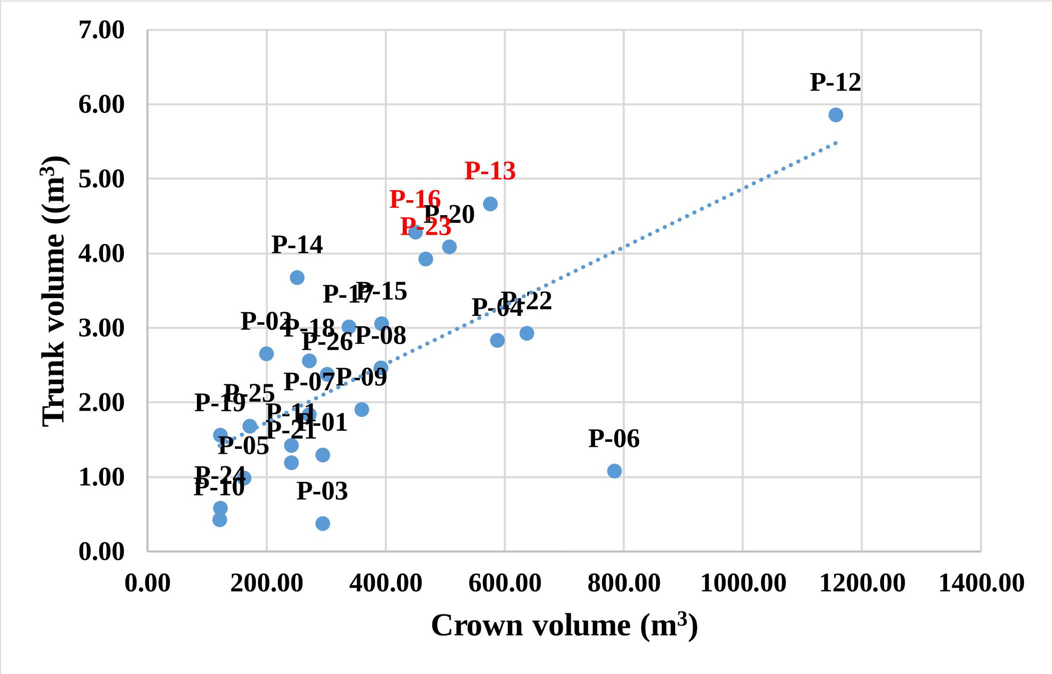

Fig. 13. Regression graph of trees located at Pudukkad showing the CPTs selected

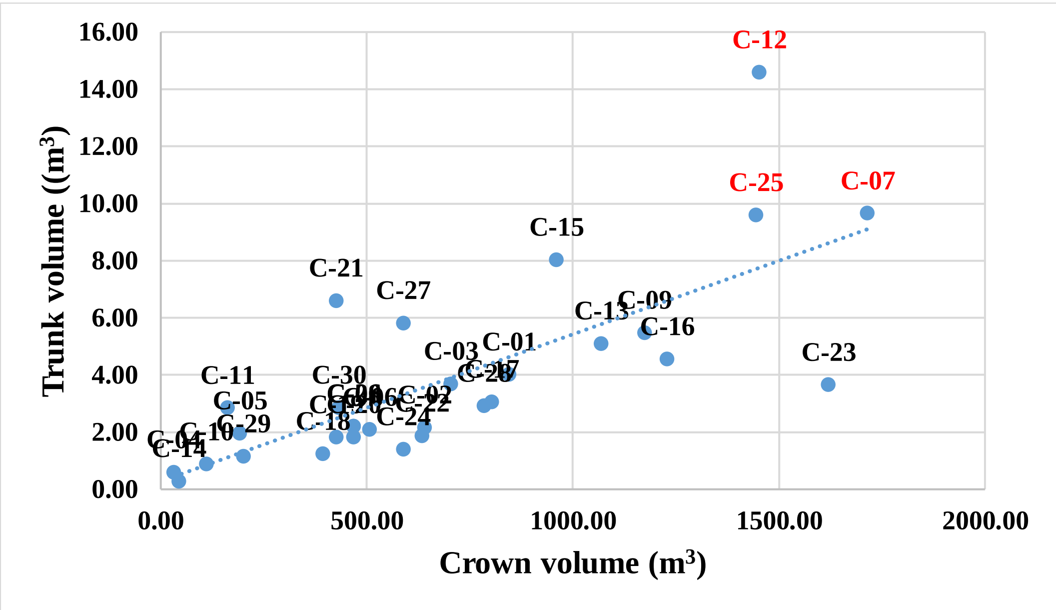

Fig. 14. Regression graph of trees located at Chalakudy showing the CPTs selected

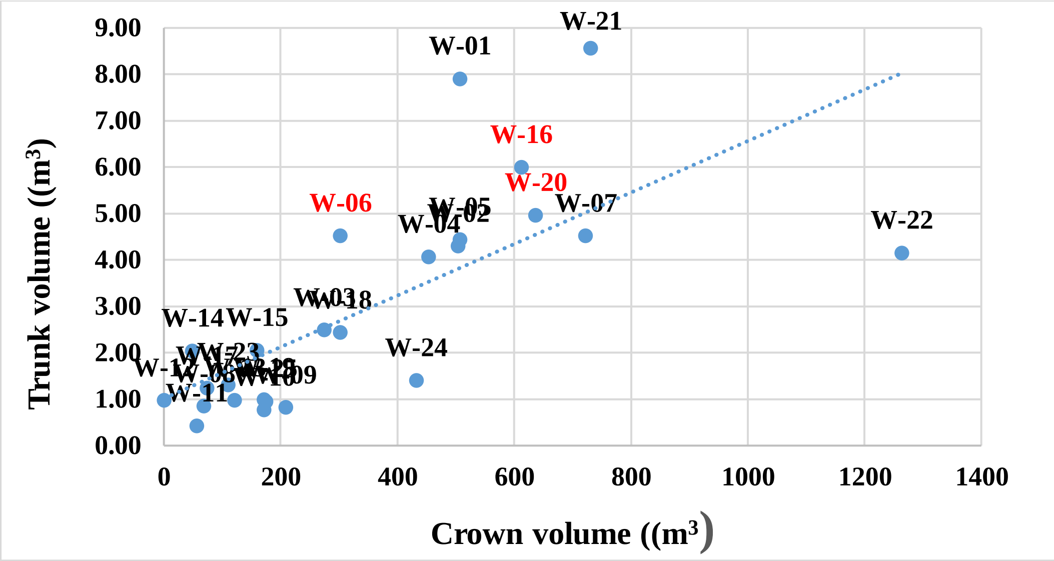

Fig. 15. Regression graph of trees located at Wadakkanchery showing the CPTs selected

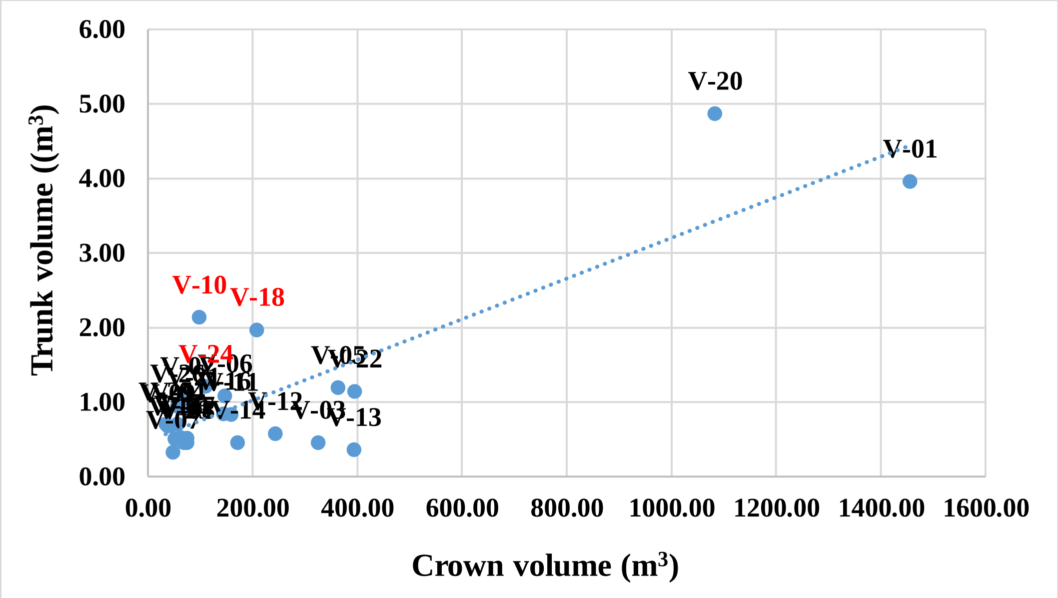

Fig.16. Regression graph of trees located at Vengara showing the CPTs selected

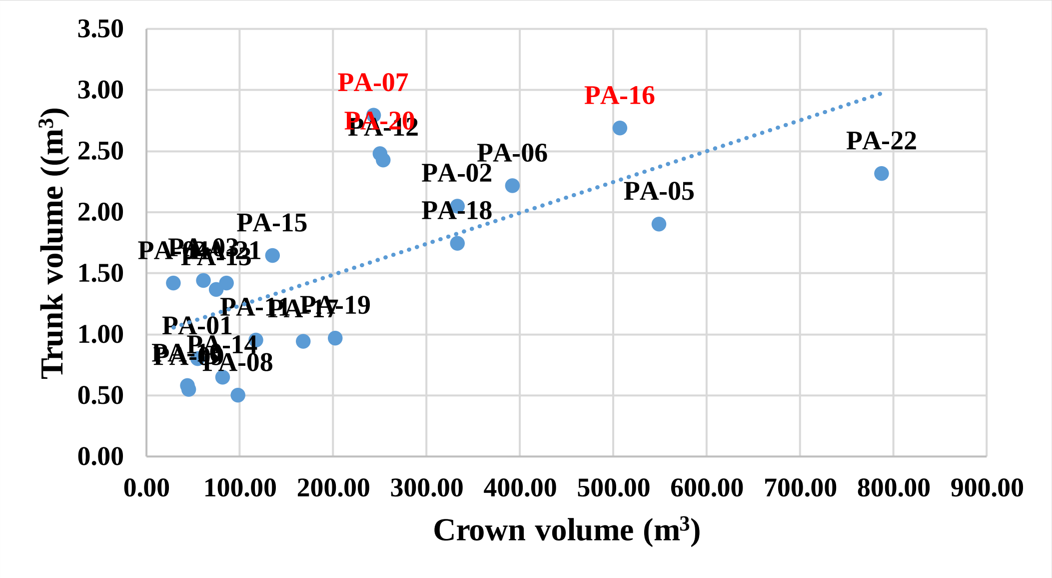

Fig. 17. Regression graph of trees located at Parappur showing the CPTs selected

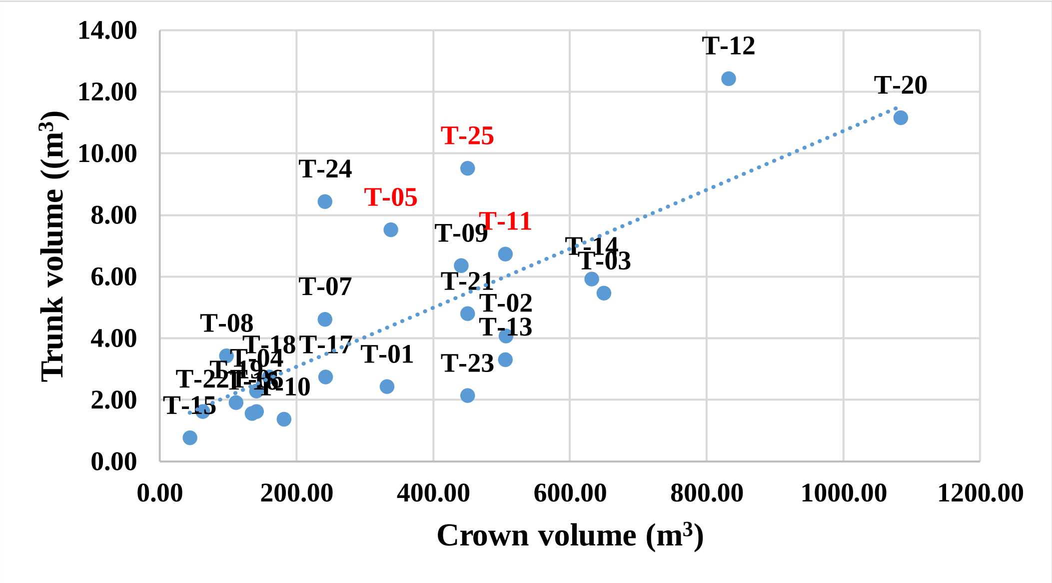

Fig. 18. Regression graph of trees located at Thrikadeeri showing the CPTs selected

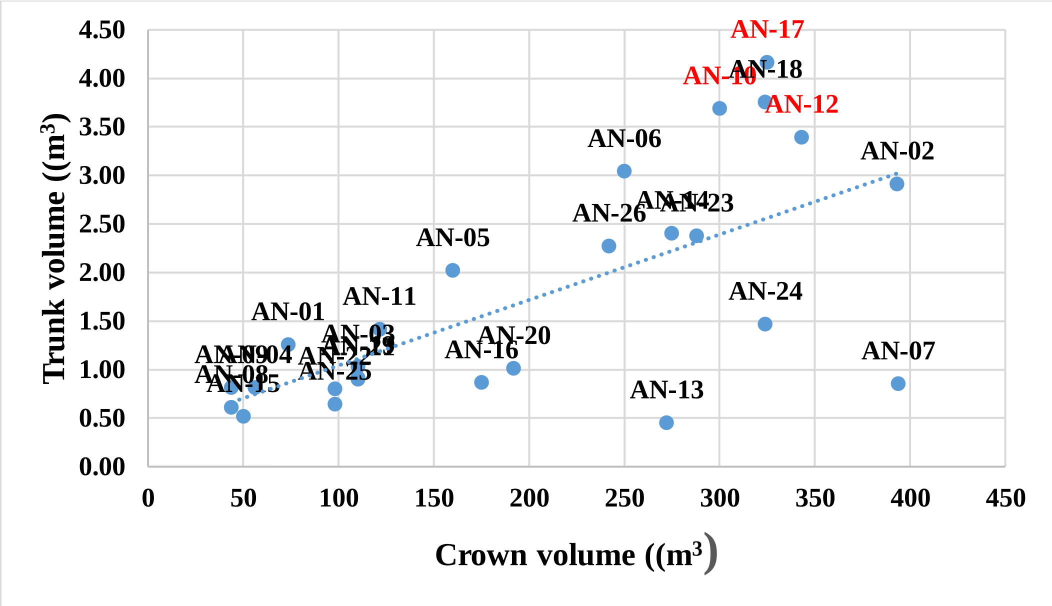

Fig. 19. Regression graph of trees located at Ananganadi showing the CPTs selected

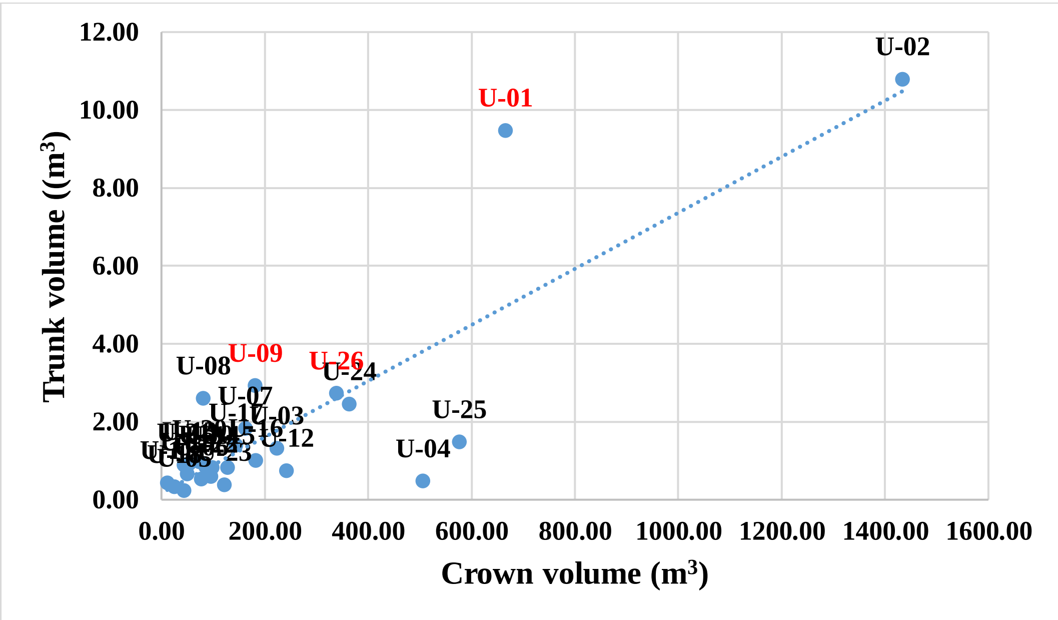

Fig. 20. Regression graph of trees located at Urakam showing the CPTs selected

Table 1. Details of enumerated trees for selection of candidate plus trees of *Ailanthus triphysa*

Panchayats	No. of trees	Height (m)			GBH (m)			Crown width (m)			Clean bole height (m)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Anthikad	24	14	26	20.5	0.5	1.1	0.7	2	8.0	4.9	4	17	10.6
Manalur	25	16	28	21.0	0.6	0.9	0.6	2.5	8.5	4.3	8	18	13.3
Pudukkad	26	16	37	26.5	0.5	1.3	0.9	3.5	8.5	6	7	24	16.7
Chalakudy	30	13	37	28.7	0.5	2.0	1.0	2.5	11	6.6	6	24	15.2
Wadakkanchery	25	15	33	25.2	0.5	1.7	1.0	2.5	9.5	5.1	4	21	14.2
Vengara	26	15	28	20.2	0.5	1.3	0.7	1.8	9.9	3.7	3	18	8.1
Parappur	22	17	27	23.1	0.5	1.1	0.8	2.2	7.5	4.2	6	19	13.0
Thrikadeeri	25	21	34	27.1	0.6	1.9	1.2	2.5	9.5	6	13	23	18.3
Ananganadi	26	16	35	25.3	0.5	1.1	0.8	2.5	7.5	4.5	7	24	16.4
Urakam	26	10	23	17.9	0.5	2.2	0.9	1.5	10.5	4.7	3	18	10.2

FCV-AT-21

FCV-AT-22 (Anthikad)

FCV-AT-23

FCV-AT-24 (Manalur)

FCV-AT-25 (Manalur)

Plate 8. Plus trees selected from Thrissur district

FCV-AT-26 (Manalur)

FCV-AT-27 (Pudukkad)

FCV-AT-28 (Pudukkad)

FCV-AT-29 (Pudukkad)

FCV-AT-30 (Chalakudy)

Plate 9. Plus trees selected from Thrissur district

FCV-AT-31 (Chalakudy)

FCV-AT-32 (Chalakudy)

FCV-AT-33

FCV-AT-34 (Wadakkanchery)

FCV-AT-35

Plate 10. Plus trees selected from Thrissur district



FCV-AT-36 FCV-AT-37 FCV-AT-38

(Vengara)



FCV-AT-39 FCV-AT-40 FCV-AT-41

(Parappur)

Plate 11. Plus trees selected from Malappuram district

FCV-AT-42

FCV-AT-43
(Thrikadeeri)

FCV-AT-44

FCV-AT-45

FCV-AT-46
(Ananganadi)

FCV-AT-47

Plate 12. Plus trees selected from Palakkad district

FCV-AT-48 (Urakam)

FCV-AT-49 (Urakam)

FCV-AT-50 (Urakam)

Plate 13. Plus trees selected from Malappuram district

Table 2. List of thirty selected plus trees of *Ailanthus triphysa* from different locations based on morphological characters

.	Locality	Tree ID	Accession No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
Low lands (Below 7.5 m)	Anthikad	A-10	FCV-AT-21	10°27′58.18″ 076°07′18.44″	25	1.02	7.5	9
		A-12	FCV-AT-22	10°27′57.67″ 076°07′16.96″	22	0.93	6.5	10
		A-19	FCV-AT-23	10°28′03.45″ 076°07′28.32″	26	0.95	6	17
	Manalur	M-05	FCV-AT-24	10°29′58.28″ 076°06′30.33″	25	0.82	7.5	17
		M-10	FCV-AT-25	10°29′57.26″ 076°06′31.15″	23	0.9	4.5	14
		M-21	FCV-AT-26	10°29′55.95″ 076°06′07.81″	25	0.88	4.5	18
Mid lands (Between 7.5 -75 m)	Pudukkad	P-13	FCV-AT-27	10°28′17.86″ 076°18′41.96″	32	1.2	6	16
		P-16	FCV-AT-28	10°28′15.52″ 076°18′46.49″	32	1.15	7.5	24
		P-23	FCV-AT-29	10°28′15.08″ 076°18′44.56″	32	1.1	6	19
	Chalakudy	C-07	FCV-AT-30	10°18′36.52″ 076°18′09.26″	35	1.65	9.5	16
		C-12	FCV-AT-31	10°18′37.01″ 076°18′07.94″	36	2	11	24
		C-25	FCV-AT-32	10°18′54.22″ 076°18′35.88″	37	1.6	9.5	21
	Wadakkanchery	W-06	FCV-AT-33	10°39′54.68″ 076°16′22.07″	31	1.2	5.5	21

		W-16	FCV-AT-34	10°39´59.47″ 076°16´01.58″	32	1.36	6	15
		W-20	FCV-AT-35	10°39´55.62″ 076°16´24.55″	29	1.3	7	16
	Vengara	V-10	FCV-AT-36	11°03´01.45″ 075°57´53.65″	29	1.6	6.5	21
		V-18	FCV-AT-37	11°03´01.24″ 075°57´56.12″	26	1.6	8.5	19
		V-24	FCV-AT-38	11°02´42.06″ 075°56´24.74″	29	1.8	7.5	21
	Parappur	PA-07	FCV-AT-39	11°02´16.91″ 075°59´22.49″	35	1.02	5	23
		PA-16	FCV-AT-40	11°02´08.62″ 075°59´50.68″	31	1.04	7	24
		PA-20	FCV-AT-41	11°01´49.34″ 075°59´51.90″	34	1.1	5	21
High lands (Above 75 m)	Thrikkadeeri I	PA-05	FCV-AT-42	10°50´41.79″ 076°22´21.14″	26	0.9	3.5	18
		T-11	FCV-AT-43	10°50´42.31″ 076°22´21.11″	24	0.9	3.5	7
		T-25	FCV-AT-44	10°50´43.30″ 076°22´22.16″	25	0.69	3.5	16
	Ananganadi	AN-10	FCV-AT-45	10°49´59.31″ 076°20´37.29″	25	1.05	4.5	13
		AN-12	FCV-AT-46	10°49´59.42″ 076°20´37.16″	26	1.01	6.5	14
		AN-17	FCV-AT-47	10°49´59.40″ 076°20´37.73″	26	0.97	5	16
	Urakam	U-01	FCV-AT-48	11°03´02.66″ 075°59´22.00″	21	2.11	9.75	14

		U-09	FCV-AT-49	11°03´03.17″ 075°59´42.17″	23	1.12	5.5	17
		U-26	FCV-AT-50	11°02´00.75″ 075°59´55.58″	20	1.16	6.5	12
Mean					28.17	1.21	6.37	17.38
Standard Deviation					4.76	0.36	1.93	4.20
Coefficient of Variation (%)					16.89	29.84	30.34	24.19

4.2. VARIATIONS OBSERVED IN THE PLUS TREES SELECTED

4.2.1. Quantitative characters

The data showing observations on all quantitative characters of all the plus trees is provided in Table 2.

4.2.1.1 Tree height

The variation in height was in the range of 20 m (FCV-AT-50) to 37 m (FCV-AT-32). The average height measured for the plus trees was 28.07 m. A total number of fourteen trees had height above the mean value. The standard deviation was 4.76 m and the coefficient of variation was 16.89 %.

4.2.1.2. Girth at breast height (GBH)

The variation in girth at breast height was in the range of 0.69 m (FCV-AT-44) to 2.11 m (FCV-AT-48). The average girth estimated was 1.20 m. Eleven CPTs were having higher a value above the average mean. The standard deviation and coefficient of variation were 0.36 m and 29.84 % respectively.

4.2.1.3. Crown width

The average crown width for CPTs was 6.41 m and the variation ranges from 3.5 m (FCV-AT-42), (FCV-AT-43) and (FCV-AT-44) to 9.75 m (FCV-AT- 48). Fifteen of the CPTs had crown width above the average mean. The standard deviation was 1.93 m and the coefficient of variation was 30.34 %.

4.2.1.4 Clean bole height (CBH)

A wide range of variation is observed in clean bole height, i.e., 7 m (FCV-AT-43) to 24 m (FCV-AT-31) and FCV-AT-40). The average clean bole height for all the CPTs was 17.10 m. A total number of twelve CPTs were above the calculated mean. The standard deviation and coefficient of variation were 4.20 m and 24.19 % respectively.

4.2.2. Correlation between quantitative characters

The correlation between the quantitative characters of all the plus trees is given in Table 3. A significant correlation was observed in the height of the tree and clean bole height and Girth at breast height (GBH) with crown width at 0.01 level.

4.2.3. Qualitative characters

The scores for the qualitative characters of all the plus trees located in different localities are given in Table 4. For the characters such as verticality, straightness, cross section, forking, foliar damage, stem damage, branch angle and self-pruning ability, it was observed that the variations were very less among the trees selected. Maximum variations were shown for the character apical dominance, and forking. Data indicated that the highest score (48) was for the plus trees FCV-AT-24, FCV-AT-26 (Manalur), FCV-AT-27 (Pudukkad), FCV-AT-35 (Wadakancherry), FCV-AT-41 (Parappur), FCV-AT-42 (Thrikadeeri) and FCV-AT-46 (Ananganadi). The tree FCV-AT-22 (Anthikad) and FCV-AT-29 (Pudukkad) had the lowest score (42). The values showed that not much variations existed for the qualitative character of the trees.

Table 3. Correlations of quantitative characters of candidate plus trees of *Ailanthus triphysa*

Parameters	Height (m)	GBH (m)	Crown width (m)	Clean bole height (m)
Height (m)	1			
GBH (m)	0.336	1		
Crown width (m)	0.337	0.794**	1	
Clean bole height (m)	0.682**	0.306	0.271	1

**. Significant at 0.01 level

*. Significant at 0.05 level

Table 4. Scoring for qualitative characters of CPTs of *Ailanthus triphysa*

Sl. No.	Accession No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	FCV-AT-21	2	4	5	5	12	3	4	6	2	2	45
2	FCV-AT-22	2	4	8	5	6	3	4	6	2	2	42
3	FCV-AT-23	2	4	8	5	12	3	4	6	2	2	46
4	FCV-AT-24	2	4	8	5	12	3	4	6	2	2	48
5	FCV-AT-25	2	3	8	3	12	3	4	6	2	2	45
6	FCV-AT-26	2	4	8	5	12	3	4	6	2	2	48
7	FCV-AT-27	2	4	8	5	12	3	4	6	2	2	48
8	FCV-AT-28	2	4	5	5	12	3	4	6	2	2	45
9	FCV-AT-29	2	4	8	5	6	3	4	6	2	2	42
10	FCV-AT-30	2	4	5	5	12	3	4	6	1	2	44
11	FCV-AT-31	2	4	8	5	12	3	4	6	1	2	47
12	FCV-AT-32	2	4	8	5	12	3	4	1	2	2	43
13	FCV-AT-33	2	3	5	5	12	3	4	6	2	2	44
14	FCV-AT-34	2	3	8	5	12	3	4	6	1	1	45
15	FCV-AT-35	2	4	8	5	12	3	4	6	2	2	48

16	FCV-AT-36	2	3	8	5	12	3	1	6	1	2	43
17	FCV-AT-37	2	4	8	5	12	1	4	6	2	2	46
18	FCV-AT-38	2	3	8	3	12	3	4	6	2	2	45
19	FCV-AT-39	2	3	8	3	12	1	4	6	2	2	43
20	FCV-AT-40	2	3	8	5	12	1	4	6	2	2	45
21	FCV-AT-41	2	4	8	5	12	3	4	6	2	2	48
22	FCV-AT-42	2	4	8	5	12	3	4	6	2	2	48
23	FCV-AT-43	2	3	5	5	12	3	4	6	2	2	44
24	FCV-AT-44	2	3	8	5	12	3	4	6	2	2	47
25	FCV-AT-45	2	4	5	5	12	3	4	6	2	2	45
26	FCV-AT-46	2	4	8	5	12	3	4	6	2	2	48
27	FCV-AT-47	2	3	8	3	12	1	4	6	2	2	43
28	FCV-AT-48	2	4	5	5	12	3	4	6	2	2	45
29	FCV-AT-49	2	4	5	5	12	1	4	6	2	2	43
30	FCV-AT-50	2	3	8	3	12	3	4	6	2	2	45

4.3. DIVERSITY ANALYSIS OF THE PLUS TREES

4.3.1. Cluster analysis

A hierarchical cluster analysis was carried out for morphological characters of the thirty selected candidate plus trees using squared Euclidean distance. Thirty candidate plus trees were grouped into nine clusters. The quantitative characters such as tree height, girth at breast height, crown width and clear bole height and qualitative characters like straightness, apical dominance, forking, branch angle, foliar damage, stem damage, cross section and bole swelling were considered and dendrogram was formulated.

Details of the nine clusters are given in Table 5. The CPTs grouped in a cluster have similar morphological characters where as it differs between two clusters. From the table, the cluster I had maximum number of CPTs with 15 accessions whereas the least number observed for the cluster VII, VIII and IX respectively as they contained only one accession. So, the CPTs of FCV-AT-32 (Chalakudy), FCV-AT-34 (Wadakancherry) and FCV-AT-36 (Vengara) were unique in their morphological traits.

4.3.1.1. Cluster I

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 25 m, 1.2 m, 7.5 m, 17 m, 4, 8, 5, 12, 3, 4, 6, 2 and 2 respectively (Table 6).

4.3.1.2. Cluster II

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 23.5 m, 1.85 m, 9.1 m, 16.5 m, 4, 8, 5, 12, 2, 4, 6, 2 and 2 respectively. The lowest height of the tree and highest GBH was recorded in this cluster (Table 6).

4.3.1.3. Cluster III

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 25.5 m, 0.9 m, 4.7 m, 16 m, 3, 8, 3, 12, 3, 4, 6, 2 and 2 respectively. The lowest crown width was observed in this cluster (Table 6).

4.3.1.4. Cluster IV

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 33 m, 1.03 m, 6 m, 23.5 m, 3, 8, 4, 12, 1, 4, 6, 2 and 2 respectively. The highest value for clean bole height was observed in this cluster IV (Table 6).

4.3.1.5. Cluster V

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 27 m, 1.02 m, 6.25 m, 14.5 m, 4, 8, 5, 6, 3, 4, 6, 2 and 2 respectively. The lowest GBH was recorded in cluster this cluster V.

4.3.1.6. Cluster VI

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in this cluster were 35.5 m, 1.83 m, 10.25 m, 20 m, 4, 6.5, 5, 12, 1, 4, 6, 1 and 2 respectively (Table 6).

4.3.1.7. Cluster VII

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees were 37 m, 1.6 m, 9.5 m, 21 m, 4, 8, 5, 12, 3, 4, 1, 2 and 2 respectively. The highest average height of the tree was observed in this cluster (Table 6).

4.3.1.8. Cluster VIII

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees were 32 m, 1.36 m, 6 m, 15 m, 3, 8, 5, 12, 3, 4, 6, 1 and 1 respectively (Table 6).

4.3.1.9. Cluster IX

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of the plus trees in cluster was 29 m, 1.6 m, 6.5 m, 21 m, 3, 8, 5, 12, 3, 1, 6, 1 and 2 respectively (Table 6).

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of plus trees for all the clusters was 29.72 m, 1.38 m, 7.31 m, 18.28 m, 3.56, 7.83, 4.67, 11.33, 2.67, 3.67, 5.44, 1.67 and 1.89 respectively. The coefficient of variation values for all the clusters showed that the variations were low to moderate for all the characters. The highest CV (%) value was observed for the character stem damage (30.61 %) and the lowest was apical dominance (8.33).

The mean intra and inter cluster distances is presented in Table 7. Intra cluster distance gives the mean distance between the elements within a cluster, whereas the distance between the two clusters gives the inter cluster distance. The diagonal elements show the intra cluster distances and the off-diagonal elements show the inter cluster distances. It is observed that intra cluster distances varied from 0.00 to 2.07. The highest intra cluster value was obtained for cluster I (2.07) followed by cluster II (1.79), cluster V (1.72), cluster III (1.57), cluster IV (1.50) and cluster VI (1.49). No intra cluster distance was observed for Clusters VII, VIII and IX as they contained only one accessions. From the inter cluster distance, the highest inter cluster distance was shown by cluster V and VI (8.91) followed by cluster V and VII (8.82) and cluster II and VII (7.95).

Table 5. Clusters analysis of *Ailanthus triphysa* based on morphological characters

Cluster I	FCV-AT-21, FCV-AT-23, FCV-AT-24, V, FCV-AT-26, FCV-AT-27, FCV-AT-28, FCV-AT-33, FCV-AT-35, FCV-AT-41, FCV-AT-43, FCV-AT-44, FCV-AT-45, FCV-AT-46, FCV-AT-48, FCV-AT-49
Cluster II	FCV-AT-37, FCV-AT-42
Cluster III	FCV-AT-25, FCV-AT-38, FCV-AT-47, FCV-AT-50
Cluster IV	FCV-AT-39, FCV-AT-40
Cluster V	FCV-AT-22, FCV-AT-29.
Cluster VI	FCV-AT-30, FCV-AT-31
Cluster VII	FCV-AT-32
Cluster VIII	FCV-AT-34
Cluster IX	FCV-AT-36

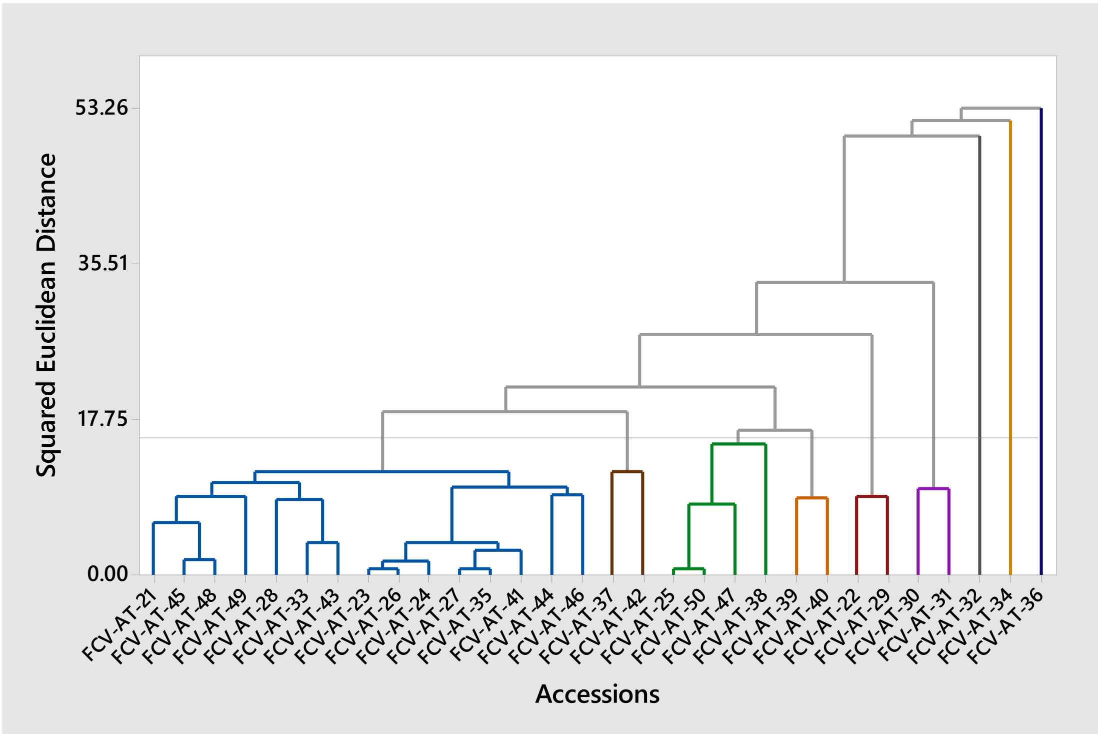

Fig. 21. The dendrogram on morphological characteristics of 30 CPTs of *Ailanthus triphysa*

Table 6. Clusters modes of morphological characters of *Ailanthus triphysa*

Variables	Cl I	Cl II	Cl III	Cl IV	Cl V	Cl VI	Cl VII	Cl VIII	Cl IX	Mean	SE	SD	CV (%)
Height	25	23.5	25.5	33	27	35.5	37	32	29	29.7	1.55	4.86	16.37
GBH	1.2	1.85	0.9	1.03	1.02	1.83	1.6	1.36	1.6	1.38	0.12	0.36	26.01
Crown width	7.5	9.1	4.7	6	6.25	10.25	9.5	6	6.5	7.31	0.63	1.90	26.01
CBH	17	16.5	16	23.5	14.5	20	21	15	21	18.2	1.06	3.18	17.38
Straightness	4	4	3	3	4	4	4	3	3	3.56	0.17	0.51	14.34
Apical dominance	8	8	8	8	8	6.5	8	8	8	7.83	0.21	0.64	8.17
Forking	5	5	3	4	5	5	5	5	5	4.67	0.24	0.71	15.15
Branch angle	12	12	12	12	6	12	12	12	12	11.3	0.67	2.00	17.65
Self-pruning	3	2	3	1	3	3	3	3	3	2.67	0.23	0.69	25.85
Foliar-damage	4	4	4	4	4	4	4	4	1	3.67	0.33	1.00	27.27
Stem damage	6	6	6	6	6	6	1	6	6	5.44	0.56	1.67	30.61
Cross section	2	2	2	2	2	1	2	1	1	1.67	0.17	0.50	30.00
Bole swelling	2	2	2	2	2	2	2	1	2	1.89	0.11	0.33	17.65

Table 7. Matrix showing inter and intra cluster distance of *Ailanthus triphysa* based on morphological characters

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Cluster I	2.07								
Cluster II	4.12	1.79							
Cluster III	3.34	5.27	1.57						
Cluster IV	4.79	6.28	6.12	1.50					
Cluster V	6.59	7.60	7.45	6.35	1.72				
Cluster VI	6.64	7.76	6.96	6.62	8.91	1.49			
Cluster VII	6.79	7.95	7.05	6.45	8.82	7.92	0.00		
Cluster VIII	3.35	5.08	4.56	4.34	6.45	7.23	7.01	0.00	
Cluster IX	4.02	5.85	3.26	5.77	7.06	7.19	7.12	4.72	0.00

4.3.2. Principal component analysis (PCA)

4.3.2.1 Morphological features

PCA was conducted to study the variations and bring out strong patterns in the data set of independent variables. Scree plot showed that five components had eigen value greater than one, which accounts for 70 % of the total variability (Fig. 22). The explanation was done with two components only (Table 8). These two components together accounted for 39.5 % of the total variability. PC1 accounted for 23.2 % of the total variability, which was mainly contributed positively by GBH, crown width, height, clean bole height, forking, self-pruning, branch angle, straightness and apical dominance. PC2 accounted for 16.3 % of the total variability, which was mainly contributed positively by straightness, forking, self-pruning, foliar damage, crown width, bole swelling, cross section and GBH.

The PCA biplot (Fig. 23) presented both the samples PC scores and variable loads. As the vectors move away from the origin of the PC, the more they influence the PC. Loading plots also explains how different variables correlate with each other, if two variables form an angle less than 90°, this implies that they are positively correlated. If the angle of the variables is 180, they are negatively correlated. If the angle was 90°, then this implies that there is no relationship between the two characteristics. The component loading plot is given in Fig. 23 showed that there was a positive relationship between heights and clean bole height (CBH), GBH and crown width, straightness and forking, foliar damage and cross section and cross section and bole swelling. On the other hand, characters like height and cross section, GBH and cross section and crown width and cross section showed a negative association. Based on the first two components of the PC analysis grouping pattern was prepared. Thirty CPTs were classified into four groups (Fig. 24), in which the relative positions of various accessions were graphically represented. It was observed that group IV had maximum and group III had a minimum number of accessions under it.

4.3.3. Selection index

The selection index value was worked out for the best plus trees based on the morphological characters of the trees using principal component analysis (Table 9). The first principal component was taken as the index value for selection.

Best plus tree = 0.403 x height of the tree + 0.473 x GBH + 0.449 x crown width + 0.313 x clean bole height + 0.077 x straightness + 0.048 x apical dominance + 0.184 x forking + -0.082 x branch angle + 0.096 x self- pruning ability - 0.18 x foliar damage - 0.217 x stem damage - 0.402 x cross section - 0.122 x bole swelling.

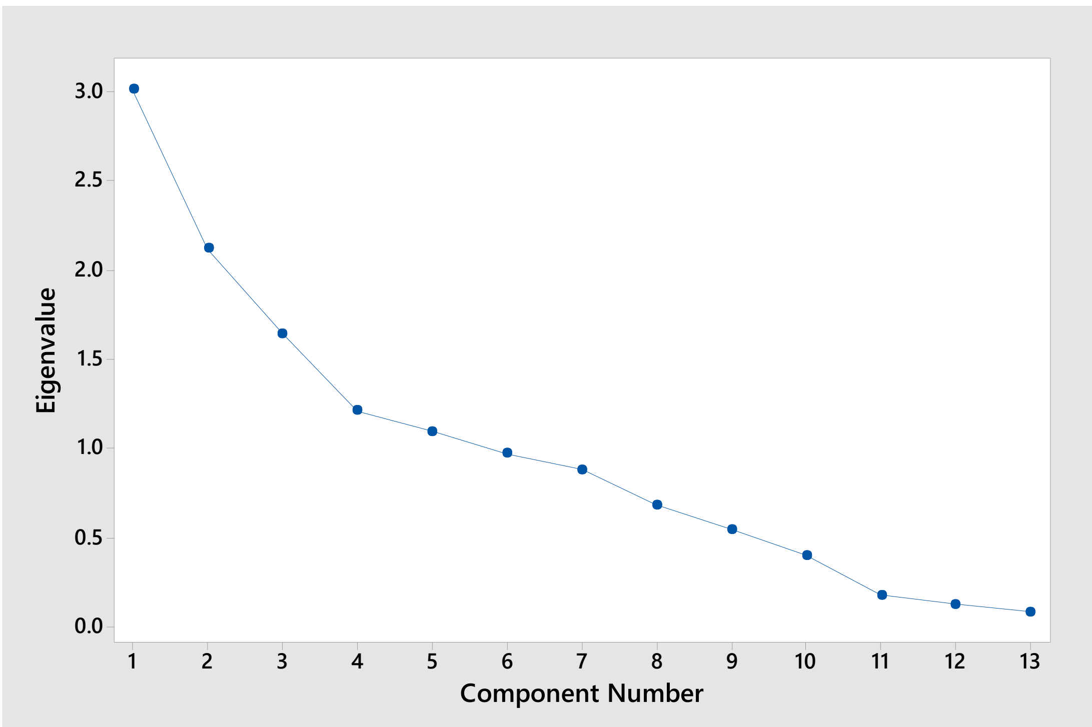

Fig. 22. Scree plot of morphological characters of selected plus trees of *Ailanthus triphysa*

Table 8. Variations in the morphological characters of selected plus trees of *Ailanthus triphysa* using Principal component analysis

Variables	PC1 (Loading values)	PC2 (Loading values)
Height	0.403	-0.14
GBH	0.473	0.029
Crown width	0.449	0.185
CBH	0.313	-0.303
Straightness	0.077	0.576
Apical dominance	0.048	-0.221
Forking	0.184	0.494
Branch Angle	0.082	-0.224
Self – pruning	0.096	0.315
Foliar damage	-0.18	0.189
Stem damage	-0.217	-0.085
Cross section	-0.402	0.121
Bole swelling	-0.122	0.145

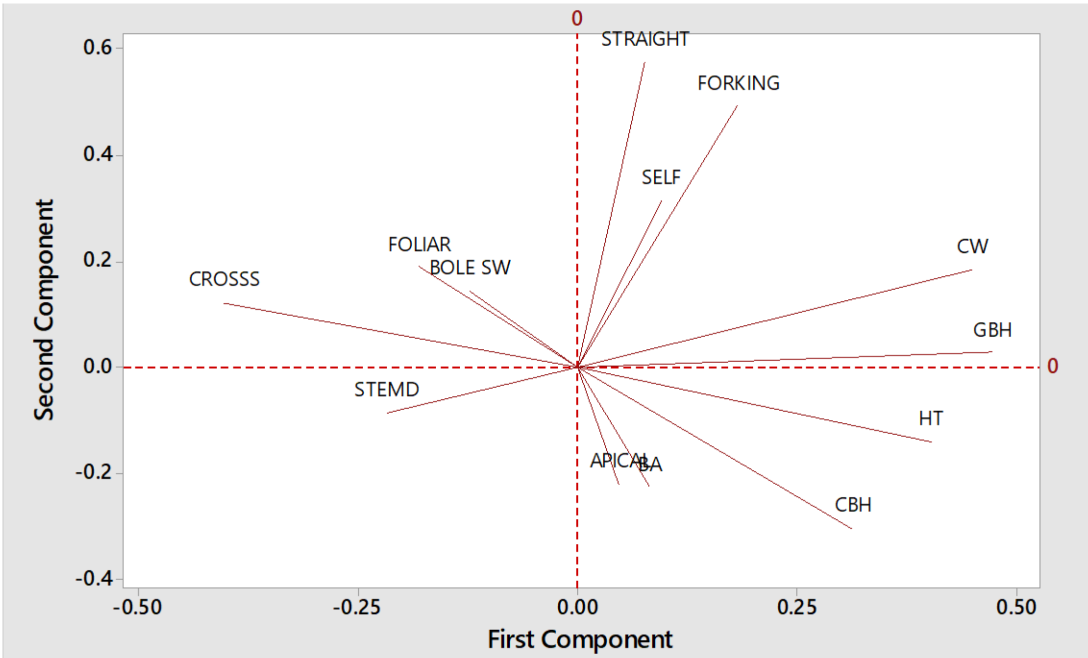

Fig. 23. Loading plot of morphological characters of selected plus trees of *Ailanthus triphysa*

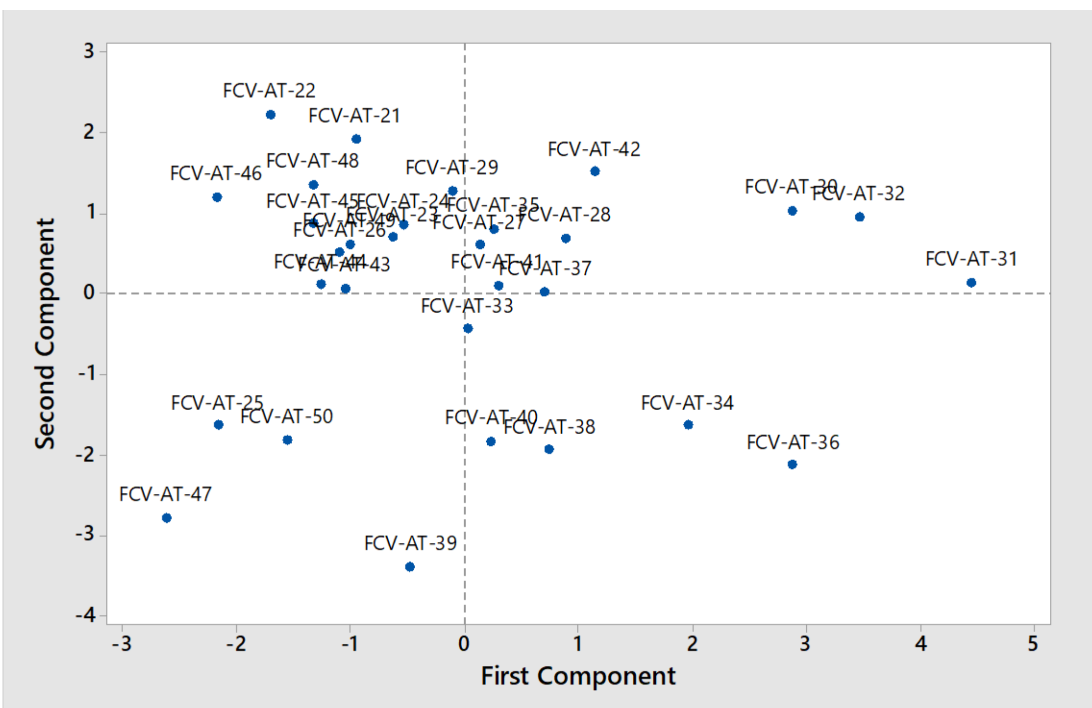

Fig. 24. Grouping of 30 plus trees of *Ailanthus triphysa* based on morphological characters from two components

Table 9. Selection Index of selected plus trees of *Ailanthus triphysa* using PC1 of Principal component analysis

CPTs	PC1
FCV-AT-21	16.41
FCV-AT-22	14.68
FCV-AT-23	18.76
FCV-AT-24	18.97
FCV-AT-25	15.47
FCV-AT-26	17.96
FCV-AT-27	20.98
FCV-AT-28	23.99
FCV-AT-29	21.38
FCV-AT-30	24.23
FCV-AT-31	28.12
FCV-AT-32	27.41
FCV-AT-33	21.70
FCV-AT-34	21.19
FCV-AT-35	20.27
FCV-AT-36	22.61
FCV-AT-37	20.62
FCV-AT-38	21.85
FCV-AT-39	23.21
FCV-AT-40	23.18
FCV-AT-41	22.85
FCV-AT-42	18.03
FCV-AT-43	17.18
FCV-AT-44	15.02

FCV-AT-45	17.78
FCV-AT-46	13.67
FCV-AT-47	16.16
FCV-AT-48	16.33
FCV-AT-49	17.73
FCV-AT-50	17.56

4.4. PROGENY EVALUATION

4.4.1. Morphological characters

4.4.1.1. Seedlings height

The data indicated that the height of all the seedlings of the progenies from selected plus trees after 30 days of transplanting did not differ significantly (Table 10). The progenies FCV-AT-21 and FCV-AT-33 were found superior on the basis of overall mean performance. The standard deviation recorded for this progenies were 0.2 cm and 0.53 cm with 1.79 % and 4.78 % coefficient of variation.

4.4.1.2. Collar diameter

Analysis of variance of the seedling collar diameter is presented in Table 10. The observation of collar diameter showed that the collar diameter of the progenies from different plus trees was significantly different at 0.01 level. The highest value (0.25 mm) was observed for the seedlings of plus tree FCV-AT-36 (Vengara). The collar diameter of the seedlings of plus tree FCV-AT-22 and FCV-AT-24 showed the least value 0.14 mm.

The progenies FCV-AT-36 and FCV-AT-37 showed superiority on the overall mean. The standard deviation was 0.03 cm and 0.02 cm and coefficient of variation were 12.2 % and 8.3 %.

4.4.1.3. Number of leaves

Analysis of the number of leaves of the progeny of plus trees was significantly different at 0.01 level (Table 10). The highest value (6.53) was observed for the seedlings of plus tree FCV-AT-40 (Parappur). The number of the seedlings of plus tree FCV-AT-22 showed the least value 4.33.

The progenies FCV-AT-40 showed superiority above all mean. The standard deviation was 0.31 and the coefficient of variation was 4.7 %

4.4.1.4. Biovolume

The product of stem diameter (mm) x plant height (cm) determined the biovolume. The analysis of variance of the seedling biovolume from different plus trees is presented in Table 10. Analysis of variance showed that the seedlings biovolume of the progenies from selected plus trees after 30 days transplanting had a significant difference at 0.01 level. The highest value (0.32 cm^3) was observed for the seedlings of plus trees FCV-AT-36 and the least value 0.12 cm^3 was observed on FCV-AT-22.

The progenies FCV-AT-36 and FCV-AT-37 showed superiority on the overall mean. The standard deviation were 0.05 cm and 0.02 cm and coefficient of variation were 14.1 % and 9.6 %.

Table 10. Morphological characters of *Ailanthus triphysa* progenies from different plus trees

Progeny	Seedlings height (cm)	Collar diameter (mm)	Number of leaves	Biovolume (cm^3)
FCV-AT-21	11.20 ± 0.20	0.16^{fghij} ± 0.02	4.60^{jkl} ± 0.20	$0.18^{bcdefghi}$ ± 0.03
FCV-AT-22	8.73 ± 0.12	0.14^{j} ± 0.02	4.33^{l} ± 0.23	0.12^{i} ± 0.02
FCV-AT-23	10.73 ± 0.42	0.21^{bcde} ± 0.03	5.47^{cdefg} ± 0.23	0.22^{bcd} ± 0.03
FCV-AT-24	10.00 ± 0.50	0.14^{j} ± 0.02	4.80^{hijkl} ± 0.20	0.13^{hi} ± 0.02
FCV-AT-25	10.13 ± 0.69	0.22^{abc} ± 0.02	5.73^{bc} ± 0.20	0.22^{bc} ± 0.05
FCV-AT-26	9.73 ± 1.60	0.21^{abcd} ± 0.04	4.93^{ghijk} ± 0.12	0.21^{bcdef} ± 0.05
FCV-AT-27	9.80 ± 0.81	0.15^{ij} ± 0.03	5.40^{cdefg} ± 0.50	0.14^{ghi} ± 0.04
FCV-AT-28	10.13 ± 0.40	0.16^{fghij} ± 0.02	5.67^{bcd} ± 0.20	0.16^{defghi} ± 0.06
FCV-AT-29	10.87 ± 2.31	0.20^{bcde} ± 0.02	5.20^{cdefgh} ± 0.50	0.22^{bcd} ± 0.01
FCV-AT-30	10.07 ± 0.64	0.21^{bcde} ± 0.03	5.47^{cdefg} ± 0.40	0.20^{bcdef} ± 0.03
FCV-AT-31	10.80 ± 1.10	$0.19^{cdefghi}$ ± 0.03	4.93^{ghijk} ± 0.31	0.21^{bcde} ± 0.04
FCV-AT-32	10.60 ± 0.69	0.21^{abcd} ± 0.03	5.00^{fghijk} ± 0.40	0.22^{bcd} ± 0.03

FCV-AT-33	11.07 ± 0.53	$0.18^{defghij} \pm 0.01$	$5.53^{cdef} \pm 0.31$	$0.2^{bcdefg} \pm 0.01$
FCV-AT-34	9.60 ± 0.23	$0.17^{defghij} \pm 0.01$	$4.80^{hijkl} \pm 0.35$	$0.17^{cdefghi} \pm 0.01$
FCV-AT-35	9.33 ± 0.40	$0.21^{bcde} \pm 0.03$	$4.47^{kl} \pm 0.31$	$0.2^{bcdefg} \pm 0.04$
FCV-AT-36	9.87 ± 0.42	$0.25^{a} \pm 0.03$	$4.80^{hijkl} \pm 0.53$	$0.32^{a} \pm 0.05$
FCV-AT-37	9.87 ± 0.46	$0.24^{ab} \pm 0.02$	$4.67^{ijkl} \pm 0.23$	$0.24^{b} \pm 0.02$
FCV-AT-38	9.73 ± 0.50	$0.21^{abcd} \pm 0.03$	$4.93^{ghijk} \pm 0.64$	$0.20^{bcdef} \pm 0.01$
FCV-AT-39	10.20 ± 1.79	$0.22^{abc} \pm 0.02$	$6.13^{ab} \pm 0.31$	$0.23^{b} \pm 0.01$
FCV-AT-40	10.33 ± 1.56	$0.2^{cdef} \pm 0.01$	$6.53^{a} \pm 0.31$	$0.20^{bcdef} \pm 0.04$
FCV-AT-41	10.33 ± 1.60	$0.18^{cdefghi} \pm 0.02$	$5.27^{cdefgh} \pm 0.31$	$0.19^{bcdefgh} \pm 0.01$
FCV-AT-42	9.87 ± 1.14	$0.15^{hij} \pm 0.03$	$4.67^{ijkl} \pm 0.46$	$0.15^{fghi} \pm 0.04$
FCV-AT-43	10.67 ± 0.90	$0.17^{efghij} \pm 0.03$	$4.60^{jkl} \pm 0.35$	$0.18^{bcdefghi} \pm 0.03$
FCV-AT-44	10.33 ± 0.70	$0.15^{ghij} \pm 0.03$	$4.47^{kl} \pm 0.23$	$0.16^{efghi} \pm 0.06$
FCV-AT-45	10.00 ± 2.14	$0.19^{cdefghi} \pm 0.02$	$5.07^{efghij} \pm 0.61$	$0.18^{bcdefghi} \pm 0.03$
FCV-AT-46	10.73 ± 2.23	$0.19^{cdefghi} \pm 0.02$	$5.13^{defghij} \pm 0.42$	$0.20^{bcdefg} \pm 0.04$
FCV-AT-47	10.00 ± 1.17	$0.19^{cdefgh} \pm 0.03$	$5.20^{cdefghi} \pm 0.20$	$0.19^{bcdefgh} \pm 0.05$
FCV-AT-48	9.53 ± 1.44	$0.21^{bcde} \pm 0.03$	$5.60^{bcde} \pm 0.20$	$0.2^{bcdefg} \pm 0.06$
FCV-AT-49	9.33 ± 1.42	$0.19^{cdefg} \pm 0.03$	$4.80^{hijkl} \pm 0.20$	$0.18^{bcdefgh} \pm 0.04$
FCV-AT-50	9.53 ± 0.50	$0.17^{defghij} \pm 0.02$	$5.20^{cdefghi} \pm 0.20$	$0.16^{defghi} \pm 0.02$
SEM	0.12	0.004	0.06	0.005
CD (0.05)	-	0.04	0.57	0.06
CV (%)	11.50	18.70	11.26	24.02

*Significant at 0.05 levels

Values with the same superscript in column are homogenous for different parameters are homogenous

4.4.2. Genetic parameters for morphological and growth traits

The data on genetic parameters associated with morphological traits is presented in Table 11.

4.4.2.1. Seedlings height

The genetic parameters for morphological and growth traits after 30 days after transplanting showed that the broad sense heritability for seedlings height was 0.09. The PCV, GCV and ECV were found to be 11.52, 3.63 and 10.93 respectively. The genetic advance for this trait was 0.10 and the genetic gain was 2.35, which was found to be the lowest of all traits. The selection was assumed at 5% intensity.

4.4.2.2. Collar diameter

For the collar diameter, the broad sense heritability was observed to be 0.4. The values of PCV, GCV and ECV were 21.60, 13.66 and 16.73 respectively. Genetic advance for this trait was 0.03 and genetic gain was 15.43. The genetic advance for this character was observed to be the least when compared to the values for other traits.

4.4.2.3. Number of leaves

Broad sense heritability for the number of leaves was observed to be 0.64 which was found to be the highest heritability value. The values for PCV, GCV and ECV were 11.34, 9.07 and 6.80 respectively. The highest genetic advance 0.76 was recorded for the number of leaves with genetic gain of 14.96.

4.4.2.4. Biovolume

The broad sense heritability for this trait was 0.5. The values for PCV, GCV and ECV were observed to be 23.1, 16.33 and 16.33 respectively. The genetic advance observed was 0.05. The highest genetic gain 26.60 was found in this trait.

Table 11. Estimated genetic parameters of morphometrical traits of *Ailanthus triphysa* plus trees.

Parameters	H^2	PCV	GCV	ECV	Genetic advance	Genetic gain
Seedlings height	0.09	11.52	3.63	10.93	0.10	2.35
Collar diameter	0.4	21.60	13.66	16.73	0.03	15.43
Number of leaves	0.64	11.34	9.07	6.80	0.76	14.96
Biovolume	0.5	23.1	16.33	16.33	0.05	26.60

4.4.3. Physiological parameters

Significant differences in photosynthetic rate, stomatal conductance, transpiration rate, leaf temperature and relative water content were observed for the progenies from different plus trees at 30 DAT (Table 12).

4.4.3.1. Photosynthetic rate

The data presented in Table 12 shows the estimation of the photosynthetic rate (µmol CO_2 $m^{-2}s^{-1}$) of different progenies of CPTs selected. Among the progenies, FCV-AT-35 (4.74 µmol CO_2 $m^{-2}s^{-1}$) CPTs from Wadakancherry recorded the highest photosynthetic rate followed by FCV-AT-41 (4.31 µmol CO_2 $m^{-2}s^{-1}$), FCV-AT-40 (4.29 µmol CO_2 $m^{-2}s^{-1}$) and FCV-AT-23 (4.29 µmol CO_2 $m^{-2}s^{-1}$). FCV-AT-50 (1.74 µmol CO_2 $m^{-2}s^{-1}$) recorded the lowest photosynthetic rate which was on par with FCV-AT-26, FCV-AT-33 and FCV-AT-48 with values of 1.88 µmol CO_2 $m^{-2}s^{-1}$.

4.4.3.2. Stomatal conductance

The data presented in Table 12 shows the estimation of stomatal conductance (mmol H_2O $cm^{-2}s^{-1}$) of different progenies of CPTs selected. The highest stomatal conductance was observed for the progenies of the plus tree FCV-AT-36 (0.67 mmol H_2O $cm^{-2}s^{-1}$) followed by FCV-AT-39 (0.66 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-43 (0.66 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-35 (0.65 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-33 (0.63 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-42 (0.63 mmol H_2O $cm^{-2}s^{-1}$) and FCV-AT-45 (0.61 mmol H_2O $cm^{-2}s^{-1}$).The lowest value 0.22 mmol H_2O $cm^{-2}s^{-1}$ was observed for the progenies of the plus tree FCV-AT-21 which was on par with FCV-AT-46 (0.23 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-40 (0.25 mmol H_2O $cm^{-2}s^{-1}$) and FCV-AT-50 (0.26 mmol H_2O $cm^{-2}s^{-1}$).

4.4.3.3. Transpiration rate

The data presented in Table 12 shows the estimation of transpiration rate (mmol H_2O $cm^{-2}s^{-1}$) of different progenies of CPTs selected. Highest transpiration rate was observed for the progenies FCV-AT-39 (4.10 mmol H_2O $cm^{-2}s^{-1}$) followed by FCV-AT-35 (3.73 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-24 (3.68 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-29 (3.67 mmol H_2O $cm^{-2}s^{-1}$) and FCV-AT-40 (3.56 mmol H_2O $cm^{-2}s^{-1}$). The lowest value was observed for the progenies FCV-AT-42 (1.34 mmol H_2O $cm^{-2}s^{-1}$) which was on par with FCV-AT-46, FCV-AT-47 (1.36 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-37 (1.39 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-48 (1.44 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-31 (1.43 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-43, FCV-AT-26 (1.46), FCV-AT-27 (1.52 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-49 (1.57 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-50 (1.65 mmol H_2O $cm^{-2}s^{-1}$), FCV-AT-36 (1.69 mmol H_2O $cm^{-2}s^{-1}$) and FCV-AT-21 (1.74 mmol H_2O $cm^{-2}s^{-1}$).

4.4.3.4. Leaf temperature

The data presented in Table 12 shows the estimation of leaf temperature (°C) of different progenies of CPTs selected. The highest leaf temperature was observed for the seedlings of plus trees FCV-AT-43 (38.41°C) followed by FCV-AT-42 (38.31°C), FCV-AT-38 (38.25°C), FCV-AT-28 (38.03°C), FCV-AT-27 (37.85°C), FCV-AT-45 (37.85°C) and FCV-AT-35 (37.82°C). The lowest value was observed for the seedlings of plus trees FCV-AT-22 and FCV-AT-49 (33.26°C).

4.4.3.5. Relative water content

The data presented in Table 12 shows the estimation of relative water content (%) of different progenies of plus trees. The highest relative water content was observed for the seedlings FCV-AT-25 (86.25 %) followed by FCV-AT-33 (85.52 %) and FCV-AT-23 (85.02 %). The lowest value was obtained for the leaves of the seedlings from plus trees FCV-AT-40 (61.57 %).

Table 12. Physiological characters of *Ailanthus triphysa* progenies from different plus trees

Progeny	Photosynthe-sis (µmol CO_2 $m^{-2}s^{-1}$)	Stomatal conductanc-e (mmol H_2O cm^{-2} s^{-1})	Transpiration rate (mmol H_2O $cm^{-2}s^{-1}$)	Leaf temperature (°C)	Relative water content (%)
FCV-AT-21	4.19^{cd}	0.22^{m}	1.74^{d}	33.51^{o}	81.64^{bcd}
FCV-AT-22	3.05^{k}	0.27^{kl}	2.58^{c}	33.65^{o}	83.80^{ab}
FCV-AT-23	4.29^{bc}	0.34^{hi}	2.68^{c}	33.26^{p}	85.02^{ab}
FCV-AT-24	2.03^{o}	0.43^{ef}	3.68^{ab}	35.35^{jk}	79.36^{cde}
FCV-AT-25	2.67^{m}	0.56^{d}	3.35^{b}	34.92^{l}	86.25^{a}
FCV-AT-26	1.88^{p}	0.34^{hij}	1.46^{d}	36.12^{gh}	83.15^{abc}
FCV-AT-27	3.28^{hi}	0.31^{ij}	1.52^{d}	37.85^{bc}	75.31^{efg}
FCV-AT-28	3.1^{k}	0.25^{lm}	3.54^{b}	38.03^{b}	82.65^{abc}
FCV-AT-29	2.79^{l}	0.36^{gh}	3.67^{ab}	35.55^{j}	82.24^{abc}
FCV-AT-30	2.28^{n}	0.36^{gh}	1.43^{d}	35.92^{I}	77.22^{ef}
FCV-AT-31	2.03^{o}	0.47^{e}	1.73^{d}	34.66^{m}	75.97^{ef}
FCV-AT-32	2.67^{m}	0.43^{e}	2.49^{c}	36.21^{fgh}	75.76^{ef}

FCV-AT-33	1.88^{p}	0.63^{ab}	3.28^{b}	36.32^{fg}	85.52^{ab}
FCV-AT-34	4.05^{ef}	0.45^{e}	3.45^{b}	37.45^{d}	76.03^{ef}
FCV-AT-35	4.74^{a}	0.65^{ab}	3.73^{ab}	37.82^{c}	76.74^{ef}
FCV-AT-36	3.09^{k}	0.67^{a}	1.69^{d}	38.03^{b}	75.34^{efg}
FCV-AT-37	3.39^{h}	0.39^{fg}	1.39^{d}	36.10^{hi}	67.22^{jk}
FCV-AT-38	3.66^{g}	0.59^{cd}	2.56^{c}	38.25^{a}	76.38^{ef}
FCV-AT-39	4.12^{de}	0.66^{a}	4.10^{a}	36.33^{f}	74.62^{fgh}
FCV-AT-40	4.29^{bc}	0.34^{hi}	3.56^{ab}	36.29^{fgh}	61.57^{l}
FCV-AT-41	4.31^{b}	0.43^{ef}	2.58^{c}	35.32^{k}	76.3^{ef}
FCV-AT-42	3.95^{f}	0.63^{ab}	1.34^{d}	38.31^{a}	75.99^{ef}
FCV-AT-43	3.59^{g}	0.66^{a}	1.46^{d}	38.41^{a}	77.98^{def}
FCV-AT-44	3.23^{ij}	0.34^{hij}	2.63^{c}	37.2^{e}	71.53^{ghi}
FCV-AT-45	2.61^{m}	0.61^{bc}	2.60^{c}	37.85^{bc}	79.45^{cde}
FCV-AT-46	2.84^{l}	0.23^{lm}	1.36^{d}	34.51^{m}	74.16^{fgh}
FCV-AT-47	3.15^{jk}	0.37^{gh}	1.36^{d}	33.65^{o}	70.81^{hij}
FCV-AT-48	1.88^{p}	0.29^{jk}	1.44^{d}	35.35^{jk}	65.77^{k}
FCV-AT-49	2.03^{o}	0.35^{ghi}	1.57^{d}	33.26^{p}	67.14^{jk}
FCV-AT-50	1.74^{q}	$0.26k^{lm}$	1.65^{d}	33.98^{n}	$69.46i^{jk}$
SEM	0.09	0.02	0.1	0.18	0.68
CD (0.05)	0.11	0.04	0.55	0.2	4.19
CV (%)	28.32	34.42	40.15	4.61	8.42

*. Significant at 0.05 levels

Values with the same superscript in column are homogenous for different parameters are homogenous

4.4.4. Genetic parameters for physiological traits

The data on genetic variation for the physiological character of different plus trees is presented in Table 13.

4.4.4.1. Photosynthetic rate

The genetic parameters for the physiological traits of seedlings 30 DAT showed that the broad sense heritability for photosynthetic rate was 0.99. The genetic advance and genetic gain were observed to be 1.80 and 58.24 respectively.

4.4.4.2. Stomatal conductance

Broad-sense heritability value was observed to be 0.95 for this character. The genetic advance was estimated to be 0.30 which was found to be the least among all the traits and genetic gain was observed to be 68.80.

4.4.4.3. Transpiration rate

The value for the broad sense heritability was observed to be 0.96 for this trait. The genetic advance was observed to be 1.74 and showed the highest value of genetic gain 72.72 respectively.

4.4.4.4. Leaf temperature

For the broad sense heritability, the highest value 0.99 was observed among all the traits. The genetic advance and genetic gain observed for these traits were 3.40 and 9.45 respectively.

4.4.4.5. Relative water content

The broad sense heritability 0.84 was found to be the least among all the characters studied. But the genetic advance showed the highest value of 11.19 and genetic gain of 14.69 respectively.

Table 13. Estimated genetic parameters of physiological traits of *Ailanthus triphysa*

Parameters	H^2	PCV	GCV	ECV	Genetic advance	Genetic gain
Photosynthesis	0.99	28.65	28.56	2.29	1.80	58.24
Stomatal conductance	0.95	34.83	34.04	7.37	0.30	68.80
Transpiration rate	0.88	40.53	38.01	14.08	1.74	72.72
Leaf temperature	0.99	4.67	4.65	0.34	3.40	9.45
Relative water content	0.84	8.52	7.83	3.36	11.19	14.69

4.4.5. Correlation study of the morphological and physiological characters of the progenies

Correlation analysis of the morphological and physiological traits of progenies of the selected plus trees was presented in Table 14. It was observed that the height of the seedlings had significant positive relationships with biovolume (0.642^{**}) and collar diameter (0.213^{*}) while no correlation was observed with the physiological characters. Collar diameter of the seedlings had positive significant correlation with the biovolume (0.878^{**}) and stomatal conductance (0.252^{*}) of the leaves of seedlings. It was not related to the number of leaves, photosynthesis, transpiration, leaf temperature, relative water content. The number of leaves was found to be positively related to transpiration (0.298^{**}).

Biovolume of the seedlings was significantly correlated with stomatal conductance (0.263^{*}) at 0.05 level. There was no relation between transpiration and relative water content. Photosynthesis showed a positive relation with transpiration (0.285^{**}), stomatal conductance (0.212^{*}), and leaf temperature (0.260^{*}) at 0.05 level. The relative water content (-0.025) was negatively correlated to photosynthesis. Stomatal conductance showed a significant ($P < 0.05$) positive relation with transpiration (0.230^{*}) and leaf temperature (0.568^{**}). Transpiration showed a significant ($P < 0.05$) positive correlation with relative water content (0.273^{**}) but no correlation with leaf temperature.

Table 14. Correlation of various morphological and physiological characters of the seedlings of *Ailanthus triphysa*

Parameters	Seedling height	Collar diameter	No. of leaves	Biovolu -me	Photosy-nthesis	Stomatal conductance	Transpi-ration	Leaf temperat -ure	RWC
Seedlings height	1								
Collar diameter	0.213*	1							
Number of leaves	0.119	0.200	1						
Biovolume	0.642**	0.878**	0.200	1					
Photosynthesis	0.021	0.019	-0.004	0.031	1				
Stomatal conductance	0.138	0.252*	-0.054	0.263*	.0212*	1			
Transpiration	-0.014	-0.031	0.298*	-0.034	0.285**	0.230*	1		
Leaf temperature	0.023	0.022	-0.052	0.029	0.260*	0.568**	0.169	1	
RWC	0.120	-0.173	-0.088	-0.078	-0.025	0.155	0.273**	0.009	1

*. Significant at 0.05 level

DISCUSSION

5. DISCUSSSION

Evaluating the size and distribution of genetic variation in plants species and its families is important for understanding the diversity and evolutionary ties among them, and helps in a systematic sampling of genetic resources for the conservation and enhancement of plants. Genetic diversity has played a significant role in the production of new improved plant varieties with desirable characteristics and has acted as a repository for genetic variation and desirable genes. Information on genetic diversity is used as the raw material in the production of new varieties through breeding. Different methods like morphological, biochemical and molecular methods can be used for the assessment of diversity among species.

The results of the study on, "Diversity assessment and selection of candidate plus trees of *Ailanthus triphysa* (Dennst) Alston in selected districts of Northern Kerala" are discussed below.

5.1. PLUS TREE SELECTION

The selection of plus trees is an important tool for the genetic improvement of tree. To make selection effective, Hazel and Lush (1942) stressed the importance of genetic variation present in the population, the heritability of the traits, and the genetic and environmental correlation of each trait with the other. Successful phenotypic selection depends on the amount of genetic variability available in the population for important economic characteristics and their interrelationship (Lone and Tewari, 2008). In every living organism, it is found that there is a substantial natural variation with various characteristics and this is seen as a feature of the majority of populations. As a result, the range of suitable genotypes can also be better selected in natural variations (Thakur and Thakur, 2015). Variations between populations are expected in species with widespread natural distribution due to genetic and environmental differences. In this study, variations in growth characteristics and many qualitative characteristics were observed between trees within localities of the 255 trees enumerated. The variation in height, GBH, crown width and clean bole height ranged from 10 m to 37 m, 0.48 m to 2.2 m, 1.5 m to 11 m and 3 m to 24 m respectively. The average height, GBH, crown width and clean bole height of all the trees enumerated were 23.56 m, 0.86 m, 5.01 m and 13.61 m respectively. The total score for all the qualitative characters ranged from 21 to 48.

The heritability is the second important criterion after variation for selecting the plus trees. Stem straightness and roundness are known to be directly related to wood quality, and even a simple selection of tree shapes can improve the quality and quantity of the product (Shelborne, 1969). In the present study, the qualitative and quantitative characteristics of trees, such as clear bole height, bole shape, and branching pattern were given importance for the selection of *Ailanthus triphysa* trees from the natural population. It was also demonstrated earlier that high heritability combined with high genetic advancement exist in several growth characteristics such as tree height, diameter (Dlamini *et al*., 2017), clear bole height (Jha, 2012) and bole straightness (Vargas-Reeve *et al*., 2013).

Plus tree selection is necessary for immediate improvements to be made in the seed stands or seed production areas. Therefore, careful selection of plus trees is needed to ensure maximum utilization of genetic variations. Plus tree selection was recorded in several hard wood species which were in line with the current studies. Binu (2019) selected candidate plus trees of *Melia dubia* from different forests of Kerala using baseline regression system. Dhillon *et al*., (2009) reported candidate plus trees selection of *M. azederach* through base line method from different agro-climatic areas of Punjab. In South Gujarat, twenty plus trees of *Melia dubia* were selected based on individual selection methods (Chauhan *et al*., 2018). Twenty-one plus trees of *Ailanthus excelsa* Roxb. were selected through an intensive survey from Haryana, Rajasthan and Gujarat based on the assessment of desirable characters of economic interest such as self-pruning ability, stem straightness, disease resistance, low branching habit, clear bole height (Daneva *et al*., 2018). Similarly, the traits based on apparent growth, clear bole and stem straightness and other traits of priority were selected in different tree species *viz. Azadirachta indica* (Dhillon *et al.,* 2003), *Dalbergia sissoo* (Bangarwa, 1993; Yadav *et al.,* 2005), *Pongamia pinnata* **(**Kaushik *et al.*, 2011). Generally, the qualitative characteristics are not taken into account in the selection of trees based on the baseline methods. However, in the present study, the qualitative characteristics of the trees were also taken into account to reduce the number of CPTs, thus making it a multistage selection. In the first stage, trees were separated with better quantitative characteristics. In the second stage, the best trees were then chosen according to the qualitative character ranking. This made the selection more robust. However, some trees of higher qualitative characters may not be selected, because the selection primarily depends mainly on baseline fitting.

Against this backdrop, selections were made from different panchayats consisting of two low lands, five mid lands and three high lands. In the present investigation, thirty candidates plus trees were selected from northern districts of Kerala using base line regression system combined with scoring of qualitative traits.

5.2. VARIABILITY

For any tree improvement programmes, the first important step is the identification of all possible variations within species. The identification and examination of various tree species genotypes for morphological and biochemical characteristics are an important feature of tree development programmes. The wide variation for commercially important traits revealed a substantial potential for phenotypic selection to maximize productivity. To make effective use of genetic plant resource selection and reproduction, it is necessary to establish the magnitude, cause, and nature of variation in the natural population. This is because, in general, forest trees are genetically variable to survive, grow and reproduce in a variety of environments (Antonovicks, 1971).

5.2.1. Morphological variations

In the present study, among the thirty candidate plus trees selected, significant variation was observed in the height of the tree, girth at breast height, crown width and clear bole height.

The variation in height, GBH, crown width and clear bole height was in the range of 20 m to 37 m, 0.69 m to 2.11 m, 3.5 m to 9.75 m and 7 m to 24 m respectively.

The variations found in this study was due to genetic factors as well as geographic variations.

Generally, the tree characters such as tree height, GBH, crown diameter etc., vary in nature. Height and GBH are commercially important for timber species. Growth characters like height are mostly influenced by the environment and hence have low heritability. So, selection based on height might not be the best choice. Similar observations were made by Abijith (2018) and Das (2018) in *Ailanthus triphysa* on the characters height, gbh and crown width. This showed that variation exists in the population is due to environmental influence and selection based on these criteria is not suggested. Similar variations were also observed in *Melia dubia* (Binu, 2019) and *Lagerstroemia speciosa* (Jamaludheen *et al*., 1995).

The scores for the qualitative characters in this study such as verticality, straightness, cross section, forking, foliar damage, stem damage, branch angle and self-pruning ability was determined and it was observed that the variations were very less among the trees located. The qualitative characters varied from score 42 (FCV-AT-22) from Anthikad to 48 (FCV-AT-24, FCV-AT-26, FCV-AT-27, FCV-AT-35, FCV-AT-36 and FCV-AT-50). The values showed that not much variations existed for the qualitative character of the trees and these characters are mostly genetically determined.

In the case of forking, the height and depth of the fork should be taken into account. Hardwood species generally fork, but some trees are predisposed and were more susceptible to do so than others. Forking can be of single or across the crown. Where single forking occurs, it is likely to be environmental factors, and trees should not be discarded (Clark and Wilson, 2005). But if the forking is persistent in the crown, it is undoubtedly due to genetic factors. Hence, these trees should be avoided. Self-pruning ability, cross section, branch angle and thickness were strong indicators of timber quality. For better growth potential of a tree, a healthy large crown is deeply important. In a study by Binu (2019) and Chauhan *et al*., (2018) in *Melia dubia*, maximum variations were shown for the character apical dominance and forking. This showed that the trees had better growth and production. Hence, weightage must be given for these traits during selection.

Availability of the variability in the population is the raw material in any breeding programme and the present study revealed that the variability is high and thus there is a better chance of selecting plus tree with individuals having desirable characteristics.

5.3. CLUSTER ANALYSIS

In this study, hierarchical cluster analysis was carried out on the 30 selected plus trees. The thirty plus trees were grouped into nine clusters. Trees coming in a cluster have similar morphological characters where as it differs between two clusters. Cluster I possess the maximum number of CPTs with 15 accessions whereas the least number was observed for cluster VII, VIII and IX respectively as they contained only one accession. Clusters with only one plus tree can either possess superior or inferior quality among the plus trees.

The average height, GBH, crown width, clean bole height, straightness, apical dominance, forking, branch angle, self-pruning, foliar damage, stem damage, cross section and bole swelling of plus trees for all the clusters was 29.72 m, 1.38 m, 7.31 m, 18.28 m, 3.56, 7.83, 4.67, 11.33, 2.67, 3.67, 5.44, 1.67 and 1.89 respectively. The clustering pattern revealed that plus trees from the same geographic sources were grouped into different clusters while plus trees from different geographic sources were grouped into the same clusters. This showed that the variations in geographic regions were not in line with genetic diversity. These trends of results were obtained by Kaushik *et al.,* (2007) in *Jatropha curcas*. The trees from one area were distributed over various clusters.

The intra and inter cluster analysis indicated that the highest intra cluster was observed on cluster I (2.07) followed by cluster II (1.79), cluster V (1.72), cluster III (1.57), cluster IV (1.50) and cluster VI (1.49). The highest inter cluster distance was shown by cluster V and VI (8.91) followed by cluster V and VII (8.82) and cluster II and VII (7.95). The maximum intra-cluster distance shown by cluster I indicates greater genetic distance within the cluster itself which may be due to environmental factors and thus, recommended that selection of plus trees should be based on genetic diversity rather than geographic diversity. Likewise, the maximum inter-cluster distance was due to environmental factors. The least inter-cluster distance revealed there was low genetic diversity and selection should be avoided from this cluster. This showed that higher inter-cluster distance should be selected for further improvement and better progeny can be achieved through hybridization. Therefore, the plus trees belonging in this cluster can be used for hybridization programme to obtain hybrid vigour as well as to identify the most distant accessions. Several investigations that are in line with the present studies were also recorded for the species such as *Pinus gerardiana* (Kant, *et al*., 2006), *Pinus wallichiana* (Aslam *et al*., 2011) and *Melia dubia* (Binu, 2019). This revealed that genetic diversity should be carefully considered to be the main criterion for the selection of plus trees instead of geographic variations.

5.4. EVALUATION OF PROGENIES OF SELECTED PLUS TREES

In the present study, significant differences among the progenies of the thirty selected plus tree were observed for various morphological traits such as collar diameter, number of leaves and biovolume except for the height of the seedlings. It was observed that among the progenies studied, the height of all the seedlings of the progenies from selected plus trees after 30 days of transplanting did not differ. The highest value of 11.2 cm was observed for the seedlings of plus trees FCV-AT-21 from Anthikad and the least height 8.73 cm was observed on FCV-AT-22 from Anthikad. Since all the seedlings were raised under the same climatic conditions, the reasons for no variation in the height of the seedlings might be due to observations taken just 30 days after transplanting. If observations were taken continuously over a longer period, variations might be evident since other parameters showed variation at this stage itself. Das (2018) also reported a non-significant difference in the height of the seedlings of *Ailanthus triphysa*. The authors found that the seedlings heights were not significant for up to 150 days after transplanting, but showed variation after planting in the field.

With regards to collar diameter, there was a significant difference in the progenies studied. The highest value (0.25mm) was observed for the seedlings of plus tree FCV-AT-36 (Vengara). The progeny FCV-AT-22 from Anthikad showed the least value 0.14mm along with FCV-AT-24 from Manalur. The variation observed was due to genetic diversity since all the progeny were raised under similar climatic conditions. Several investigations that were in line with the present studies include *Ailanthus triphysa* (Paul, 2017; Abhijith, 2018), *Melia dubia* (Binu, 2019) and *Acacia mangium* (Salazar, 1989).

The number of leaves also showed a significant difference among the progenies. The highest value (6.53) was observed for the seedlings of plus tree FCV-AT-40 (Parappur) and the least value 4.33 was found to be on FCV-AT-22. The causes for such variation was due to genotypical differences. Binu (2019) in *Melia dubia*, Shu *et al.*, (2012) in *Magnolia officinalis* and Sekar (2003) in *Simarouba glauca* found significant variations in the number of leaves of progenies from different seed sources. Such growth differences in the nursery from various seed sources are likely due to adaptation because seedlings from all sources are grown under the same climatic conditions.

There were also significant variations in the seedlings biovolume from different plus trees. The seedlings biovolume ranged from 0.12 cm^3 (FCV-AT-22) to 0.32 cm^3 (FCV-AT-36). Similar variations were recorded on the species *Melia dubia* (Binu, 2019). This variation was due to the genotypic differences rather than climatic factors. The existence of variability in growth parameters due to different genotypes and their variations with the differences in soil and climatic conditions at the nursery stage have been reported in studies done earlier (Thakur and Thakur, 2015).

The traits which have been studied here from the breeding point of view are all economically important. The evaluation of the progenies can be done among themselves by using results from the assessment of progenies of the plus trees. A good amount of the information about the ability of the parents to pass on the characters to its progeny can be obtained, for which the original selection was done. The selection of exceptionally good parents can be done by using the information gathered from this study, which can be used for establishing a seed orchard or can be used for hybridization over and over again in the future.

5.5. GENETIC ANALYSIS

5.5.1. Morphological traits

In the current study, the phenotypic coefficient of variation, genotypic coefficient of variation, variability and heritability of the four growth parameters such as height, collar diameter, the number of leaves and biovolume were estimated under similar climatic conditions.

The highest phenotypic and genotypic coefficient of variation were observed for the character biovolume, which was followed by the collar diameter (Table 11). For all the characters studied, the phenotypic coefficient of variation was higher than the genotypic coefficient of variations indicating that there were non-additive effects. The character height recorded lowest GCV and PCV compared to other parameters. There is evidence that there exists adequate genotypic variation which can be exploited for the further improvement of the species. A similar trend of results was also observed in *Ailanthus triphysa* (Das, 2018), *Melia dubia* (Binu, 2019). The variation in all these traits was mostly influenced by environmental factors rather than genetic factors.

Heritability indicates the total amount to which a character is influenced by heredity when compared to the environment. The values of the heritability for different characters were 0.09 for height, 0.4 for collar diameter, 0.64 for the number of leaves, and 0.5 for biovolume. It was reported that heritability estimates combined with genetic advance are more important than heritability alone to predict the selection of individuals based on phenotypes (Johnson *et al.*, 1955). In the present study, high heritability was observed in the number of leaves and collar diameter. Maximum genetic gain was observed in biovolume (26.60), followed by collar diameter (15.43) and the number of leaves (14.96). High heritability, coupled with moderate to high genetic gain obtained for these characters indicated that the higher values are due to additive gene effects. This showed a broad scope for the genetic improvement in the species, as it gives an indication of the relative strength of heredity versus environment and thus plays important role in improving tree genotypes (Dorman, 1976). Similar findings were also seen in *Tectona grandis* (Arun, 1996), *Azadirachta indica* (Dhillon *et al.*, 2003), *Melia* *dubia* (Binu, 2019), *Eucalyptus globulus* (Apiolaza *et al*., 2005); where high heritability with moderate to high genetic advance was observed in the characters height and DBH. Similarly, in *Eucalyptus grandis*, the heritability for height and tree volume was low to moderate (Raymond, 2002). In other experiments, it was also observed that the heritability varied with changing environment and age (Devagiri *et al*., 1997).

5.6. VARIATION IN PHYSIOLOGICAL TRAITS AMONG THE PROGENIES AND CORRELATION WITH THE GROWTH CHARACTERS

The physiological traits such as photosynthetic rate, stomatal conductance, transpiration rate, leaf temperature and relative water content of the seedlings were determined and were found to have significant difference at 0.01 level. Photosynthesis rate of the progenies of different plus trees ranged from 1.74 µmol $m^{-2}s^{-1}$ (FCV-AT-50) to 4.74 µmol $m^{-2}s^{-2}$ (FCV-AT-35). Stomatal conductance of the seedlings of plus trees ranged from 0.22 mmol H_2O $cm^{-2}s^{-1}$ (FCV-AT-21) to 0.67 mmol H_2O $cm^{-2}s^{-1}$ (FCV-AT-36). The highest transpiration rate was observed for the progenies FCV-AT-39 (4.10 µg cm^{-2} s^{-1}) while the lowest value was observed for the progenies FCV-AT-42 (1.34 µg cm^{-2} s^{-1}). Leaf temperature varied from 33.26°C (FCV-AT-22 and FCV-AT-49) to 38.41°C (FCV-AT-43). The highest relative water content was observed for the seedlings FCV-AT-25 (86.25 %) followed by FCV-AT-33 (85.52 %) and FCV-AT-23 (85.02 %). The lowest value was obtained for the leaves of the seedlings from plus trees FCV-AT-40 (61.57 %).

Photosynthesis is the fundamental mechanism that provides the organic bases, which make a major contribution to the production and growth of plants, between various life processes that regulate plant growth (Rapparini and Penuelas 2014). Photosynthesis has a significant impact on the growth and yield of plants (Yamori *et al*., 2016). The rate of photosynthesis is determined by both environmental and plant genetic factors. It can, therefore, be inferred that photosynthetic behavior is complex, and that there is an association between plant genetic and environmental factors.

Stomatal conductance measures the degree of stomatal opening that can be further used as a guide to plant water status (Surendar *et al*., 2013). It is an important factor in energy, CO_2 and water cycles between plants and the atmosphere. It is also vital for both the prevention of desiccation and the acquisition of CO_2 (Medici *et al*., 2007). Studies have shown that plants respond very early to the water deficit by closing the stomata, which leads to a reduction in the carbon uptake of the leaves. This can, in turn, lead to a reduction in the photosynthetic rate of plants (Chaves, 1991 and Cornic and Massacci, 2000). Studies showed that increased stomatal conductance of plants was related to higher levels of leaf water (Auge *et al*., 2015). Net photosynthesis and stomatal conductance are frequently interrelated in terms of performance (Salisbury and Ross, 1992). Besides, studies demonstrated the indirect correlation between net photosynthetic levels and the opening of stomata (Bunce, 1988). Therefore, fluctuation in stomatal behavior can cause photosynthetic levels to change (Meng and Arp, 1992). Plants respond to the water deficit which has been established much earlier, and which is regulated by stomata. The stomatal closure contributes to a reduction of the carbon intake in leaves (Chaves, 1991).

Several determinants of plant productivity have also been identified. The most critical of the shifts are net photosynthesis, stomatal density and size variations (Wang *et al*., 1995).

Earlier studies focused primarily on the ecophysiological aspects of photosynthesis in forest trees, such as the effects of stress on photosynthetic physiology and photosynthetic reactions to light intensity (Zhang *et al*., 2002) and CO_2 concentrations (Su *et al.*, 2003). The present study carried out here focused on measuring the photosynthesis rate. A significant variation was observed between the seedlings of plus trees for different physiological characters such as net photosynthesis, stomatal conductance, leaf temperature, relative water content. Binu (2019) for *Melia dubia*, Mebrahtu and Hanover (1991) for black locust (*Robinia pseudoacacia*) and Johnsen and Major (1995) for black spruce (*Picea mariana*) reported similar findings. In a study conducted in *Quercus serrata* to investigate the dependence of the chlorophyll concentration on stomatal conductivity, it was observed that a corresponding decrease in stomatal conductivity was also observed as the chlorophyll concentration decreased (Matsumoto *et al*., 2005).

In this study, it was observed that the progenies of the selected plus trees had high variation and high heritability (H^2) for most of the growth and physiological traits. The PCV for the physiological traits was found to be highest for the transpiration rate (40.53) followed by stomatal conductance (34.83), photosynthetic rate (28.65), relative water content (8.52) and leaf temperature (4.67). It was observed that the GCV for the traits varied from 4.65 (leaf temperature) to 38.01 (Transpiration rate). The values of heritability varied from 0.84 (Relative water content), 0.88 (Transpiration rate), 0.95 (Stomatal conductance) and 0.99 (Photosynthesis and leaf temperature). The genetic gain was maximum for transpiration rate (72.72), followed by stomatal conductance (68.80), photosynthesis (58.24), relative water content (14.69) and the least for leaf temperature (9.45). The results showed that there was more influence on genetic factors compared to environmental factors.

A correlation was done on the physiological characters of the seedlings with their growth. Photosynthesis showed a positive relation with transpiration, stomatal conductance and leaf temperature. Stomatal conductance showed a positive relationship ($P<0.05$) to transpiration and leaf temperature while no correlation with relative water content. Transpiration showed a significant ($P < 0.05$) positive correlation with relative water content and no significant relationship with leaf-temperature. The leaf temperature was not correlated with relative water content. Stomatal conductance enhances gas exchange, helps in the uptake of CO_2 and subsequently increases photosynthesis. This showed that an increase rate of photosynthesis will enhance the growth of the plants. Chu *et al*. (2010) in *Populus nigra*, observed that the growth, the gas exchange and chlorophyll fluorescence had a high correlation. The findings suggest that in the future, this germplasm can be added to the breeding system because of high correlation and strong photosynthetic efficiency can increase plant growth. Relative water content had a high impact on photosynthesis. A decrease in 5 % RWC led to a 40 % - 50 % reduction in photosynthesis rate (Surendar *et al.,* 2013).

This study and the results of other research indicate that the net photosynthetic rate showed variation between the genotypes. It could, therefore, be used as an efficiency enhancement parameter for *Ailanthus triphysa* breeding. One can evaluate photosynthesis of *Ailanthus* germplasm and information can be used for introducing and improving *Ailanthus* resources in the tree improvement programme. The present study showed that the photosynthetic rate, transpiration rate, stomatal conductance, leaf temperature and relative water content of different plus trees were significantly different. These studies concluded that a breeding program based on the morpho-physiological characters of the seedlings was possible to choose the best plus tree.

The experimental results revealed that out of the thirty progenies studied, the progenies FCV-AT-21, FCV-AT-33, FCV-AT-36, FCV-AT-37, and FCV-AT-40 were found superior based on overall mean performance of the morphological characters. The standard deviation from these progenies exhibit a values of 0.20 cm, 0.03 cm, 0.05 cm 0.02 cm and 0.31 cm. This showed that the mother plant is promising and the seeds produced from this tree can be collected directly for field deployment. Hence, these CPTs can be further used for future breeding programme.

SUMMARY

6. SUMMARY

A study was conducted to determine the genetic diversity of the trees and to select plus trees of *Ailanthus triphysa* from selected Northern districts of Kerala. Ten panchayaths, comprising two low lands, five mid lands and three high lands have been selected after a preliminary survey conducted at all places. A total of 255 trees was identified during the survey. Thirty trees were selected from the enumerated trees based on the baseline regression selection system. Seedlings of the selected thirty plus trees were evaluated for their growth and physiological characteristics. The experiment was conducted in the nursery at the College of Forestry, Thrissur, Vellanikkara.

The salient findings of the study are given below.

1. A total of 255 trees were enumerated from different locations of selected Northern districts of Kerala. The candidate plus tree selection was carried out using the baseline regression system. Thirty trees were selected as CPTs from the total trees enumerated.
2. Selected CPTs were assigned with the accession number as FCV-AT (FORESTRY COLLEGE VELLANIKKARA AILANTHUS TRIPHYSA).
3. The variation in height was in the range of 20 m (FCV-AT-50) to 37 m (FCV-AT-32). Average height measured for the plus trees was 28.07 m.
4. The variation in girth at breast height was in the range of 0.69 m (FCV-AT-44) to 2.11 m (FCV-AT-48). Average girth estimated was 1.20 m.
5. The average crown width for CPTs was 6.41 m and the variation ranged from 3.5 m (FCV-AT-42, FCV-AT-43 and FCV-AT-44) to 9.75 m (FCV-AT-48).
6. Wide range of variation is observed in clean bole height, i.e., 7 m (FCV-AT-43) to 24 m (FCV-AT-31 and FCV-AT-40). The average clean bole height for all the CPTs was 17.10 m.
7. The correlation matrix between the quantitative characters of all the plus trees showed that there was significant relation between heights of the tree and clean bole height, girth at breast height (GBH) and crown width. However, no significant relation was observed between GBH and clean bole height, crown width and clean bole height.

8. For the qualitative characters, it was observed that the variations were very less among the trees located. Maximum variations were shown for the character apical dominance, and forking. The highest score 48 was for the plus trees FCV-AT-24, FCV-AT-26, FCV-AT-27, FCV-AT-35, FCV-AT-41, FCV-AT-42 and FCV-AT-46. The tree FCV-AT-22 and FCV-AT-29 had the lowest score (42).
9. A hierarchical cluster analysis was carried out for morphological characters of the thirty selected candidate plus trees using squared Euclidean distance. Thirty candidate plus trees were grouped into nine clusters. The cluster I possess maximum number of CPTs with 15 accessions, whereas the least number observed for the cluster VII, VIII and IX respectively.
10. Principal component analysis showed that five components had eigen value greater than one which accounts for 70 % of the total variability. First two components together accounted for 39.5 % of the total variability. PC1 accounted for 23.2 % of the total variability, which was mainly contributed positively by GBH, crown width, height, CBH, forking, self-pruning, branch angle, straightness and apical dominance. PC2 accounted for 16.3 % of the total variability, which was mainly contributed positively by straightness, forking, self-pruning, foliar damage, crown width, bole swelling, cross section and GBH. The selection index value was also worked out for the best plus trees based on the morphological characters of the trees using principal component analysis.
11. The nursery performance of the progenies of plus trees also showed significant differences in collar diameter, number of leaves and biovolume. However, the seedlings height showed no significant variation. It was observed that the progenies from the plus tree FCV-AT-21 showed the highest seedlings height, while FCV-AT-36 showed the maximum collar diameter, maximum number of leaves by FCV-AT-40 and FCV-AT-36 showed the highest biovolume. The lowest value for the seedlings height, collar diameter, number of leaves and biovolume was observed for plus tree FCV-AT-22.
12. The genetic parameters for morphological and growth traits after 30 days after transplanting showed that the broad sense heritability values for different characters were 0.09 for height, 0.4 for collar diameter, 0.64 for number of

leaves, and 0.5 for biovolume. Highest genetic gain (26.60) was observed in biovolume and least value (2.35) was observed in seedlings height.

13. Differences among the progenies of the selected plus trees were observed for the physiological characters. It was observed that the progenies of the plus tree FCV-AT-35 showed the highest photosynthetic rate, highest stomatal conductance by FCV-AT-36, highest transpiration rate by FCV-AT-39, highest leaf temperature recorded by FCV-AT-43 and FCV-AT-25 recorded the highest relative water content. The least value for photosynthetic rate, stomatal conductance, transpiration rate, leaf temperature and relative water content was recorded by FCV-AT-50, FCV-AT-21, FCV-AT-42, FCV-AT-22 and FCV-AT-40.
14. The genetic parameters for physiological traits after 30 days after transplanting showed that the broad sense heritability values for different characters were 0.84 for relative water content, 0.88 for transpiration rate, 0.95 for stomatal conductance, 0.99 for both photosynthetic rate and leaf temperature. Highest genetic gain 72.72 was observed in transpiration rate and the least value 9.45 was observed in leaf temperature.
15. The progenies FCV-AT-21, FCV-AT-33, FCV-AT-36, FCV-AT-37, FCV-AT-39 and FCV-AT-40 were found superior based on overall mean performance of the morphological characters. Hence, seeds of these CPTs can be used in immediate field planting operations.
16. Correlation analysis of the morphological and physiological traits of progenies of the selected plus trees showed that there was positive and significant relations between seedlings height and biovolume, collar diameter and biovolume, collar diameter and stomatal conductance, number of leaves and transpiration, biovolume and stomatal conductance, photosynthesis and transpiration rate, photosynthesis and stomatal conductance, photosynthesis and leaf temperature, stomatal conductance and transpiration rate, stomatal conductance and leaf temperature, transpiration rate and relative water content. While no correlations were observed in seedling height and transpiration rate, biovolume and transpiration rate, biovolume and relative water content, and relative water content and photosynthesis.

17. It can be concluded from the results that considerable morpho-physiological variations exist in selected candidate plus trees of *Ailanthus triphysa*.
18. The estimated heritability for the various morphological and physiological characters showed moderate to high heritability. The high values of heritability help the breeder in the selection programme. The heritability estimates together with genetic advance are usually more helpful in selecting the best individuals.
19. The clusters analysis also revealed that grouping of the members were independent to the geographic locations. This clearly shows that the factors other than geographic distribution might be responsible for the genetic similarity.
20. These findings could be useful for the efficient management and exploitation of *Ailanthus triphysa* germplasm in future breeding programmes, as well as for the optimal use and improvement of *Ailanthus triphysa* resources.

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APPENDICES

APPENDIX I			
GRADING OF THE TRAITS FOR SELECTION OF PLUS TREES			
Sl. No.	**Traits**	**Variations**	**Score**
1	Verticality	Vertical	2
		Not vertical	1
2	Straightness	Very crooked with serious bending	1
		Slightly crooked with 2 small bends or less than 2 serious bends	2
		Almost straight with 1-2 small bends	3
		Completely straight	4
3	Cross section	Circular	2
		Not circular	1
2	Bole swelling	Present	1
		Absent	2
3	Branch angle	Upright <60°	6
		Horizontal>60°	12
4	Self-pruning	Poor, branches exists below 2/3rd of total height	1
		Good, branches exist below 2/3rd of total height	3
5	Apical dominance	Points for length (clean bole) expressed as percent of total height of the tree <25%	0
		25-39 %	1
		40-54 %	5
		55-69%	8
		>70 %	10
6	Forking	Above 10 m	5
		Between 5-10 m	3
		Below 5 m	1
7	Foliar damage	Present	1
		Absent	4
8	Stem damage	Present	1
		Absent	6

APPENDIX II

Scoring for the quantitative characters of trees of *Ailanthus triphysa*

Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
ANTHIKAD						
1	A-01	10°27′40.46″ 076°07′15.51″	24	0.72	4.5	15
2	A-02	10°27′40.69″ 076°07′15.84″	19	0.65	2.5	13
3	A-03	10°27′40.71″ 076°07′15.86″	21	0.67	6.5	14
4	A-04	10°27′44.63″ 076°07′11.67″	23	0.86	5.5	9
5	A-05	10°27′44.61″ 076°07′11.74″	22	0.75	6.5	14
6	A-06	10°27′44.56″ 076°07′12.47″	19	0.57	2.5	12
7	A-07	10°27′47.23″ 076°07′13.50″	22	0.75	6	4
8	A-08	10°27′49.17″ 076°07′21.51″	14	0.5	3	9
9	A-09	10°27′55.20″ 076°07′19.74″	21	0.86	5.5	4
10	A-10	10°27′58.18″ 076°07′18.44″	25	1.02	7.5	9
11	A-11	10°27′57.63″ 076°07′17.12″	21	0.6	2.75	9
12	A-12	10°27′57.67″ 076°07′16.96″	22	0.93	6.5	10
13	A-13	10°27′57.79″ 076°07′16.96″	26	1.18	8	13
14	A-14	10°27′57.69″ 076°07′16.68″	14	0.6	3	8
15	A-15	10°27′57.66″ 076°07′16.60″	19	0.63	3.5	13
16	A-16	10°28′02.43″ 076°07′20.36″	19	1.03	7	12
17	A-17	10°28′03.32″ 076°07′25.64″	16	0.48	3.5	12
18	A-18	10°28′03.34″ 076°07′28.42″	23	0.85	5	16
19	A-19	10°28′03.45″ 076°07′28.32″	26	0.95	6	17

20	A-20	10°28′02.95″ 076°07′28.63″	26	1.1	8	13
21	A-21	10°28′01.38″ 076°07′27.43″	21	0.65	6.5	11
22	A-22	10°28′01.36″ 076°07′27.47″	18	0.5	2.5	4
23	A-23	10°28′04.07″ 076°07′24.36″	18	0.62	3.5	8
24	A-24	10°27′45.56″ 076°07′09.87″	15	0.52	2	7

MANALUR						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
25	M-01	10°29′36.18″ 076°06′43.97″	28	0.95	8.5	14
26	M-02	10°29′51.48″ 076°06′34.92″	16	0.6	2.5	8
27	M-03	10°29′52.01″ 076°06′34.97″	22	0.7	3.5	14
28	M-04	10°29′58.19″ 076°06′30.32″	19	0.7	6	12
29	M-05	10°29′58.28″ 076°06′30.33″	25	0.82	7.5	17
30	M-06	10°29′58.53″ 076°06′30.74″	16	0.56	2.5	10
31	M-07	10°29′58.48″ 076°06′30.89″	17	0.55	5	11
32	M-08	10°29′58.34″ 076°06′30.84″	22	0.57	5.5	10
33	M-09	10°29′57.62″ 076°06′31.00″	19	0.71	3	12
34	M-10	10°29′57.26″ 076°06′31.15″	23	0.9	4.5	14
35	M-11	10°29′55.27″ 076°06′09.15″	19	0.65	3	12
36	M-12	10°29′56.08″ 076°06′08.87″	19	0.55	2.5	14
37	M-13	10°29′56.30″ 076°06′09.07″	21	0.55	3	9
38	M-14	10°29′56.43″ 076°06′09.26″	22	0.65	4	16
39	M-15	10°29′56.43″ 076°06′09.41″	20	0.68	5	12
40	M-16	10°29′56.46″ 076°06′09.06″	18	0.55	4.5	12

41	M-17	10°29′56.04″ 076°06′08.60″	20	0.7	5	16
42	M-18	10°29′56.13″ 076°06′08.09″	22	0.7	4.5	18
43	M-19	10°29′56.15″ 076°06′08.11″	21	0.6	2.5	15
44	M-20	10°29′55.84″ 076°06′07.88″	22	0.69	5.5	16
45	M-21	10°29′55.95″ 076°06′07.81″	25	0.88	4.5	18
46	M-22	10°29′55.84″ 076°06′07.85″	24	0.7	3.5	17
47	M-23	10°29′55.95″ 076°06′08.21″	20	0.7	5	10
48	M-24	10°29′56.09″ 076°06′07.82″	24	0.74	3.5	16
49	M-25	10°29′55.10″ 076°06′07.64″	22	0.74	5	10

PUDUKKAD						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
50	P-01	10°39′59.47″ 076°16′01.58″	24	0.73	7	18
51	P-02	10°28′15.82″ 076°18′40.40″	29	0.95	5	21
52	P-03	10°28′16.26″ 076°18′40.44″	16	0.48	7	10
53	P-04	10°28′15.66″ 076°18′41.24″	28	1	7	16
54	P-05	10°28′15.66″ 076°18′41.43″	21	0.68	4.5	13
55	P-06	10°28′16.88″ 076°18′42.21″	23	0.68	7	7
56	P-07	10°28′16.95″ 076°18′42.36″	27	0.82	5.5	18
57	P-08	10°28′17.02″ 076°18′42.43″	30	0.9	7	22
58	P-09	10°28′16.77″ 076°18′42.04″	26	0.85	6	16
59	P-10	10°28′16.68″ 076°18′41.95″	17	0.5	5.5	13
60	P-11	10°28′16.41″ 076°18′41.63″	25	0.75	5.5	17
61	P-12	10°28′17.14″ 076°18′41.08″	37	1.25	8.5	21

62	P-13	10°28′17.86″ 076°18′41.96″	32	1.2	6	16
63	P-14	10°28′17.63″ 076°18′44.24″	30	1.1	6	23
64	P-15	10°28′15.95″ 076°18′46.45″	29	1.02	7.5	22
65	P-16	10°28′15.52″ 076°18′46.49″	32	1.15	7.5	24
66	P-17	10°28′14.28″ 076°18′46.04″	27	1.05	6.5	19
67	P-18	10°28′15.46″ 076°18′45.06″	28	0.95	5.5	19
68	P-19	10°28′15.58″ 076°18′44.85″	19	0.9	3.5	9
69	P-20	10°28′15.66″ 076°18′44.67″	28	1.2	6.5	16
70	P-21	10°28′15.77″ 076°18′44.52″	24	0.7	5.5	16
71	P-22	10°28′15.79″ 076°18′44.45″	32	0.95	7	19
72	P-23	10°28′15.08″ 076°18′44.56″	32	1.1	6	19
73	P-24	10°28′15.07″ 076°18′44.60″	19	0.55	3.5	9
74	P-25	10°28′15.05″ 076°18′44.28″	26	0.8	3.5	12
75	P-26	10°28′14.57″ 076°18′44.61″	29	0.9	5.5	19

CHALAKUDY						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
76	C-01	10°18′08.25″ 076°18′23.40″	30	1.15	6.5	10
77	C-02	10°18′18.30″ 076°18′23.80″	18	1.09	8	8
78	C-03	10°18′29.52″ 076°18′19.81″	20	1.35	8	9
79	C-04	10°18′35.14″ 076°18′15.65″	14	0.65	2.5	9
80	C-05	10°18′37.34″ 076°18′13.64″	25	0.88	4	13
81	C-06	10°18′37.27″ 076°18′13.73″	26	0.89	6.5	14
82	C-07	10°18′36.52″ 076°18′09.26″	35	1.65	9.5	16

83	C-08	10°18′36.51″ 076°18′08.89″	30	0.85	6	17
84	C-09	10°18′36.91″ 076°18′08.64″	32	1.3	9.5	19
85	C-10	10°18′36.96″ 076°18′08.41″	24	0.6	3.5	15
86	C-11	10°18′36.87″ 076°18′08.23″	26	1.04	4.5	18
87	C-12	10°18′37.01″ 076°18′07.94″	36	2	11	24
88	C-13	10°18′36.62″ 076°18′08.11″	35	1.2	7.5	16
89	C-14	10°18′36.64″ 076°18′08.09″	13	0.47	2.5	6
90	C-15	10°18′36.36″ 076°18′08.03″	33	1.55	8	18
91	C-16	10°18′36.13″ 076°18′08.04″	34	1.15	8.5	17
92	C-17	10°18′35.99″ 076°18′08.02″	35	0.93	6.5	16
93	C-18	10°18′35.57″ 076°18′09.20″	29	0.65	5.5	16
94	C-19	10°18′37.58″ 076°18′09.02″	32	0.75	5	15
95	C-20	10°18′39.17″ 076°18′11.43″	25	0.85	6	12
96	C-21	10°18′39.66″ 076°18′11.27″	31	1.45	5	14
97	C-22	10°18′40.80″ 076°18′11.27″	33	0.75	6.5	18
98	C-23	10°18′40.80″ 076°18′05.48″	34	1.03	9	14
99	C-24	10°18′40.86″ 076°18′05.27″	24	0.76	7	12
100	C-25	10°18′54.22″ 076°18′35.88″	37	1.6	9.5	21
101	C-26	10°18′54.60″ 076°18′40.31″	27	0.9	6	14
102	C-27	10°18′54.46″ 076°18′05.12″	34	1.3	7	22
103	C-28	10°18′40.19″ 076°18′05.11″	32	0.95	7	16
104	C-29	10°18′39.33″ 076°18′11.25″	27	0.65	5	19
105	C-30	10°18′39.69″ 076°18′11.99″	30	0.97	6	18

WADAKKANCHERY						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
106	W-01	10°40´04.72″ 076°16´02.76″	27	1.7	6.5	15
107	W-02	10°40´01.47″ 076°16´15.67″	31	1.17	6	17
108	W-03	10°39´54.89″ 076°16´22.58″	29	0.92	5	18
109	W-04	10°39´54.60″ 076°16´22.60″	32	1.12	5.5	17
110	W-05	10°39´54.64″ 076°16´22.44″	32	1.17	6.5	20
111	W-06	10°39´54.68″ 076°16´22.07″	31	1.2	5.5	21
112	W-07	10°39´55.01″ 076°16´21.97″	29	1.24	8.5	19
113	W-08	10°39´55.30″ 076°16´21.93″	24	0.59	2.5	13
114	W-09	10°39´55.52″ 076°16´21.77″	21	0.62	3.5	4
115	W-10	10°39´55.60″ 076°16´21.85″	18	0.65	3.5	4
116	W-11	10°39´55.41″ 076°16´21.85″	17	0.5	2.5	8
117	W-12	10°39´49.05″ 076°16´24.76″	15	0.8	4.5	15
118	W-13	10°39´48.71″ 076°16´24.63″	18	0.73	4.5	12
119	W-14	10°39´48.22″ 076°16´24.50″	21	0.98	3.5	17
120	W-15	10°39´46.89″ 076°16´26.57″	24	0.92	3.5	11
121	W-16	10°39´59.47″ 076°16´01.58″	32	1.36	6	15
122	W-17	10°39´54.28″ 076°16´24.67″	19	0.8	3.5	13
123	W-18	10°39´55.64″ 076°16´24.36″	25	0.98	5.5	15
124	W-19	10°39´47.54″ 076°16´24.72″	23	0.65	3.5	9
125	W-20	10°39´55.62″ 076°16´24.55″	29	1.3	7	16

126	W-21	10°39′55.32″ 076°16′24.44″	33	1.6	7.5	20
127	W-22	10°39′55.24″ 076°16′24.35″	31	1.15	9.5	17
128	W-23	10°39′55.33″ 076°16′24.48″	23	0.75	3.5	14
129	W-24	10°39′55.31″ 076°16′24.41″	24	0.76	6	12
130	W-25	10°39′54.17″ 076°16′21.17″	21	0.67	5	14

VENGARA						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
131	V-01	11°03′28.84″ 075°61′19.03″	25	1.25	9.85	10
132	V-02	11°02′41.99″ 075°59′22.03″	21	0.7	2.5	9
133	V-03	11°02′44.91″ 075°59′19.14″	16	0.53	5	3
134	V-04	11°03′02.24″ 075°58′51.09″	18	0.62	2.5	9
135	V-05	11°03′00.14″ 075°57′58.38″	24	0.7	5.5	12
136	V-06	11°03′00.32″ 075°57′58.42″	23	0.68	3.5	11
137	V-07	11°02′57.08″ 075°57′52.87″	15	0.46	2	3
138	V-08	11°03′01.07″ 075°57′52.42″	16	0.53	2.5	4
139	V-09	11°03′01.32″ 075°57′53.48″	23	0.54	2.5	17
140	V-10	11°03′01.45″ 075°57′53.65″	26	0.9	3.5	18
141	V-11	11°03′01.61″ 075°57′53.69″	20	0.64	3.5	7
142	V-12	11°03′02.22″ 075°57′53.62″	18	0.56	4.5	6
143	V-13	11°03′01.77″ 075°57′52.37″	16	0.47	5.5	3
144	V-14	11°03′00.80″ 075°57′56.32″	18	0.5	3.5	4
145	V-15	11°03′00.83″ 075°57′56.04″	17	0.54	2	4

146	V-16	11°03′01.13″ 075°57′56.15″	21	0.63	3	5
147	V-17	11°03′01.22″ 075°57′56.22″	18	0.53	2.5	6
148	V-18	11°03′01.24″ 075°57′56.12″	24	0.9	3.5	7
149	V-19	11°03′00.67″ 075°57′55.42″	16	0.57	2.5	6
150	V-20	11°03′01.02″ 075°57′53.53″	28	1.31	9.5	16
151	V-21	11°03′00.81″ 075°57′53.84″	21	0.65	3.5	14
152	V-22	11°03′00.78″ 075°57′54.20″	23	0.7	4.5	3.5
153	V-23	11°02′43.34″ 075°56′23.07″	18	0.5	2.5	7
154	V-24	11°02′42.06″ 075°56′24.74″	25	0.69	3.5	16
155	V-25	11°03′03.24″ 075°58′16.84″	15	0.68	1.75	4
156	V-26	11°03′00.02″ 075°58′23.27″	19	0.7	2	5

PARAPPUR						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
157	PA-01	11°02′43.26″ 075°59′22.38″	22	0.6	2.8	15
158	PA-02	11°02′43.86″ 075°59′22.49″	25	0.9	5.5	14
159	PA-03	11°02′44.10″ 075°59′22.48″	24	0.77	3.5	19
160	PA-04	11°02′43.94″ 075°59′22.59″	23	0.78	2.2	17
161	PA-05	11°02′44.24″ 075°59′22.28″	26	0.85	6.5	13
162	PA-06	11°02′25.88″ 075°59′38.42″	27	0.9	6.6	18
163	PA-07	11°02′16.91″ 075°59′22.49″	25	1.05	4.5	13
164	PA-08	11°02′43.86″ 075°59′46.00″	17	0.54	3.5	9
165	PA-09	11°02′16.14″ 075°59′45.12″	18	0.55	2.25	9
166	PA-10	11°02′16.24″ 075°59′44.64″	17	0.58	2.5	10
167	PA-11	11°02′16.37″ 075°59′44.34″	21	0.67	3	8
168	PA-12	11°02′08.51″ 075°59′50.16″	26	0.96	4.6	14
169	PA-13	11°02′07.81″ 075°59′49.21″	24	0.75	2.5	12
170	PA-14	11°02′08.69″ 075°59′48.81″	19	0.58	2.5	6
171	PA-15	11°02′08.51″ 075°59′50.00″	23	0.84	3.5	12
172	PA-16	11°02′08.62″ 075°59′50.68″	26	1.01	6.5	14
173	PA-17	11°01′49.00″ 075°59′52.20″	22	0.65	4.1	12
174	PA-18	11°01′49.10″ 075°59′52.18″	25	0.83	5.5	14
175	PA-19	11°01′49.22″ 075°59′52.07″	22	0.66	4.5	12
176	PA-20	11°01′49.34″ 075°59′51.90″	26	0.97	5	16

177	PA-21	11°01´48.76″ 075°59´51.49″	23	0.78	3.5	16
178	PA-22	11°01´48.72″ 075°59´51.09″	27	0.92	7.5	13

THRIKKADIRI I						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
179	T-01	10°50´36.72″ 076°22´21.06″	26	0.96	5.5	15
180	T-02	10°50´38.48″ 076°22´18.74″	28	1.2	7.5	19
181	T-03	10°50´41.72″ 076°22´21.01″	30	1.34	8.5	21
182	T-04	10°50´41.65″ 076°22´21.05″	28	0.9	4.5	21
183	T-05	10°50´41.79″ 076°22´21.14″	29	1.6	6.5	21
184	T-06	10°50´41.91″ 076°22´21.05″	25	0.8	4.5	18
185	T-07	10°50´41.86″ 076°22´21.19″	27	1.3	5.5	19
186	T-08	10°50´41.87″ 076°22´21.19″	28	1.1	3.5	20
187	T-09	10°50´41.96″ 076°22´20.99″	32	1.4	7	23
188	T-10	10°50´42.22″ 076°22´21.11″	24	0.75	5.5	18
189	T-11	10°50´42.31″ 076°22´21.11″	26	1.6	8.5	19
190	T-12	10°50´43.12″ 076°22´21.59″	34	1.9	8	21
191	T-13	10°50´43.41″ 076°22´21.92″	27	1.1	8.5	20
192	T-14	10°50´43.2262″ 076°22´22.07″	26	1.5	9.5	19
193	T-15	10°50´43.33″ 076°22´22.21″	21	0.6	2.5	14
194	T-16	10°50´43.25″ 076°22´22.04″	24	0.8	3.5	13
195	T-17	10°50´43.24″ 076°22´22.07″	27	1	4.5	15

196	T-18	10°50´43.30″ 076°22´22.16″	27	1	4	17
197	T-19	10°50´43.25″ 076°22´22.16″	21	0.95	4	14
198	T-20	10°50´43.16″ 076°22´22.31″	34	1.8	8.5	19
199	T-21	10°50´43.13″ 076°22´22.32″	28	1.3	7.5	20
200	T-22	10°50´43.12″ 076°22´22.68″	25	0.8	2.5	15
201	T-23	10°50´42.37″ 076°22´22.08″	26	0.9	7.5	18
202	T-24	10°50´42.26″ 076°22´22.32″	26	1.79	5.5	18
203	T-25	10°50´43.30″ 076°22´22.16″	29	1.8	7.5	21

ANANGANADI						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
204	AN-01	10°49´58.90″ 076°20´37.33″	24	0.72	3.5	18
205	AN-02	10°49´58.86″ 076°20´37.31″	34	0.92	5.5	21
206	AN-03	10°49´58.95″ 076°20´37.29″	22	0.68	3.5	13
207	AN-04	10°49´58.96″ 076°20´37.29″	21	0.62	2.5	12
208	AN-05	10°49´59.01″ 076°20´37.46″	27	0.86	4	17
209	AN-06	10°49´58.95″ 076°20´37.28″	34	0.94	5	24
210	AN-07	10°49´58.13″ 076°20´37.11″	22	0.62	7.5	15
211	AN-08	10°49´59.19″ 076°20´37.18″	18	0.58	2.5	11
212	AN-09	10°49´59.30″ 076°20´37.20″	21	0.62	2.5	14
213	AN-10	10°49´59.31″ 076°20´37.29″	35	1.02	5	23
214	AN-11	10°49´59.34″ 076°20´37.05″	27	0.72	4.5	21

215	AN-12	10°49´59.42″ 076°20´37.16″	31	1.04	7	24
216	AN-13	10°49´59.43″ 076°20´37.15″	16	0.53	5.5	7
217	AN-14	10°49´59.60″ 076°20´37.35″	30	0.89	5	19
218	AN-15	10°49´59.61″ 076°20´37.50″	17	0.55	2.5	9
219	AN-16	10°49´59.45″ 076°20´37.72″	18	0.69	5	11
220	AN-17	10°49´59.40″ 076°20´37.73″	34	1.1	5	21
221	AN-18	10°49´58.30″ 076°20´37.79″	33	1.06	6	24
222	AN-19	10°49´59.23″ 076°20´37.65″	22	0.64	3.5	13
223	AN-20	10°49´59.28″ 076°20´37.56″	23	0.66	4	11
224	AN-21	10°49´59.24″ 076°20´37.54″	21	0.65	3.5	12
225	AN-22	10°49´59.24″ 076°20´37.50″	22	0.6	3.5	14
226	AN-23	10°49´59.24″ 076°20´37.50″	29	0.9	6	21
227	AN-24	10°49´59.10″ 076°20´37.40″	28	0.72	6	19
228	AN-25	10°49´59.15″ 076°20´37.40″	19	0.58	3.5	11
229	AN-26	10°49´59.17″ 076°20´37.42″	29	0.88	5.5	21

URAKAM						
Sl. No.	Tree id. No.	Location	Height (m)	GBH (m)	Crown width (m)	Clean Bole Height (m)
230	U-01	11°03′02.66″ 075°59′22.00″	21	2.11	9.75	14
231	U-02	11°03′04.09″ 075°59′22.53″	22	2.2	10.5	9
232	U-03	11°03′03.79″ 075°59′22.48″	18	0.85	4.5	7
233	U-04	11°03′02.79″ 075°59′22.57″	16	0.54	8.5	9
234	U-05	11°03′00.86″ 075°59′25.90″	10	0.48	2.5	3
235	U-06	11°02′58.99″ 075°59′27.84″	13	0.63	3	4.5
236	U-07	11°03′02.37″ 075°59′29.78″	20	0.95	4.5	12
237	U-08	11°03′03.26″ 075°59′42.20″	22	1.08	4.5	18
238	U-09	11°03′03.17″ 075°59′42.17″	23	1.12	5.5	17
239	U-10	11°03′02.84″ 075°59′42.51″	20	0.64	3.5	13
240	U-11	11°03′02.51″ 075°59′42.22″	17	0.5	1.5	12
241	U-12	11°03′02.44″ 075°59′43.11″	15	0.7	5.5	7
242	U-13	11°03′02.43″ 075°59′43.53″	18	0.71	3	12
243	U-14	11°03′02.45″ 075°59′43.57″	19	0.65	3.5	11
244	U-15	11°03′06.29″ 075°59′37.02″	18	0.67	4	10
245	U-16	11°03′06.72″ 075°59′36.87″	19	0.72	4.5	10
246	U-17	11°03′06.96″ 075°59′36.91″	17	0.9	4	8
247	U-18	11°03′03.51″ 075°59′37.82″	12	0.52	2.5	8
248	U-19	11°03′04.75″ 075°59′39.79″	19	0.58	2.5	11
249	U-20	11°03′28.36″ 076°01′19.44″	18	0.73	3.5	12

250	U-21	11°03´28.01″ 076°01´19.19″	20	0.66	2.5	13
251	U-22	11°03´27.74″ 076°01´16.77″	18	0.57	3.25	9
252	U-23	11°03´28.70″ 076°01´16.14″	14	0.52	4.5	8
253	U-24	11°03´29.60″ 076°01´16.32″	20	1.1	5.5	8
254	U-25	11°01´48.01″ 075°59´52.73″	18	0.9	8	9
255	U-26	11°02´00.75″ 075°59´55.58″	20	1.16	6.5	12

APPENDIX III

Scoring for qualitative characters of *Ailanthus triphysa*

Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
ANTHIKAD												
1	A-01	2	2	1	5	12	3	1	1	2	2	31
2	A-02	2	3	1	3	12	3	1	1	2	2	30
3	A-03	1	2	1	3	12	3	1	6	2	2	34
4	A-04	2	3	5	3	6	3	1	6	2	2	33
5	A-05	2	3	0	1	12	1	4	6	2	2	33
6	A-06	2	3	0	5	12	3	4	1	1	2	33
7	A-07	1	3	1	5	6	3	4	6	2	1	32
8	A-08	2	3	1	5	6	3	4	6	2	2	34
9	A-09	2	3	1	3	6	3	4	6	1	1	30
10	A-10	2	4	5	5	12	3	4	6	2	2	45
11	A-11	1	4	5	3	12	1	1	6	2	1	36
12	A-12	2	4	8	5	6	3	4	6	2	2	42
13	A-13	2	4	1	3	6	3	4	1	1	2	28
14	A-14	2	3	1	3	12	3	4	1	2	2	33
15	A-15	2	3	5	3	6	1	4	1	2	2	29
16	A-16	2	2	5	1	6	3	1	6	1	1	28
17	A-17	1	3	8	5	6	1	1	6	1	1	33
18	A-18	2	3	8	3	6	1	1	6	2	2	32
19	A-19	2	4	8	5	12	3	4	6	2	2	46
20	A-20	2	4	1	3	6	3	4	6	1	2	32
21	A-21	2	4	1	5	6	3	4	6	2	1	34
22	A-22	2	2	1	3	6	3	4	6	1	1	29
23	A-23	2	3	5	3	6	3	1	1	2	1	27
24	A-24	1	4	1	1	12	1	4	6	2	2	34

MANALUR												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	M-01	2	3	5	5	12	3	1	1	2	2	36
2	M-02	2	3	5	3	6	1	4	1	2	2	29
3	M-03	2	3	8	3	12	1	4	1	1	1	36
4	M-04	2	4	8	1	6	1	4	6	2	2	34
5	M-05	2	4	8	5	12	3	4	6	2	2	48
6	M-06	2	3	5	1	6	3	4	6	1	2	33
7	M-07	2	3	5	3	6	3	1	6	2	1	32
8	M-08	1	3	8	3	6	3	1	6	2	1	34
9	M-09	1	2	8	3	6	3	1	1	2	2	29
10	M-10	2	3	8	3	12	3	4	6	2	2	45
11	M-11	1	3	5	5	6	1	4	6	1	2	34
12	M-12	2	3	1	3	6	1	4	1	2	2	29
13	M-13	1	2	5	3	6	3	1	6	2	1	30
14	M-14	2	3	5	1	6	3	4	6	2	1	33
15	M-15	2	3	8	1	12	1	1	6	2	2	38
16	M-16	2	4	1	1	12	3	4	1	1	1	30
17	M-17	2	3	1	3	6	3	1	1	1	2	23
18	M-18	2	3	1	3	6	3	4	1	1	2	26
19	M-19	1	3	5	3	6	3	4	6	2	1	34
20	M-20	2	2	8	3	6	1	4	6	2	2	36
21	M-21	2	4	8	5	12	3	4	6	2	2	48
22	M-22	1	3	8	3	12	1	1	6	1	1	35
23	M-23	1	3	5	3	12	3	1	1	2	2	33
24	M-24	2	3	1	1	6	3	1	6	1	1	27
25	M-25	2	2	1	3	6	3	4	6	2	2	31

PUDUKKAD												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	P-01	2	4	5	3	6	1	4	6	2	1	34
2	P-02	1	4	5	5	12	1	4	1	2	2	37
3	P-03	2	3	5	1	6	1	1	6	2	2	29
4	P-04	2	3	8	1	6	3	4	6	1	1	35
5	P-05	2	3	5	5	6	3	1	1	2	2	30
6	P-06	1	3	1	3	6	3	1	1	1	2	24
7	P-07	1	4	5	5	6	3	4	1	2	2	33
8	P-08	2	3	5	5	6	3	1	6	2	2	35
9	P-09	2	4	1	5	12	1	4	6	2	1	38
10	P-10	1	3	5	5	12	1	4	6	2	1	40
11	P-11	1	4	5	3	12	1	4	1	2	1	35
12	P-12	2	4	1	3	6	3	4	1	1	1	26
13	P-13	2	4	8	5	12	3	4	6	2	2	48
14	P-14	2	3	5	3	12	1	4	6	1	2	39
15	P-15	2	3	5	3	6	3	4	6	2	1	35
16	P-16	2	4	5	5	12	3	4	6	2	2	45
17	P-17	2	3	1	3	12	3	1	1	1	2	29
18	P-18	2	3	5	3	12	3	1	1	1	2	33
19	P-19	2	3	1	3	6	1	1	1	2	1	21
20	P-20	1	3	8	3	6	3	1	6	2	1	34
21	P-21	1	3	1	5	6	3	1	6	2	1	29
22	P-22	2	4	1	5	6	3	4	1	1	2	29
23	P-23	2	4	8	5	6	3	4	6	2	2	42
24	P-24	1	4	5	3	12	1	4	6	1	2	39
25	P-25	1	4	1	1	12	3	4	1	2	2	31
26	P-26	2	2	8	1	6	3	4	1	2	1	29

CHALAKUDY												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	C-01	2	3	1	1	12	1	1	1	1	1	24
2	C-02	1	2	5	5	6	3	1	6	1	1	31
3	C-03	2	2	5	3	6	1	1	1	1	1	23
4	C-04	2	3	8	3	6	3	4	6	1	2	38
5	C-05	1	4	5	3	12	1	4	6	1	2	39
6	C-06	2	4	1	3	12	1	1	1	1	1	27
7	C-07	2	4	5	5	12	3	4	6	1	2	44
8	C-08	2	2	5	5	6	1	4	1	2	2	30
9	C-09	1	2	8	5	6	1	1	1	2	2	29
10	C-10	1	4	8	3	12	1	1	6	2	2	40
11	C-11	2	4	1	3	6	3	1	6	2	1	29
12	C-12	2	4	8	5	12	3	4	6	1	2	47
13	C-13	2	4	1	3	6	3	4	1	1	1	26
14	C-14	2	4	8	1	6	3	4	1	1	1	31
15	C-15	1	3	5	1	6	3	4	6	2	2	33
16	C-16	2	2	5	5	6	3	1	6	1	1	32
17	C-17	1	3	5	3	12	1	4	6	1	1	37
18	C-18	1	2	5	5	6	3	1	6	2	1	32
19	C-19	2	2	5	3	6	3	4	6	1	1	33
20	C-20	2	2	8	5	6	3	4	1	2	2	35
21	C-21	2	3	1	3	6	1	4	1	2	2	25
22	C-22	2	3	1	5	6	1	1	1	1	1	22
23	C-23	2	2	5	5	12	3	1	6	1	1	38
24	C-24	2	3	5	3	12	3	1	6	1	1	37
25	C-25	2	4	8	5	12	3	4	1	2	2	43
26	C-26	1	3	1	1	6	1	4	1	2	1	21
27	C-27	1	4	1	3	6	3	4	1	2	1	26
28	C-28	2	2	1	5	12	1	4	6	1	1	35
29	C-29	2	2	5	3	6	3	4	1	2	1	29
30	C-30	2	3	1	3	6	3	1	6	2	1	28

WADAKKANCHERY												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	W-01	2	3	1	3	6	3	1	6	2	1	28
2	W-02	1	4	1	3	12	1	4	1	2	1	30
3	W-03	2	2	5	1	6	1	4	1	2	1	25
4	W-04	2	3	8	1	6	3	4	1	1	2	31
5	W-05	2	3	1	3	12	1	4	6	1	2	35
6	W-06	2	3	5	5	12	3	4	6	2	2	44
7	W-07	1	2	5	3	6	3	1	6	2	2	31
8	W-08	2	2	5	3	6	1	4	6	1	2	32
9	W-09	2	3	8	3	6	1	4	6	1	2	36
10	W-10	1	1	8	3	12	3	4	1	1	1	35
11	W-11	2	2	1	5	12	3	4	1	2	1	33
12	W-12	2	2	1	5	6	3	1	1	1	1	23
13	W-13	2	3	5	1	6	1	1	1	1	1	22
14	W-14	1	4	5	1	6	1	1	1	1	2	23
15	W-15	2	3	8	1	6	1	4	6	1	2	34
16	W-16	2	3	8	5	12	3	4	6	1	1	45
17	W-17	2	2	5	3	12	3	4	6	1	1	39
18	W-18	2	1	5	3	12	3	1	1	2	1	31
19	W-19	1	4	1	3	6	1	4	1	2	2	25
20	W-20	2	4	8	5	12	3	4	6	2	2	48
21	W-21	1	1	5	3	6	3	1	6	2	2	30
22	W-22	2	2	5	5	6	3	1	6	2	2	34
23	W-23	2	1	8	1	6	3	4	1	2	1	29
24	W-24	2	3	8	3	12	3	4	1	2	1	39
25	W-25	2	3	1	3	6	3	4	1	1	1	25

VENGARA												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	V-01	2	3	1	3	6	1	1	6	2	2	27
2	V-02	2	1	1	3	6	1	1	1	1	1	18
3	V-03	2	2	8	3	6	1	1	1	1	1	28
4	V-04	2	2	5	3	6	1	4	1	1	2	27
5	V-05	2	2	5	3	6	3	4	1	2	2	30
6	V-06	2	2	8	1	12	3	4	1	2	2	37
7	V-07	1	2	8	1	12	3	4	6	2	2	41
8	V-08	1	2	8	1	12	3	1	1	2	2	33
9	V-09	1	2	8	1	12	3	1	6	2	2	38
10	V-10	2	3	8	5	12	3	1	6	1	2	43
11	V-11	2	1	5	3	12	1	4	1	2	1	32
12	V-12	2	1	5	3	6	1	4	6	2	2	32
13	V-13	2	1	5	3	12	1	4	1	1	2	32
14	V-14	2	3	5	3	12	1	4	1	1	2	34
15	V-15	2	3	5	1	6	3	4	1	1	2	28
16	V-16	1	3	5	1	6	3	4	1	1	2	27
17	V-17	1	3	8	1	6	3	4	1	1	2	30
18	V-18	2	4	8	5	12	1	4	6	2	2	46
19	V-19	2	2	5	1	12	1	1	6	1	1	32
20	V-20	1	2	1	1	12	3	1	6	1	1	29
21	V-21	1	2	8	1	6	1	4	1	2	1	27
22	V-22	2	3	5	3	6	3	4	1	2	1	30
23	V-23	2	3	5	3	6	3	4	1	2	2	31
24	V-24	2	3	8	3	12	3	4	6	2	2	45
25	V-25	1	1	1	3	6	3	1	1	1	2	20
26	V-26	1	1	1	1	6	1	1	6	2	2	22

PARAPPUR												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	PA-01	1	3	5	3	12	3	4	6	1	2	40
2	PA-02	2	2	1	1	6	3	4	1	2	1	23
3	PA-03	1	1	1	3	6	3	4	6	2	1	28
4	PA-04	2	1	5	5	6	3	1	6	1	2	32
5	PA-05	1	1	5	5	12	1	4	1	2	2	34
6	PA-06	2	3	5	3	6	1	4	6	2	2	34
7	PA-07	2	3	8	3	12	1	4	6	2	2	43
8	PA-08	2	3	5	3	6	1	4	1	2	2	29
9	PA-09	2	3	5	3	6	1	1	1	2	2	26
10	PA-10	1	2	5	5	6	3	4	1	1	2	30
11	PA-11	1	2	8	1	12	3	1	6	1	1	36
12	PA-12	2	2	1	1	12	3	1	6	1	2	31
13	PA-13	1	2	5	3	6	3	1	1	2	2	26
14	PA-14	1	2	1	5	6	1	4	6	1	2	29
15	PA-15	2	4	5	5	12	1	4	1	1	2	37
16	PA-16	2	3	8	5	12	1	4	6	2	2	45
17	PA-17	2	3	5	3	12	3	4	1	1	2	36
18	PA-18	1	2	5	3	6	3	4	6	2	2	34
19	PA-19	2	4	5	3	6	3	4	6	1	1	35
20	PA-20	2	4	8	5	12	3	4	6	2	2	48
21	PA-21	2	3	1	5	12	1	4	6	2	1	37
22	PA-22	1	2	5	1	12	3	4	6	2	1	37

THRIKADEERI I												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	T-01	2	2	5	1	12	1	4	1	1	2	31
2	T-02	1	2	5	1	12	3	4	6	2	2	38
3	T-03	2	3	1	2	6	1	4	6	1	1	27
4	T-04	2	2	5	1	6	3	4	6	2	1	32
5	T-05	2	4	8	5	12	3	4	6	2	2	48
6	T-06	2	2	1	3	6	1	4	6	1	2	28
7	T-07	2	3	1	3	6	3	1	1	1	2	23
8	T-08	2	3	5	5	6	3	1	1	2	1	29
9	T-09	2	2	8	5	12	1	1	1	2	1	35
10	T-10	2	2	5	3	6	3	1	1	2	2	27
11	T-11	2	3	5	5	12	3	4	6	2	2	44
12	T-12	1	1	5	3	6	3	1	6	1	2	29
13	T-13	2	3	1	5	12	1	4	6	1	1	36
14	T-14	2	3	1	1	12	3	4	6	1	1	34
15	T-15	2	4	8	5	6	3	4	1	1	2	36
16	T-16	1	2	1	3	6	1	1	1	2	2	20
17	T-17	1	2	5	3	6	1	1	1	2	1	23
18	T-18	2	3	1	5	6	3	1	16	2	1	40
19	T-19	2	2	5	5	12	3	1	6	1	2	39
20	T-20	1	2	1	3	6	1	4	6	1	2	27
21	T-21	2	2	5	1	12	1	4	1	1	1	30
22	T-22	2	4	5	1	6	1	4	1	2	1	27
23	T-23	1	3	1	3	12	1	1	6	2	2	32
24	T-24	1	3	1	1	6	3	1	6	1	2	25
25	T-25	2	3	8	5	12	3	4	6	2	2	47

ANANGANADI												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	AN-01	2	3	1	2	6	1	4	6	1	1	27
2	AN-02	1	2	5	1	12	3	4	6	2	2	38
3	AN-03	2	3	1	2	6	1	4	6	1	1	27
4	AN-04	2	3	1	5	6	3	1	6	2	1	40
5	AN-05	2	3	1	1	12	3	4	6	1	1	34
6	AN-06	1	3	1	3	12	1	1	6	2	2	32
7	AN-07	2	3	1	3	6	3	1	1	1	2	23
8	AN-08	2	3	5	5	6	3	1	1	2	1	29
9	AN-09	2	3	5	3	6	3	4	1	2	2	31
10	AN-10	2	4	5	5	12	3	4	6	2	2	45
11	AN-11	2	2	1	3	6	1	4	6	1	2	28
12	AN-12	2	4	8	5	12	3	4	6	2	2	48
13	AN-13	2	3	1	5	12	1	4	6	1	1	36
14	AN-14	2	3	1	5	6	3	1	6	2	1	40
15	AN-15	2	4	8	5	6	3	4	1	1	2	36
16	AN-16	1	2	1	3	6	1	1	1	2	2	20
17	AN-17	2	4	5	5	12	1	4	6	2	2	43
18	AN-18	2	2	5	5	12	3	1	6	1	2	39
19	AN-19	2	3	5	3	6	3	4	1	2	2	31
20	AN-20	1	2	1	3	6	1	4	6	1	2	27
21	AN-21	2	2	5	1	12	1	4	1	1	1	30
22	AN-22	2	4	5	1	6	1	4	1	2	1	27
23	AN-23	2	3	1	5	6	3	1	6	2	1	40
24	AN-24	1	3	1	1	6	3	1	6	1	2	25
25	AN-25	2	3	5	3	6	3	4	1	2	2	31
26	AN-26	2	4	8	5	6	1	1	1	2	2	32

URAKAM												
Sl. No.	Tree ID. No.	Verticality	Straightness	Apical dominance	Forking	Branch angle	Self-pruning ability	Foliar damage	Stem damage	Cross section	Bole swelling	Total score
1	U-01	2	4	5	5	12	3	4	6	2	2	45
2	U-02	2	3	5	3	12	3	4	1	1	1	35
3	U-03	1	1	1	3	12	3	1	1	1	1	25
4	U-04	1	1	1	1	12	3	1	1	1	2	24
5	U-05	2	3	1	1	6	3	4	1	2	2	25
6	U-06	2	3	5	1	12	3	4	1	2	2	35
7	U-07	2	3	5	1	12	1	4	6	2	2	38
8	U-08	2	3	5	3	6	3	4	1	2	2	31
9	U-09	2	4	5	5	12	1	4	6	2	2	43
10	U-10	1	2	5	3	6	1	4	6	1	2	31
11	U-11	1	2	8	3	6	3	4	1	2	1	31
12	U-12	1	2	8	5	6	3	4	6	2	2	39
13	U-13	2	3	1	3	6	3	4	1	1	2	26
14	U-14	2	3	1	3	6	3	4	1	1	2	26
15	U-15	2	3	1	3	12	3	1	1	1	2	29
16	U-16	1	3	1	3	12	3	1	1	1	2	28
17	U-17	2	2	5	3	12	1	1	1	1	2	30
18	U-18	1	2	5	5	6	1	4	1	2	2	29
19	U-19	2	2	1	5	6	3	4	6	1	1	31
20	U-20	2	2	5	3	6	1	1	6	1	1	28
21	U-21	2	3	1	3	12	3	4	1	2	1	32
22	U-22	2	3	1	1	12	3	1	1	2	1	27
23	U-23	1	3	1	3	6	3	4	1	2	2	26
24	U-24	1	2	5	3	6	1	1	6	1	2	28
25	U-25	1	2	5	1	12	1	4	1	1	2	30
26	U-26	2	3	8	3	12	3	4	6	2	2	45

Table 10. Summary of ANOVA giving for the various morphological characters of *Ailanthus triphysa* progenies

Source of Variations	Df	Height	Collar diameter	Number of leaves	Biovolume
Half sib families	29	1.654	0.003	0.767	0.004
Error	60	1.243	0.001	0.121	0.001
CV (%)		11.50	18.70	11.26	24.02

Table 12. Summary of ANOVA giving Mean square values for the physiological characters of *Ailanthus triphysa* progenies

Source of Variations	Df	Photosynt-hesis	Stomatal conducta-nce	Transpirat-ion rate	Leaf temperatu-re	Relative water content
Half sib families	29	2.346	0.065	2.583	8.430	113.173
Error	60	0.005	0.001	0.113	0.015	6.568
CV (%)		28.32	34.42	40.15	4.61	8.42

DIVERSITY ASSESSMENT AND SELECTION OF CANDIDATE PLUS TREES OF *Ailanthus triphysa* (Dennst.) Alston IN SELECTED DISTRICTS OF NORTHERN KERALA

by

JES LALNUNPUIA

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ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF FOREST BIOLOGY AND TREE IMPROVEMENT

COLLEGE OF FORESTRY

VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

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ABSTRACT

Matti *(Ailanthus triphysa* [Dennst.] Alston), belonging to the family Simaroubaceae is a medium to tall evergreen rainforest tree. It is one of the most important and extensively used trees for making match splints in India. The study attempted to determine the diversity and select candidate plus trees from selected districts of Northern Kerala and to evaluate their progeny.

Thirty candidate plus trees were selected based on baseline regression of trunk volume to crown volume combined with scoring for qualitative characters. The tree height, GBH, crown diameter and clear bole height of the plus trees varied from 20 m to 37 m, 0.69 m to 2.11 m, 3.5 m and 9.75 m and 7 m to 24 m respectively. The thirty candidate plus trees were grouped into nine clusters through cluster analysis. Cluster I had a maximum number of CPTs with 15 accessions, whereas the least number observed for cluster VII, VIII and IX respectively. Clusters with only one plus tree can either possess superior or inferior quality among the plus trees. The clustering pattern revealed that plus trees from the same geographic sources were grouped into different clusters, while plus trees from different geographic sources were grouped into the same clusters. The highest intra and inter cluster was observed on cluster I (2.07) and cluster III and IV (8.91). This indicates there was greater genetic distance within and between the clusters.

Seedling biometric observations for different morphological and physiological characters showed significant differences except for the height of the seedlings. The seedlings height, collar diameter, the number of leaves and biovolume ranged from 8.73 cm (FCV-AT-02) to 11.2 cm (FCV-AT-01), 0.14 mm (FCV-AT-02) to 0.25mm (FCV-AT-16), 4.33 (FCV-AT-02) to 6.53 (FCV-AT-20) and 0.12 cm^3 (FCV-AT-02) to 0.32 cm^3 (FCV-AT-16). The progenies FCV-AT-21, FCV-AT-33, FCV-AT-36, FCV-AT-37, FCV-AT-39 and FCV-AT-40 were found superior based on overall mean performance of the morphological characters. Hence, seeds of these CPTs can be used in immediate field planting operations.

The genetic analysis of the causes of variation for the morphological and physiological traits was studied. The highest phenotypic and genotypic coefficients of variation were observed on the character biovolume. For all the characters studied, the phenotypic coefficient of variation was higher than the genotypic coefficient of variations indicating that there were non-additive effects. High heritability coupled with a genetic gain was observed in the number of leaves and collar diameter. Similarly, heritability was high for all the physiological traits with an adequate genotypic variation that can help in the further improvement programme.

The correlation studies on morphological and physiological studies showed that positive correlation was observed in the seedlings height and collar diameter of the CPTs. The relation with collar diameter and biovolume, collar diameter and stomatal conductance, biovolume and stomatal conductance of the CPTs were also found positive. A positive correlation was also recorded on the plus trees selected on the characters photosynthesis and transpiration and stomatal conductance and leaf temperature.

It can be concluded from the study that considerable morpho-physiological variations exist in selected candidate plus trees of *Ailanthus triphysa*. These results could help in the future breeding programme as well as efficient management of the trees.