EVALUATION OF *Morus alba* L. CLONES FOR MORPHOMETRIC AND WOOD CHARACTERISTICS

Thesis

by

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CERTIFICATE-I

This is to certify that the thesis titled **"Evaluation of *Morus alba* L. clones for morphometric and wood characteristics."**, submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **FOREST GENETIC RESOURCES** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Mr. Vipul Sharma (F-2018-65-M)** Son of Shri Thakur Dass under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place: Nauni, Solan
Dated:

(Dr. I. K. THAKUR)
Chairman
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CERTIFICATE-II

This is to certify that the thesis entitled, **"Evaluation of *Morus alba* L. clones for morphometric and wood characteristics"** submitted by **Mr. VIPUL SHARMA (F-2018-65-M)** Son of Shri Thakur Dass to Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni), Solan (H.P.) 173 230 India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **Forest Genetic Resources** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the Internal Examiner.

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Being a social animal, nobody is perfect, so all errors and omissions are mine.

Place: Nauni, Solan

Date: **(Vipul Sharma)**

CONTENTS

ABBREVIATIONS USED

%	:	Per cent
amsl	:	Above mean sea level
ANOVA	:	Analysis of Variance
CD	:	Critical Difference
cm	:	Centimeter
CV	:	Coefficient of Variation
Dbh	:	Diameter at breast height
DOB	:	Diameter over bark
DUB	:	Diameter under bark
e.g.	:	For example
et al.,	:	And others
etc.	:	et cetera
Fig.	:	Figure
g	:	Gram
GCV	:	Genotypic coefficient of variation
H.P.	:	Himachal Pradesh
i.e.	:	That is
kg	:	kilogram
KMO	:	Keyse-meyer-olkin
L.	:	Linnaeus
m	:	Meter
MC	:	Moisture content
mg	:	Milligram
ml	:	Milliliter
mm	:	Millimeter
MMC	:	Maximum moisture content
No.	:	Number

PCA	:	Principal Component Analysis
PCV	:	Phenotypic coefficient of variation
RBD(F)	:	Randomized Block Design (Factorial)
SG	:	Specific gravity
ssp	:	Sub species
viz.	:	videlicit
wrt	:	With respect to

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Chapter-1

INTRODUCTION

India pre-dominantly an agricultural country has the largest cattle population in the world. A large cattle population, particularly in hilly areas, cannot be maintained on the fodder produced on arable land alone. India has nearly 18 per cent of the world's livestock population, the density working out to be nearly 80 animals per 40 hectares of arable land. Livestock constitute an important component of the rural economy. An overview of the growth of the livestock population in India from 1996 to 2006 was 495.02 million to 587.59 million, respectively. In India about 70 per cent of the population is dependent on agriculture for their livelihood. The main reason for low milk production is the large deficit in the availability of palatable and nutritious green fodder round the year. The available fodder resources can provide only about one third of the maintenance ration per day which is inadequate as against the total requirement of the green fodder (698.55 million tons) and dry fodder (550.90 million tons) for livestock in the country.

Agricultural crops are seldom grown in India especially for fodder production except in certain marginal areas which account for only less than two per cent of the total cultivable area in the country. In view of the higher income of human population and also because of higher income from cereals and cash crops than from forage crops, more agricultural area cannot be set apart for fodder production. Trees which can be grown either in combination with agricultural crops or on separate land usually not fit for agriculture, offer opportunity of producing green nutritious fodder for the livestock. The leaf fodder of some trees is almost as nutritious as that of the leguminous fodder crops. Trees can produce almost as much green fodder per unit area as agriculture fodder crops. Further trees have the capacity of growing under adverse conditions and in areas where it may not be possible to grow conventional agricultural crops, such as rocky mountain slopes, steep slopes, arid, saline or waterlogged soils and areas with severe climatic conditions. Trees also do not need such heavy inputs in the form of pesticides, fungicides, fertilizers and labour etc., as are needed for growing agriculture crops.

White mulberry (*Morus alba L.*) is a fast-growing small to medium sized tree which grows 10–20 m tall. It belongs to family Moraceae. It is native to northern China however it is widely cultivated elsewhere (India, United States, Mexico, Australia, Kyrgyzstan, Argentina, etc.). Indian gene centre is rich in *Morus* species. *Morus alba* is cultivated especially in northern India from Jammu and Kashmir to Assam. In some areas it is found wild. In the Himalayas it ascends up to an elevation of about 1200m. In the hills it is mostly confined to stream beds or such other places where sufficient moisture is available for its growth. It does not grow on dry slopes or shallow soils where moisture becomes a limiting factor.

The species is widely cultivated in Jammu and Kashmir, Haryana, Punjab, Uttar Pradesh, Karnataka, Tamil Nadu, West Bengal, Kerala and to a lesser extent in Madhya Pradesh, Bihar, Orissa, Assam, Manipur, Andhra Pradesh (Ghosh, 1977). Wild relatives of genus *Morus* are reported to occur in India in tropical and sub-tropical Himalayan belt. It grows on soils ranging from sandy loam to clay loam however, alluvial and deep loamy soil with sufficient moisture supply supports its best growth. The tree cannot tolerate alkalinity and grows best on soils with pH ranging between 6.0-7.5.The soil texture and depth are the important factors affecting its growth. The old leaves are shed in November-December and trees are leafless during winter season. The new leaves on the tree appear in March-April depending upon the climate of the locality. The flowering takes place in March-April and the fruits ripen from April to June (Brandis, 1906).

White mulberry is a multipurpose agroforestry tree species having high ecological and economic importance in terms of production of fodder, timber, silk and fuel. It is an important crop for silkworm (*Bombyx mori* L.) feed, fruit and timber as well as an excellent amenity tree. Its leaves and young bark are recognized as an excellent animal fodder. The fruit can be eaten fresh, preserved, vinified and in some semi-arid areas dried for winter use. It is also pollarded to furnish round wood. The species provides excellent timber which is used for sports good as well as local needs in furniture. White mulberry is said to be potentially invasive and to compete with native forest vegetation. The male clones are sometimes used as avenue trees to avoid seeding as well as soiling of the ground by fallen fruit. Apart from this it is known to have a wide medicinal importance for treating a number of diseases like cancer, improves blood circulation, cleanses blood, strengthens kidney, controls blood sugar speeds up recovery etc.

To establish priorities for the conservation and improvement of tree genetic resources, understanding of the degree of diversity among and between trees is required. The determination of amount, nature and cause of variation present in the species of interest is the first step towards any improvement programme. All differences among trees are the result of three things viz., the genetic differences among trees, different environment in which tree is growing and interaction between tree genotype and environment in which they grow. Continuous development is possible if variation exists in a species. Variations are essential for adaptation and improvement of the species and the amount of variation determines the potential for improving it through breeding programmes. The species (*Morus alba*) offers an opportunity for studying variation among clones and to select superior individuals for further use in clonal seed orchard, production orchard and clone×site interaction trials etc. Therefore, different clones were evaluated for various morphometric and wood characteristics in the already established clonal evaluation trial in the department with the following objectives:

OBJECTIVES

i) To study variation in different morphometric characters.

ii) To determine variation in physical properties of wood.

Chapter-2

REVIEW OF LITERATURE

Variation is essential to a species' long-term survival. These are the result of a continuous selection from the environment from generation to generation. It is the result of differences or the combination of both between the individuals caused by hereditary material or environment. Studies of variation for breeding program are thefirst-hand knowledge.

It helps in comparing populations. We can screen out the natural genetic variation available to make use of the best material for maximum productivity and further breeding work. In order to determine the study's goals it was deemed necessary to have knowledge of the results of certain earlier findings and the methodology adopted to arrive at some conclusion.

Such a review of literature linked to the study's main objectivewill provide a framework for either supporting the earlier results or contradicting the same and thereby suggesting further improvement concerns. The brief overview of the research relating to the proposed studies is as follows:

2.1 VARIATION IN MORPHOMETRIC CHARACTERISTICS OF TREES:

Tikader and Kamble (2008) arranged and devloped twenty-five indigenous mulberry germplasm in a partially balanced lattice configuration at the Central Sericultural Germplasm Genetic Resources Centre, Hosur, Tamil Nadu for growth and yield traits. They noted that leaf yield output showed high variability among the accessions of mulberry. Analysis of variance on growth and yield showed substantial variation for all of the traits among the accessions. Seasonal variability has also been found in the yield of leaves. For all traits the interaction between accession and season has been highly significant. The variation coefficient was maximum for single leaf weight (36.32 %) and minimum for leaf moisture content (2.08 %). Analysis of the correlation coefficient indicated significant association of leaf yield and other growth characteristics. They also found that the number of branches per plant, length of the longest shoot, total length of shoots, leaf moisture content and leaf moisture retention capacity showed associations with leaf yield at various levels of significance. Certain characteristics displayed complex interrelationships.

Tikader and Kamble (2009) also evaluated exotic germplasm accessions of the mulberry (*Morus* spp.) under India's tropical agro-climatic condition. Accessions of Mulberry showed significant variability in growth and yield traits. Variance analysis showed major variances in both growth and yield characteristics. The relationship between the accession and season was important for all characteristics except number of branches per plant, total length of shoot and internodal size. The coefficient of variability was found to be highest for leaf yield per plant followed by total shoot length and where it was minimized for leaf moisture content. This study revealed that the yield of the leaf depends on number of branches per plant and total length of the shoot.

Rao *et al.* (2011) carried out three surveys and exploration activities in 19 districts of Rajasthan arid region. This resulted in *Morus*spp gathering 75 accessions. (*Morusindica*-37,*Moruslaevigata*-23, *Morusalba*-7, Accessions *Morushybrids*-8). In the ex-situ field gene bank the collections which had large variation in morpho-reproductive characters were preserved and evaluated for various histological and growth parameters for the leaf. The promising accessions have been identified for developing line tolerant to drought.

Murthy *et al*. (2012) field tested nine mulberry varieties along with one M5 review variety in Karnataka. The propagation parameters such as sprouting, survival, shoot growth and rooting behavior were considered and evaluated for these mulberry varieties. These mulberry varieties exhibited significant variations in the weight of fresh shoot and dry shoot.

Iqbal et al. (2012) have also investigated three indigenous mulberry varieties, namely *Morus alba, Morus nigra, Morus rubra* for their antioxidant ability and their proximate composition. The features investigated showed strong nutritional and antioxidant qualities with mutually meaningful variations for all the varieties.

Murthy *et al.* (2013a) investigated yield and phyto-chemical parameters of the Vishwa mulberry variety under various spacing systems (2'x1', 2'x2', 3'x3', 4'x4'). Results showed that the branching pattern was significantly different depending on the spacing where the highest number of shoots / plant and the longer shoot length / plant was located in 4'x4 'followed by 3'x3' spacing. In addition the lowest internodal distance was observed in the spacing of 4'x4' and the maximum in plants below 2'x2'. The average yield of the leaf / plant washighest in spacing 4'x4 while the yield / unit area of the leaf was greater in the spacing of 2'x1 'followed by 2'x2' and 3'x3. No improvement in moisture retention capacity was observed in leaves even under different spacing after 12hrs. The proteins, total sugars, and chlorophyll contents were also found to be high in plants below 4'x4' spacing. Based on the findings it was found that Vishwa mulberry variety grown under 4'x4 'spacing showed significant improvement in yield and phyto-chemical parameters.

Murthy *et al*. (2013b) evaluated 10 mulberry varieties by phyto-chemical tests namely Tr8, Tr12, Tr20, S1708, Ms5, C6, C10, Matigara black, *Morusnigra* and M5 for their leaf consistency. They revealed high total proteins, total sugars and amino acids in tender leaves followed by medium and coarse leaves. High moisture content in tender leaves was also noted followed by and medium and coarse leaves.

Wani *et al.* (2014) studied the nature and magnitude of genetic variability in 17 mulberry genotypes (*Morus* spp) and their interrelationship for leaf and yield traits. Analysis of the variance in lamina length, lamina width, lamina weight, petiole weight and leaf petiole ratio by weight, petiolelength, leaf petiole ratio by length and leaf yield per plant showed significant variation. Leaf yield was the highest (4,751 kg / plant) in Goshoerami followed by SKM-33 (4,100 kg / plant) in the spring season as recorded in Goshoerami (4,863 kg / plant) and in SKM-33 in the autumn season (4,450 kg / plant). He concluded that Goshoerami and SKM-33 had the largest yield of leaves that could be used in potential breeding programs.

Peris *et al*. (2014) examined the genetic divergence of twelve phenotypic traits of five mulberry accessions, including Embu, Thika, Thailand (*M.alba*), Kanva-2 and S41 (*M. indica*), grown in Kenya. They found that the traits varied significantly across mulberry accessions included lamina width and petiole length (P 0.01), petiole width and growth height (P = 0.05), internode size, and branch number (P 0.001). Study revealed that there were fewer branch numbers characterizing Embu and Thailand accessions than the rest of the accessions. Thika 's accession on the other handhad a large number of branches and short internode reach. Except in internode distance and number of branches which were significantly and negatively correlated, significant and positive correlations were found between leaf yield traits.

Sharma *et al.* (2015) studied 14 mulberry varieties in the existing Dehradun district agro-climatic conditions collected from the germplasm bank held at the Regional Sericulture Research Station, Sahaspur. They observed morphological and bio-chemical characteristics and revealed significant variations in growth and bio-chemical characteristics. In addition to growth parameters in mulberry tree improvement their study revealed that morphological and bio-chemical markers can enhance selection intensity.

Bajpai *et al*. (2015) studied ten quantitative morphological characters in 56 *Morus alba* accessionsrepresenting 3 natural populations from the trans-Himalayan region of Ladakh. Variability coefficient suggested a high phenotypic variation in *Morus alba*. Linear regression analysis showed that the size of the leaves and fruits decreased with increased altitude. It was observed for leaf length, leaf width, smalllet length, leaf area, internodal distance, number of nodes, length of fruit, fruit width and weight of the fruit. Likewise a high phenotypic plasticity index for bud length, leaf length, leaf width, petiole length and leaf internode was observed. Variance analysis showed a pre-dominant altitudinal effect on morphological character as compared to the effect on population. A slight altitude changes induced major changes in the morphological characteristics of the plant.

Ma *et al*. (2015) investigated the clonal variation in four hybrid poplar clones that were grown at three North China sites and identified the top clones. They also measured the wood properties at the Fengfeng Nursery of four 6-years-old clones. The difference in growth traits and stem volume rankings varied among sites. Fiber traits and components of wood chemicals showed significant interclonal variations.

2.2 VARIATION IN PHYSICAL PROPERTIES OF WOOD OF TREES:

Bhat *etal*. (1985) reported that the average percentage of the bark in branches was significantly higher than in stems ranging from 10.3 in Benteak to 28.9 in Cashew in branches as opposed to 4.8 to 16.2 in stems of selected tree species grown in Kerala. On an average the length of the branch fiber was 12% lower than the length of the stem fiber. The study further revealed a higher percentage of wood density and bark at the top while at the bottom of branches and stem the heartwood percentage and fibre length were higher.

Olson *etal*. (1985) studied seventy-five Eastern cotton wood clones (*Populusdeltoides*) for specific gravity and found significant differences after three growing seasons among the clones. They also reported an average specific gravity of 0.33, with clones ranging from 0.27 to 0.39.

Chauhan*etal*. (1999) worked on anatomical wood quality parameters such as fiber characteristics, vessel frequency and diameter and tissue proportion in *Populusdeltoides*clone plantations(8 years old). Significant clonal variations in fiber length, vessel length, fiber diameter, lumen diameter, vessel frequency and vessel diameter were reported. The length of the fibers and of the vessels increased with age. They also stated that specific gravity in all the clones was positively associated with fibre length but only in 4 clones with vessel diameter.Their study further revealed that the percentage of cell type among clones was not significantly varied but the increase in the percentage of fibers was found to be related to the decrease in the percentage of the vessels. The observed variation in parameters of wood quality offers possibilities for selecting tree breeding stock with desirable wood qualities.

Geyer *etal*. (2000) studied biomass and gasification properties of young *Populus* clones and reported that the wood 's characteristics were close to those of soft hardwoods, the length of the fiber was comparatively shorter (0.84 mm), and the specific gravity was 0.37. Mean specific bark and wood gravity values were 0.37 at the base of the tree and 0.34 at dbh (all based on green volume).

Quilho *et al.* (2000) studied *Eucalyptus globulus* bark’s quantitative anatomical characteristics and found that fiber width and wall thickness decreased from base to base. Parenchyma was the bark 's main cell type (50%), followed by fibers (27.9%), rays (12.1%), sieve tubes (2.7%), and sclereids (7.3%).

Thakaran *et al.*. (2003) studied the characteristics of willow and hybrid poplar clones in energy feedstock at harvest age. They reported less variability in specific gravity (0.33–0.48), percentage of bark (3.6–8.1 percent) and percentage of moisture (49–56 per cent). They also reported that as a group willow clones had a higher specific gravity and bark percentage compared with hybrid poplar clones. They concluded that clonal variation in these characteristics present opportunities to manipulate the quality of feedstock through selection, breeding, and management of plantations.

Pan *et al.*. (2005) studied the anatomical wood properties of hybrid tulip (*LiriodendronchinensexLtulipifera*) which was 24 years old. The results showed an average length of 0.80-1.74 mm of fibre. The length of the fibre from pith to bark grew exponentially continuing to stabilize at the growth ring of 11th year.

Gurau *et al.*(2008) compared branch and stem wood moisture content for three species, viz. Maple (*Acer* spp.), Scots pine (*PinussylvestrisL.*) and Beech (*FagussylvaticaL.*)

found a moisture content in beech wood of 15.4% in stem and 33.8% in branch. The Scot pine showed 15.3 percent moisture in stem and 20.9 percent in branch while in maple tree, stem moisture content was 11.8 percent and branch moisture content 16.9 percent.

Acacia mangium, Acacia auriculiformisand Acacia hybrid clones were examined by Nguyen *et al.*(2009) for growth, specific gravity and wood fiber length. The length of the wood fiber was initially 0.5-0.6 mm near the pith and then slowly increased finally reaching 1.0-1.2 mm near the bark. Acacia 's specific gravity grew from 0.49-0.58 near the pith to 0.63-0.47 near the bark.

Rokeya *etal*. (2010) investigated the physical properties of hybrid *Acacia*, produced from natural crossing of two introduced timber species (*Acacia auriculiformis* and *Acacia mangium*). The timber of hybrid Acacia is of medium density and in green condition had a specific gravity of 0.56 which was lower than that of teak (*Tectonagrandis*). Hybrid Acacia wood volumetric shrinkage was found to be higher but the specific gravity was found to be lower than that of teak.

Wani and Khan (2010) reported significant variation in anatomical characteristics of the wood viz. fiber length, fibre diameter and fiber wall thickness from various positions of Populusnigra trees.

Kilemwa (2010) studied 21 promising willow clones and found significant variations in wood physical characteristics, moisture content, specific gravity, and fiber length. Clone 131/25showed specific gravity of 0.81, clone MB-368 recorded fiber length of 1.93 mm and clone 172 recorded maximum moisture content of 110.49 per cent.

Izekor and Fuwape (2011) studied *Tectonagrandis* wood in the State of Edo, Nigeria and recorded mean fiber length values of 1,45, 1,73 and 1,96 mm; fiber diameters of 26,79, 29,47 and 32,83 µm. Fiber weight, fiber diameter, and cell wall thickness increased with age, while fiber lumen width decreased with age.

Pande (2011) studied 10 clones of *Populusdeltoides* raised at Rudrapur (Udhamsingh Nagar), India, by WIMCO Plantations Ltd. It was recorded that female parents exhibited greater specific gravity than male parents.

Gupta (2012) studied the characteristics of different woods after bio-preservative treatment and found that *Pinus roxburghii* wood density ranged from 0.516 to 0.492 for treated and untreated wood. Kumar (2016) also recorded the specific gravity range of 0.523 to 0.560 for chir wood.

Headlee et al. (2013) worked on the specific gravity of hybrid poplars in the North Central region of the United States with the aim of characterizing the effects of bole location, place, clone and place-like clone interactions for twelve hybrid genotypes. They observed that for 612 samples taken from 204 trees, specific gravity ranged from 0.267 to 0.495, with bole position and site-like clone interactions having significant effects. Further investigation on site-specific clone interactions indicated that key predictors of specific gravity were environmental conditions related to water stress. They believed the results of these investigations were important to inform genotypical selection and silvicultural management decisions related to growing hybrid poplars.

Dhiman (2014) analyzed the difference in specific gravity in three species of wood, i.e., *Pinus roxburghii*, *Celtisaustralis* and *Bombax ceiba*, using *Acorus calamus* extract as bio-preservative and reported values as 0.544, 0.586 and 0.465, respectively.

Latib*et al.*(2014) studied Kelempayan (Neolamarckiacadamba) wood's physical properties, and reported that Kelempayan 's highest specific gravity was found at the bottom followed by middle and top portions. Specific gravity was highest along the radial direction near the bark followed by the middle and near the pith. The percentage of the moisture content increased from bottom to top.

Kiaei and Moya (2015) studied physical properties of the Alder (*Alnusglutinosa*L) species in stem, branch and root wood. Variance analysis (ANOVA) showed that the wood samples had a significant difference on the density of the wood. In stem wood the highest density of wood and volumetric shrinkage was found whereas root wood had a lighter density. Compared to stem wood and branch wood the relationship between wood density and volumetric shrinkage in root was very weak.

Kiaei and Moya (2015) determined the fiber dimensions for the Alder (*Alnusglutinosa* L) species in stem, branch and root wood. Variance analysis (ANOVA) indicated that there was a significant difference between the wood samples on fiber length, fiber diameter and lumen diameter. Highest fiber length was found in stem wood whereas root wood had a larger diameter of fiber and a larger diameter of fiber lumen. Compared to other parts of the wood sample, the branch wood had the lowest fiber dimensions (fibre length, fibre diameter and lumen diameter).

Bhatt (2016) conducted studies on exotic and native species of Shorea 's wood quality parameters and found that Sal registered maximum specific gravity (0.681) with medium texture among various physical characteristics.

Bhatt (2016) found the largest diameter of fibre (31.14 μm) in teak. In Shorea the maximum vessel element length and vessel element diameter were as 630.09 μm and 230.75 μm , respectively. The maximum ray height was recorded in Shorea (845,63 μm) and the maximum ray width was obserbed in teak (82,91 μm).

Bhatt (2016) also found the longest fiber length in light red meranti (1222.24μm), while in teak the maximum fiber diameter (31.14 μm) was found. The dark red meranti recorded the maximum vessel element length and the vessel element diameter as 630.09 μm and 230.75 μm , respectively. The highest frequency of the vessels was found in yellow Meranti (8.21). The maximum ray height was registered in light red meranti (845,63 μm) and the maximum ray width in teak (82,91 μm).

Chauhan (2016) noticed that the length of the tracheid (3,97 mm), the diameter of the tracheid (50,01 μm) and the width of the rays (32,05 μm) were the highest in *Pinus roxburghii* and the length of the rays (0,680 μm) in *Cedrusdeodara*.

Sharma (2016) studied the physical properties of wood samples of *Cedrusdeodara* collected from different sites in Himachal Pradesh and reported the highest moisture content (91.09 percent) for wood samples procured from Nankhari site and highest specific gravity (0.5138) from Chopal site in Shimla district of Himachal Pradesh.

The wooden discs, collected from different heights of 20 selected Eucalyptus clones, were investigated for their physical properties*viz.* colour of wood, texture, grain, specific gravity and moisture content by Behra *et al.* (2016). For most clone wood samples the study revealed yellowish sapwood with brownish pink heartwood and medium texture with straight grain. For 20 clones specific gravity ranged from 0.52 to 0.62 with a moisture content for 59.5 to 80.7 per cent. For clones C12, C10 and C13, respectively, the maximum specific gravity was observed at 0.62, 0.60, and 0.59. Clone C12 was observed with the lowest moisture content of 59.5 per cent followed by C13. Clones C12, C10 and C13 performedbetter and were suggested for large-scale plantation program in the South Gujarat area considering overall physical properties.

Mir *et al*. (2017) studied nursery output of male poplar clones (*Populus deltoides*.) under Kashmir Valley's temperate conditions and identified interclonal differences in different wood gravity. Among non-local clones the stated wood gravity for clone G-3 was maximum (0.415) and minimum (0.388) for clone S7C4. Although LM-1, LM-2 and LM-3 clones obtained locally exhibited a similar wood gravity of 0.398, 0.394 and 0.396, respectively. Various earlier studies on*Populustremuloides* (Yanchuk et al., 1984), *Populustomentosa* (Song et al., 1997), *Populusdeltoides* (Zhang *etal*., 1999) and *Populuseuramericana* (Beaudoin *etal*., 1992) indicated high genetic variations in wood-specific gravity. When analyzing 20 clones, Rajput *etal*. (1997) reported that as growth rates differ from clone to clone there is also variability in specific gravity.

Bardak*et al*. (2017) examined the effect of raw material grown in the area on the particle board's anatomical properties and found that *Ailanthusaltissima*wood grown in Trabzon had a longer fiber length, a thicker fiber and trachea cell wall than that of the wood grown in Artvin.

Sunny (2017) found In the wood samples of *Dalbergia sissoo* from Ghumarwin site, fiber diameter of (0,020 mm) an also from the wood samples (Dattowal site) greater vessel diameter and fiber length (1,66 mm).

Salvo *etal*. (2017) analyzed radial density variation and some of *Eucalyptusnitens*anatomical properties such as vessel size, vessel distance, ring width, fiber cell wall thicknesses and fiber length cut from a 17-year-old plantation in Southern Chile. It was reported that the anatomical properties did not gradually change from pith to bark but were better described by dividing the tree radius into three distinct woods, i.e., inner, middle, and outer wood. The results also showed that density depended on the area of the vessel, the area of the cell wall, ring width and the width of the latewood. The coefficient of correlation between apparent density and area of the vessels was found to be negative and the coefficient of correlation between apparent density and latewood ring width of the area of the cell wall and total ring width was positive. They concluded however that*Eucalyptusnitens*low density nitenswood tended to have greater vessel area and lower fiber cell wall area, ring width and latewood thickness.

Thakur (2017) conducted the studies on the physical properties of *Acacianilotica* wood market samples and concluded that in most of the samples collected from different locations, fine texture and light to moderate reddish-brown colour were observed. The highest moisture content (28.033%) was found at Parwanoo-1, while the lowest was in Datowal (8.559%)sample. The overall moisture content (percentage) was found to be the highest at Nalagarh-2 location (107.719 percent) and the lowest at Baddi (59.255 percent). In Baddi the maximum specific gravity (0.802) was reported and in Nalagarh-2 the minimum (0.585).

Thakur (2017) studied the various anatomical properties of *Acacia nilotica* wood market samples and confirmed that the maximum vessel diameter (0.158 mm) was recorded in the Parwanoo-K samples, whereas the minimum (0.127 mm) was formed in Chowkiwala. Usually vasicentric and sometimes aliform type of parenchymatous tissues were observed in cross sectional studies. In the radial sections of wood medium and thicker fibers were found while gum ducts were present in most longitudinal sections of wood. Jhadhmajri recorded the maximum fiber length (1,320 mm) and Barotiwala the minimum fiber length (0,668 mm). The average fiber diameter (0.0248 mm) was recorded in Baddi while the minimum size (0.0219 mm) was in Jhadhmajri samples.

2.3 GENETIC ESTIMATES

Morphological and physiological characteristics shows considerable amount of genetic variation within and between populations of plants (Stebbins, 1950, Stem and Roche, 1974).

Vihera-Aarnio (1988) estimated broad sense heritability in various Salix hybrids for various coppicing characteristics and biomass growth. The existence of genetic variation for dry matter production has also been shown to be beneficial (Gullberg, 1989) in improvement programmes.

Hosalli (1997) recorded moderate to high heritability and genetic benefit for seedling height, collar diameter, internodal length, shoot and root fresh and dry weight among forty-nine *Leucaena leucocephla* species/varieties at nursery level.

Lune *et al*. (2008) evaluated eight morphological characteristics of 49 exotic and indigenous poplar clones. They formed a wide range of GCV and PCV for petiole volume, plant height and diameter. In *Eucalyptus* hybrid studies, Luna *et al.* (2009) recorded high heritability values for height (0.67-0.71), diameter (0.50-0.59) with hereditary height gain up to three years of observation.

Huse *et al*. (2018) studied quantitative genetic parameters viz; variability, heritability, genetic gain and genetic correlation on different characters of willow growth, leaf and biomass (*Salix* spp.) and found the wide variation in clones. None of the growth traits showed more phenotypic coefficient 8 variationthan the genotypic variation coeificient.High heritability was reported for height followed by diameter of the neck, the area of the leaf index length, the days of the leaf show and number of branches and showedwide range of genetic gain.

2.4 CORRELATION STUDIES

The correlations show the magnitude or degree of linear association between character pairs and form the selection index base thereby assisting the breeder in crop improvement programmes.This helps the breeder to know how the improvement of one character brings improvements in other characters at the same time. Yield is a character inherited polygenically and is strongly affected by influences on the environment.Awareness of genetic similarity among the factors contributing to yield contributes to the most effective method of selection by using a favorable combination of characters, on such the direction and magnitude of yielding component characters serves as a prerequisite for productive breeding programmes. The studies of correlation provide stronger pathways to increasing yields during selection (Johnson *et al*., 1955).

Tikader and Roy (1999) studied *Morus* species and reported a highly positive correlation of the number of shoots with the longest shoot length, total shoot length and leaf yield, longest shoot length with total shoot length, internodal distances and leaf yield which clearly indicated that these were the most important features for improving leaf yields in mulberry.

Thakur *et al.* (2000) reported a positive and sognificantcorrelation for number of leaves per plant, leaf length and width at genotypic and phenotypic stage levelin *Alnus nitida*.Lune *et al*. (2008) tested 49 exotic and indigenous poplar clones for eight morphological characteristics. The height of the plant has shown a strong and important correlation with diameter.

Sharma *et al*. (2011) reported genotypic, phenotypic and environmental maximum variation coefficients for the volume index in five years old clonesof *Salix*. The coefficient between plant height and volume was the highest (0.921).

Sharma *et al.* (2014) recorded correlation between superior *Populus deltoides* clones tested in nursery for three consecutive years and found that mean height was significantly correlated with mean volume index. In 2011 the plant diameter showed significant correlation (0.559) with the volume index whereas there was no significant correlation between diameter and volume index.However, mean basal diameter was highly correlated with volume index.

2.5PRINCIPAL COMPONENT ANALYSIS

Davidson (1975) used main-component analysis to study variability in 24 parameters in*Eucalyptus delgupta* smallwood samples.In addition to this he used factor analysis and rotation of verimax to define this component and to determine the relative value of variables within each component.

Kendall (1980) concluded that PCA could be used as an alternative in linear regression models where there is collinearity among the regression variable.Bernard and Gregory (1991) used the key component analysis to resolve the multicollinearity effect.

James and Bell (1995) performed the key component study of climal factors leaves of six *Eucalypius camaidulensis* clonal subjects Dehnh. from 5Australians sites, derived from BIOCLIM.They observed that the morphological and anatomical features of the leaf displayed patterns similar to the parent plants' habitat environment but substantial genetic variability could be found even within a single region. The leaf thickness was typically the highest for clones from the most arid locations and the least for clones from the most mesic locations however none of the climatic factors considered were correlated with leaf length and width.There was generally a lack of correlation between feature of the leaf and climatic data.The availability of groundwater, root structure and internal water transport may have a greater intluence to the leaf structure than atmospheric demand.

Aravanopoulos (2010) studied *Salix* species, families and clonal entry with respect to lamina length, lamina width, leaf morphometric characters. The duration of the petioles, size at the base of the leaf to the full width of the leaf, number of teeth per centimeter, stipulated length and width of the stipule. Most important variables were leaf and stipule on the basis of the principal component analysis.

Singh *et al.* (2012a) studied principal component analysis (PCA) in clones in wilows. In the study they found variance of 83.49 percent revealed by three key components. The first main component included ten characters that contributed 59.55 percent of the variance in total dry weight (0.966), total fresh weight (0.953), shoot fresh weight (0.928), shoot dry weight (0.921) and root fresh weight (0.901). Therefore these characters should be taken for the improvement of willow.

Chapter-3

MATERIALS AND METHODS

The presentstudy entitled **"Evaluation of *Morus alba* L.clones for morphometric and wood characteristics"** was carried out in the experimental field and laboratory of the Department of Tree Improvement and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2018-2020 to evaluate different clones for various morphometric and wood characteristics. The experimental details relating to experimental areaand material and methodology adopted for the study are described hereunder:

3.1 Experimental area
3.2 Experimental procedure
3.3 Statistical analysis

3.1 EXPERIMENTAL AREA

The experiment was conducted in the main campus of Dr. Y.S. Parmar University of Horticulture and Forestry, Nauniat Majgaon experimental area andthe wood analysis was carried out in the Forest Product departmental laboratory.The experimental area lies at an altitude of 1250m above msl with 30^0 51'N latitude and 76^0 11'E longitude.

The region has sub-tropical climate with moderately hot summers and cold winters. Maximum temperature often exceeds 37^0 C in May /June andminimum temperature drops to as low as 1^0 C in January.The occurrence of frost in winter is quite common. Mean annual rainfall varies from 950-1350 mm/yr,most of which is concentrated during monsoon season. Winter rains due to western disturbances in the area are also not uncommon.

3.2 EXPERIMENTAL PROCEDURE

A clonal evaluation trial of 24 clones (procured from different areas)of*Morus alba* was raised in the experimental field of the department in the year 2008 usingRandomized Block Design with three replications.The detailsof theexperimental trail are as follows:

Number of treatments (clones)	=	24
Number of replications	=	3
Number of ramet in each replication	=	1
Spacing	=	2m×2m
Design	=	RBD

Table 3.1 Details of clones of *Morus alba*

Sr. No.	Name of clone	Place	State
1	Kanva 2	Panchkula	Haryana
2	S30	Sahaspur	Uttarakhand
3	Phillipino	Sahaspur	Uttarakhand
4	China White	Sahaspur	Uttarakhand
5	K2MS	Sahaspur	Uttarakhand
6	S146	Sahaspur	Uttarakhand
7	S1531	Sahaspur	Uttarakhand
8	S799	Sahaspur	Uttarakhand
9	S41	Sahaspur	Uttarakhand
10	Mandaley	Sahaspur	Uttarakhand
11	Berhampore	Jammu	Jammu & Kashmir
12	Mesuguama	Jammu	Jammu & Kashmir
13	Kali kothari	Jammu	Jammu & Kashmir
14	C741	Jammu	Jammu & Kashmir
15	S36	Jammu	Jammu & Kashmir
16	S1307	Jammu	Jammu & Kashmir
17	ME-65	CSGRC, TN	Tamilnadu
18	L-2	Sahaspur	Uttarakhand
19	L-3	Sahaspur	Uttarakhand
20	L-4	Sahaspur	Uttarakhand
21	L-6	Sahaspur	Uttarakhand
22	Tr8	Sahaspur	Uttarakhand
23	Tr10	Sahaspur	Uttarakhand
24	Nauni	Nauni	Himachal Pradesh

The observations were recorded on the following parameters:

3.2.1 Morphometric characters

A. Tree growth characters

i) Tree diameter (cm)

Tree diameter was measured at ground level with the help of vernier caliper.

ii) Number of primary branches per tree

Number of primary branches (branches arising from the main stem) per tree were counted.

iii) Crown spread

Crown spread area was measured by measuring tape at 12 Noon for fair readings.

B. Leaf characters

i) Petiole length

Single leaf was taken from each direction i.e, North-South, East-West and one leaf from the centre (5 leaves/tree) were taken and then petiole length of each leaf was measured using ruler.

ii) Leaf area(cm^2)

Single leafwas taken from each direction i.e. North-South, East-West and one leaf from the centre (5 leaves/tree) were taken and kept separately and pressed between the folds of blotting paper and thereafter measured the leaf area with the help of leaf area meter (Laser area meter model C-I-203).

iii) Lamina length

Single leaf was taken from each direction i.e, North-South, East-West and one leaf from the centre (5 leaves/ tree) were taken and then lamina length of each leaf was measured using ruler.

iv) Lamina width

Single leaf was taken from each direction i.e, North-South, East-West and one leaf from the centre (5leaves/tree) were taken and then lamina width of each leaf was measured using ruler.

v) Green leaf yield

All the green leaves from each clone at the maximum growth period were collected and their weight was recorded using weighing balance.

3.2.2 Wood parameters

Collection of wood samples

Wood samples having dimensions of $2.5cm^3$ were chipped with chiesel at 30 cm height from the bark of the tree for wood analysis in the first week of January 2020.

Observations Recorded

i) Bark per cent

Diameter over bark (DOB) and bark thickness were measured with the help of digital caliper. Diameter under bark (DUB) was calculated by deducting the twice of bark thickness from the the diameter over bark. The bark percentage in the main stem was calculated on the basis of dark over Bark. The recorded bark thickness was expressed in percentage w.r.t.

$$\text{Bark (\%)} \quad \frac{\text{D.O.B.} - \text{D.U.B.}}{\text{D.O.B.}} = \text{x}100$$

Where,

D.O.B = Diameter over bark

D.U.B = Diameter under Bark

ii) Wood per cent

Diameter over bark (DOB) was measured with digital caliper. Bark thickness was also measured with the help of digital caliper. The wood percentage was calculated on the basis of diameter over bark. The recorded wood thickness was expressed in percentage.

$$\text{Wood (\%)} = \frac{\text{D.O.B.} - 2 \quad \text{Bark thickness}}{\text{D.O.B.}} \text{x} \quad 100$$

Where,

D.O.B = Diameter over bark

iii) Moisture content (%)

Fresh weights of the samples were recorded just after they were cut from the tree and brought to the laboratory. After initial weighing, the samples were oven dried first at 60 ^{o}C for few hours and then at 102±1 ^{o}C till constant weight. Then weight of samples was recorded as oven dried weight (g). The moisture per cent of the samples was then calculated by using the formula given by Desch and Dinwoodie (1996).

$$\text{Moisture content (\%)} = \frac{\text{Mini - Mod}}{M_{od}} \times 100$$

Where,

M_{ini} = Initial weight of samples (g)

M_{od} = Oven dried weight of samples (g)

iv) Maximum moisture content (MMC %)

Maximum moisture content (MMC) of wood samples was determined as per the procedure given in Indian Standard IS: 1708 (BIS, 1986). The wood samples were submerged in distilled water for 7 days to ensure complete saturation. The saturated samples were taken out and weighed. These samples were then dried first in air and then at 105±2^{o}C till constant weight. The maximum moisture content (%) was then calculated by the following formula:

$$\text{Maximum moisture content (MMC) \%} = \frac{\text{Mm-Mo}}{\text{Mo}} \times 100$$

Where,

M_m = Saturated weight of wood samples (g)

M_o = Oven dried weight of wood sample (g)

v) Specific gravity

The specific gravity of the samples was determined by maximum moisture content method (Smith, 1954). Wood samples of different clones were submerged and kept in water till saturation by daily replacing the water to avoid fungi growth on the surface of the discs. Once the samples were completely saturated with water the weight of the samples was recorded as weight at maximum moisture content level. These samples were then oven dried at 102±1^{o}C until a constant weight. Finally the specific gravity was calculated as per the formula given below:

Specific gravity = $\frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{GS}}$

Where,

Mm = Fresh / green weight of the sample having maximum moisture

Mo = Oven dried constant weight of the sample

GS = Average density of wood substance, a constant, having value 1.53

Fibre dimensions

The fibre dimensions were determined by macerating the wood shavings in,Jeffery s solution, *i.e*. 10 per cent chromic acid and 10 per cent nitric acid, for 48 hours (Pandeya *et al*. 1968). Therefore, the shavings were thoroughly washed, stained withsafranine, and teased with the help of needle in 10 per cent glycerin prior to slide mounting. The straight and complete fibers were selected and measured under a Stereo Microscope equipped with a 10X eyepiece. About 7-8 measurements of fibers were made in each slide using an Ocular Micrometer fitted to the eyepiece of a microscope at 10X magnification and standardized with the help of Stage Micrometer.

vi) Fiber length (mm)

The length of fibres for different clones was recorded from the macerated wood samples by using ocular and stage micrometer of ERMA make (Tokyo, Japan).

vii) Fiber diameter (mm)

Average diameter of the fibers was measured from macerated wood samples by measuring mid diameter of fibers with the help of Ocular and Stage micrometer of ERMA make (Tokyo, Japan).

3.3 STATISTICAL ANALYSIS

The data were analysed statistically for the assessment of analysis of variance as described by Panse and Sukhatme, (1967). Variance components, heritability, genetic gain, correlation, path analysis and genetic divergence were worked out using the methodology of Zobel and Talbert (1984). The analysis of variance (ANOVA) table was set up as under:

3.3.1 Analysis of variance (ANOVA)

Source	Degree of freedom (df)	Sum of squares	Mean sum of squares	Expected MS
Replications	r-1	-	-	-
Treatments	t-1	SS_1	MS_1	$\sigma^2{}_e + r\sigma^2 g$
Within treatment or error	(r-1)(t-1)	SS_2	MS_2	$\sigma^2 e$
Total	(rt-1)			

Where,

r = number of replications

t = number of treatments

The calculated 'F' values were compared with tabulated 'F' values at appropriate degrees of freedom.

3.3.2 Critical difference:

In order to compare the mean of various entries, the critical difference was calculated by the formula:

$$CD = SExt0.05$$

$$SE = \frac{\sqrt{2MSE}}{r}$$

Where,

SE = Standard error of the difference of means to be compared.

t = Tabulated value of t at 5% levels of significance

r = No. of replications

MSE = Error mean sum of squares

Mean difference between any two treatments greater than calculated CD value was taken as significant difference.

3.3.3 Variance component:

Phenotypic variance (V_p) and genotypic variance (V_g) will be calculated as:

$$Vg = \frac{M_g - M_e}{r}$$

$$V_p = V_g + M_e$$

Where,

V_p = phenotypic variance

V_g = genotypic variance

M_g = mean sum of squares due to genotype

M_e = mean sum of squares due to error

r = no. of replications

3.3.4 Coefficients of variability:

Formula by Burton and De-Vane, 1953.

$$PCV\% = \frac{\sqrt{V_p}}{\overline{X}} \times 100$$

$$GCV\% = \frac{\sqrt{V_g}}{\overline{X}} \times 100$$

Where,

PCV = Phenotypic coefficient of variation

GCV= Genotypic Coefficients of Variation respectively

$\overline{X}$ = the population mean of the character.

i) Heritability:

Heritability in broad sense (h^2) is calculated as:

$$h^2 = \frac{V_g}{V_p} \times 100 \text{ (Expressed as \%age)}$$

ii) Genetic advance

$$\text{Genetic advance} = h^2 \times \sqrt{V_p} \times K$$

Where,

h^2 = Heritability (Broad sense)

V_p = Phenotypic variance

K = Selection differential at 5% selection intensity 2.06 (Allard, 1960)

iii) Genetic gain

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{\overline{X}} \times 100$$

Where,

$\overline{X}$ = population mean of the character

3.3.5 Correlation coefficient:

Karl Pearson correlation coefficient determined as per Panse and Sukhatme (1967):

$$r_{xy} = \frac{C_o V_{xy}}{\sqrt{V_x . V_y}}$$

Where,

r_{xy}= correlation between x and y

V_x = Variation of x

V_y = Variation of y

V_{xy} = Covariance between x and y

3.3. 6Principal Component Analysis:

It is a multivariate statistical technique to reduce the data with large number of correlated variables in to a substantially smaller set of new variables. A principal component analysis is concerned with explaining the variance- covariance structure of a set of variables through a few linear combinations of these variables. Its general objectives are:

1. Data reduction
2. Interpretation

It does not require the assumption of multivariate normality. It deals with the internal structure of the variables involved. Its aim is to sacrifice some information contained in the original variables in order to keep as few variables as possible, but the lost information is kept as minimum as possible.

Biology, economics, meteorology, anthropology, social sciences and agriculture are some of the areas where the technique of principal component analysis is widely used. It has been used in conjunction with discriminant analysis for improving the stability of the coefficients, multiple regression analysis to tackle the problem of multicollinearity.

The aim of principal component analysis is to ascertain new variables, called principal components, which carry most of the information present in original variables. Principal components are generally estimated from either the correlation matrix (R) or sample variance-covariance matrix (S). When the variables are measured in different units, scale effect can influence the composition of the derived components. In order to overcome such situation it is desirable to standardize the variable. Also correlation matrix should be used.

The first few principal components usually account for most of the variation of the original variables and the variation described by following principal components is relatively little, it is often useful to retain only those first few principal component and drop all subsequent components from the analysis. It is so because the variable they express is largely random and is of no use in the analysis. Several thumb rules have been proposed for the number of principal components of the correlation matrix with eigen roots less than one. The principal component's with the variance less than one contains less information.

Various steps involved in worked out of principal components can be summarized as below:

i. First of all Keyse-meyer-olkin measure for sampling adequacy is computed. If the value of KMO comes out to be more than 0.5 only then we should go for principal component analysis.
ii. After that find the eigen value of variance-covariance matrix of correlation matrix.
iii. Arrange eigen values in decreasing order. Let these values in decreasing order be $\lambda_{1,}$ $\lambda_{2,}$. . . . . , $\lambda_{p,}$ and corresponding variability be V_1, V_2…. Vp, Where Vp is variability for $\lambda_{p.}$
iv. Starting from first principal component, go on adding the variance or first few principal components whose value is more than unity. The variability described by them is of greater use. Discard the remaining principal components.
v. From the eigen vectors of chosen principal components variables which load the respective principal components are found.

The output desired for interpretation and grouping should include:

i. Eigen value and percentage of total variation explained by each principal component.
ii. The eigen vector for each principal component.
iii. The principal component scores
iv. The correlation between original Standardized variable and the corresponding principal component scores (occasionally called loading).

Principal component analysis technique wase used to identify the important characteristics contributing towards the yield of *Morus alba* L.

Chapter-4

RESULTS AND DISCUSSION

The assessment of phenotypically superior clones is used not only to evaluate the clones themselves but also the parents' ability to pass their good characters on to the offspring for which the tree was originally selected.This information about the parent trees can be used to discard a tree whose progeny is not doing well.Idea is to classify the exceptionally good parents on the basis of progeny success those can be used repeatedly in the future to create a new seed orchard, breeding orchard and clone site interaction trial.Therefore the present investigation entitled "**Evaluation of *Morus alba* L. clones for morphometric and wood characteristics**"as undertaken to evaluate and characterize clones for better growth and quality wood parameters and to study the extent and pattern of variation between them.The experiment was carried out comprisingtwenty four clones in the laboratory and field of Department of Tree Improvement and Genetic Resource, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The experimental results so obtained are presented and discussed under following sub-heads:

4.1 Evaluation of clones

- 4.1.1 Growth performance
- 4.1.2 Wood characteristics

4.2 Variability estimates and genetic parameters

4.3 Correlation analysis

4.4 Principal components analysis

4.1 EVALUATION OF CLONES

Twenty four clones were evaluated for their growth performance and wood characteristics values to select the best among them.

4.1.1 Growth performance

Analysis of variance showed significant differences among clones for different morphometric traits viz; basal diameter, number of primary branches, crown area, lamina width, lamina length, petiole length, leaf area and green leaf yield.

(i) Basal diameter (cm)

The results presented in Table 4.1& Fig.1 exhibited the maximum basal diameter for Clone Tr10 (17.84) which was significantly at par with Clones S146 (15.53) and China white (15.27). The minimum basal diameter was recorded for clone L-6 (8.91).

(ii) Crown area (m^2)

The results (Table 4.1 & Fig.1)showed the maximum crown area forClone Tr10 (22.27) which was significantly different from all other clones, however minimum crown area was found for L-6 (3.05).

Table 4.1 Variation in growth characters among different clones of *Morus alba*

Clone	Basal diameter (cm)	Crown area (m^2)	No. of primary branches
Kanva 2	12.02	3.11	7.00
S30	14.29	4.58	5.67
Phillipino	12.97	4.68	6.67
China White	15.27	14.43	4.00
K2MS	14.87	5.19	5.33
S146	15.53	10.84	6.00
S1531	13.77	5.41	6.67
S799	14.77	7.65	3.67
S41	9.86	7.48	3.67
Mandaley	11.87	4.58	5.67
Berhampore	15.03	8.55	4.00
Mesuguawa	10.03	7.03	4.33
Kali Kothari	10.81	7.69	3.33
C741	11.66	7.47	3.33
S36	12.07	7.40	3.33
S1307	12.56	9.38	6.67
ME-65	12.87	9.34	5.33
L-2	9.67	5.65	3.00
L-3	11.88	5.95	3.33
L-4	11.90	6.16	4.00
L-6	8.91	3.05	4.33
Tr8	12.01	7.80	3.67
Tr10	17.84	22.27	7.33
Nauni	12.03	4.07	3.67
Mean	12.69	7.49	4.75
$C.D_{0.05}$	2.76	1.20	1.94

Photograph 1. General view of the experimental trial

(iii) Number of primary branches

A critical observations of Table 4.1 & Fig.1 depicted the highest value for Clone Tr10 (7.33) which was statistically at par with Clones Kanva 2 (7.00), Phillipino (6.67), S1531 (6.67), S1307 (6.67), S146 (6.00), S30 (5.67), Mandaley (5.67). However, the minimum value for this character was obtained for Clone L-2 (3.00).

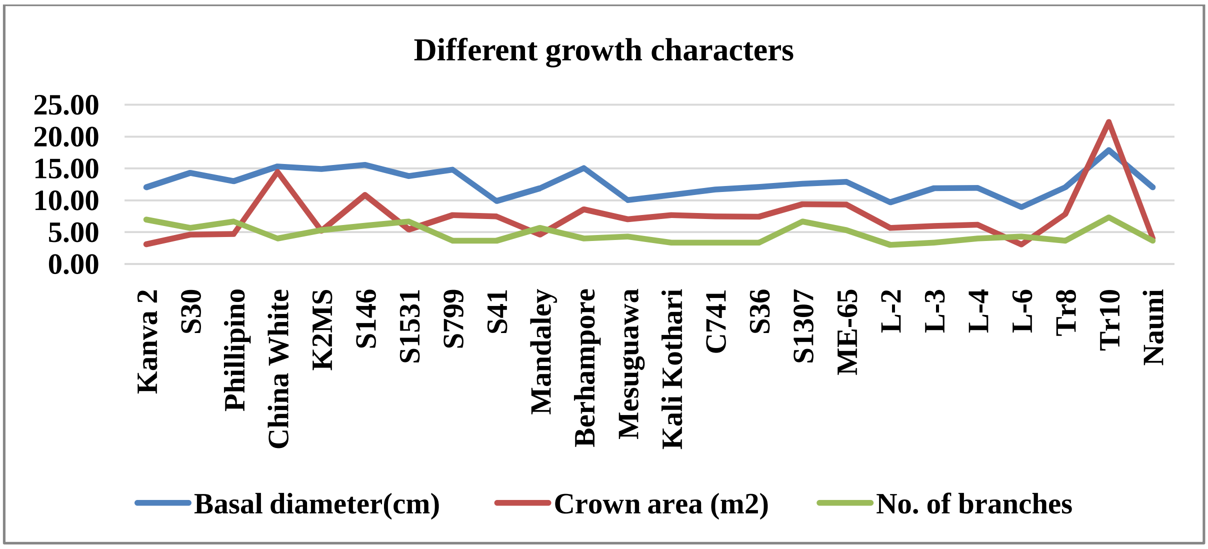


Figure 1:Variation in growth characters among different clones of *Morus alba*

(iv) Lamina width (cm)

Result depicted in Table 4.2& Fig. 2 revealed the maximum lamina width for Clone S146 (11.99)which was significantly different from all other clones, whereas minimum value was shown by clone L-3 (5.68).

(v) Lamina length (cm)

The results given in Table 4.2 and Fig. 2 exhibited the maximum lamina length for the clone S146 (17.52) which was significantly different from all other clones, while minimum lamina length was recorded for clone L-4 (8.41).

(vi) Petiole length (cm)

Results obtained after analysis & variance (Table 4.2 and Fig.2) showed maximum petiole length for the clone Berhampore (4.63) which was significantly at par with Clones Mandaley (4.52), S146 (4.27). However CloneL-3 (2.17) recorded the minimum value for petiole length.

Table 4.2 Variation in leaf characters among different clones of *Morus alba*

Clone	Lamina width (cm)	Lamina length (cm)	Petiole length (cm)
Kanva 2	9.94	12.43	3.93
S30	7.89	14.05	3.35
Phillipino	7.30	10.17	2.26
China White	7.59	12.69	2.54
K2MS	5.99	12.34	3.02
S146	11.99	17.52	4.27
S1531	10.66	10.24	3.52
S799	9.70	12.45	4.23
S41	9.10	11.77	3.53
Mandaley	9.21	12.48	4.52
Berhampore	7.87	10.93	4.65
Mesuguawa	9.08	9.04	3.59
Kali Kothari	8.88	8.93	2.68
C741	8.99	11.09	3.50
S36	9.58	10.31	3.80
S1307	7.45	8.95	2.79
ME-65	7.81	12.15	2.39
L-2	9.24	8.62	2.48
L-3	5.68	8.96	2.17
L-4	6.65	8.41	2.78
L-6	7.88	8.64	2.83
Tr8	8.08	10.34	2.63
Tr10	9.39	12.65	3.74
Nauni	8.51	11.12	2.55
Mean	8.52	11.09	3.24
$C.D_{0.05}$	0.55	0.27	0.26

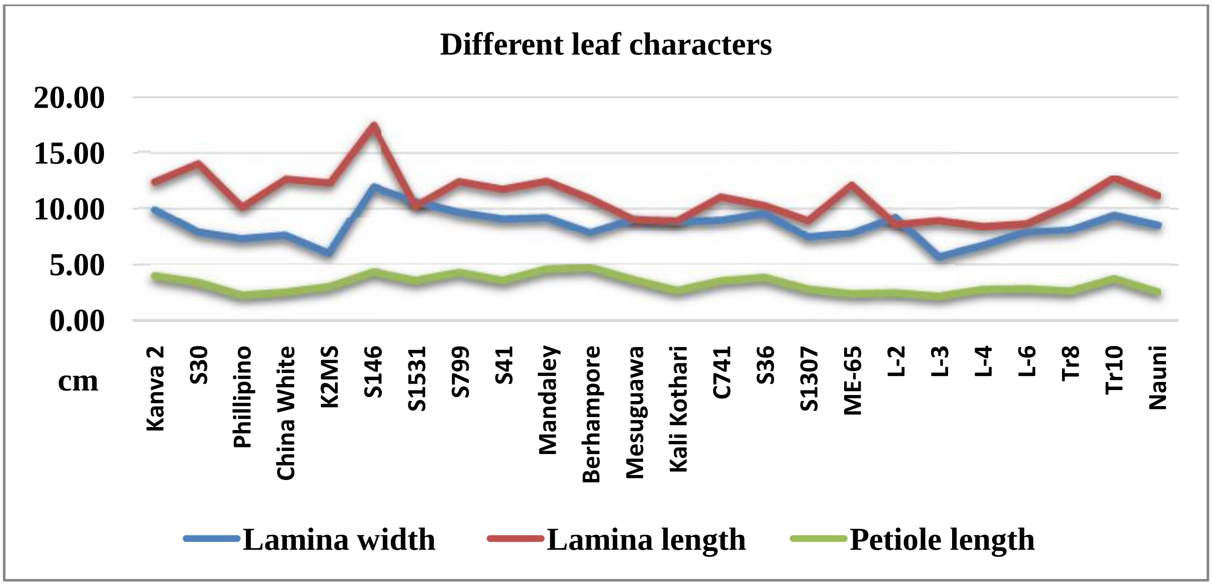


Figure 2: Variation in leaf characters among different clones of *Morus alba*

Photograph 2. Inter-clonal variation in leaf size

Photograph 3. Intra-clonal variation in leaf size

(vii)Leaf area (cm^2)

The results given in Table 4.3 and Fig 4 showed maximum leaf area for the clone S146 (179.13) which was significantly different from all other clones, while minimum leaf area was recorded for the Clone L-3 (48.49).

(viii)Green leaf yield (kg/tree)

An appraisal of Table 4.3 & Fig 3exhibited maximum green leaf yield for the Clone Tr10 (7.60) which was significantly different from all other clones, however minimum green leaf yield was observed for the clone L-3 (3.81).

Table 4.3 Variation in leaf characters among different clones of *Morus alba*

Clone	Leaf area (cm^2)	Green leaf yield (kg/tree)
Kanva 2	82.53	5.08
S30	86.81	6.03
Phillipino	60.88	4.50
China White	56.85	5.06
K2MS	57.99	5.55
S146	179.13	5.86
S1531	66.40	6.52
S799	75.81	5.50
S41	76.39	4.91
Mandaley	149.10	4.75
Berhampore	78.31	6.52
Mesuguawa	73.63	4.22
Kali Kothari	61.69	4.76
C741	78.38	3.97
S36	66.15	6.61
S1307	52.06	4.87
ME-65	76.07	4.05
L-2	58.29	4.78
L-3	48.49	3.81
L-4	49.36	3.90
L-6	78.55	4.21
Tr8	81.48	4.79
Tr10	95.93	7.60
Nauni	52.87	5.67
Mean	76.80	5.15
$C.D_{0.05}$	1.36	0.15

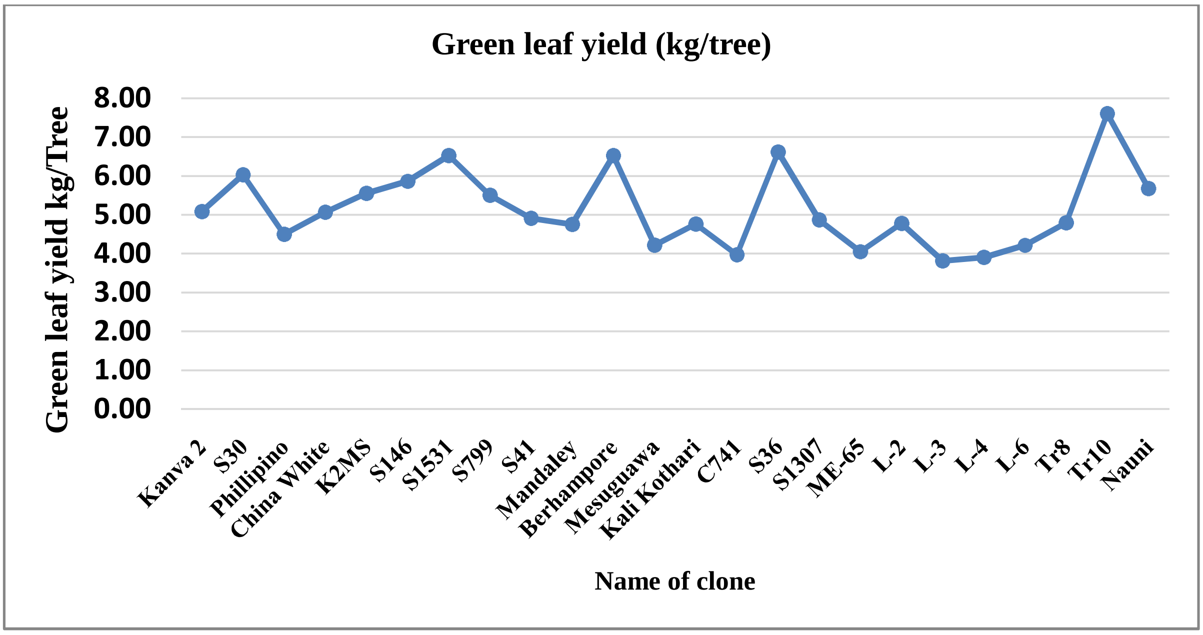


Figure 3: Variation in leaf characters among different clones of *Morus alba*

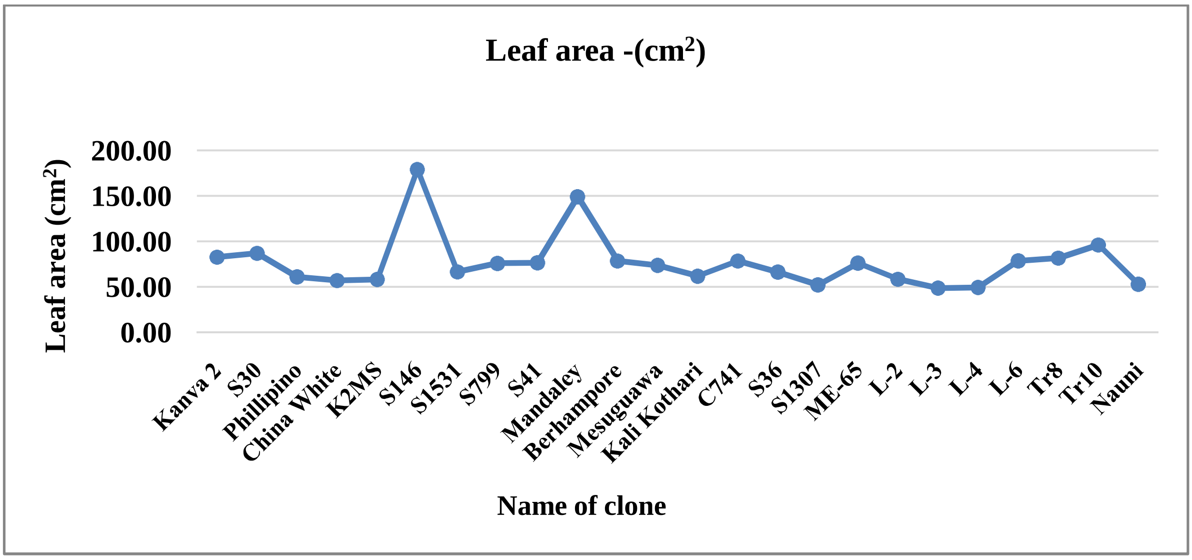
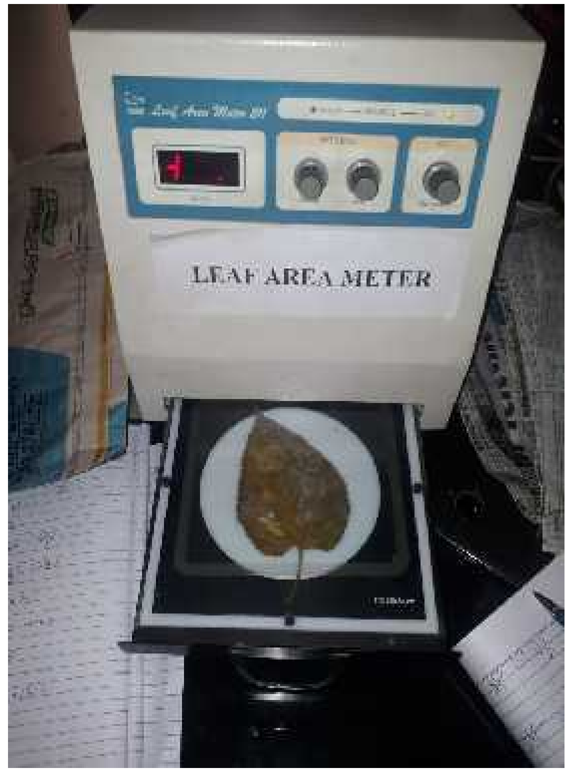


Figure 4: Variation in leaf area among different clones of *Morus alba*

Overall the clones Tr10, S146, S36, S799 and Mandaley were found to be better for all the growth characteristics.The superiority of these clones could be attributed to their superior genetic makeup as the environment in which they were grown was the same for all. The above findings are in line with the investigations of Tikader and Kamble (2009) who reported significant differences in growth and yield traits of different accessions of *Morus* spp. They observed that the relationship among different growth traits indicate that leaf yield is dependent on number of branches per plant. The present investigation are also supported



Photographs 4 & 5. Measurement of leaf area by leaf area meter

Photograph 6. Best clone (Tr10) in the experimental trial

by the findings of Peris *et al.* (2014) in mulberry and Bajpai *et al.* (2015) for different quantitative morphological characters of *Morus alba.*

4.1.2 Wood characteristics

i. Bark percentage

The data on bark percentage of different clones are presented in Table 4.4. The scrutiny of the data revealed non-significant variation in bark percentage. However, the maximum bark percentage of 8.79 percent was recorded in clone 'ME-65' and the minimum in clone 'Phillipino' (6.97 %)

ii. Wood percentage

The wood percentage also showed non-significant variation amongclones Table-4.4. The highest wood percentage(93.03) was found in clone 'Phillipino'. However, the lowest wood per cent in clone 'ME-65'(91.21%).

The variation in wood percentage could be ascribrd to provenance, site and provenance and site interactions in the species (Kumar *et al*., 2005). Heena (2014) has also reported variation in wood percentage of poplar wood.

Table 4.4: Variation in bark and wood percentage among different clones of *Morus alba*

Clone	Bark (%)	Wood (%)
Kanva 2	8.08	91.92
S30	8.41	91.59
Phillipino	6.97	93.03
China White	7.90	92.10
K2MS	8.29	91.71
S146	7.22	92.78
S1531	7.65	92.35
S799	7.76	92.24
S41	8.31	91.69
Mandaley	8.27	91.73
Berhampore	7.98	92.02
Mesuguawa	8.67	91.33
Kali Kothari	8.49	91.51
C741	8.09	91.91
S36	7.86	92.14
S1307	8.38	91.62
ME-65	8.79	91.21
L-2	8.40	91.60
L-3	7.43	92.57
L-4	7.72	92.28
L-6	8.24	91.76
Tr8	8.33	91.67
Tr10	7.51	92.49
Nauni	8.13	91.87
Mean	8.04	91.96
$C.D_{0.05}$	1.81	1.81

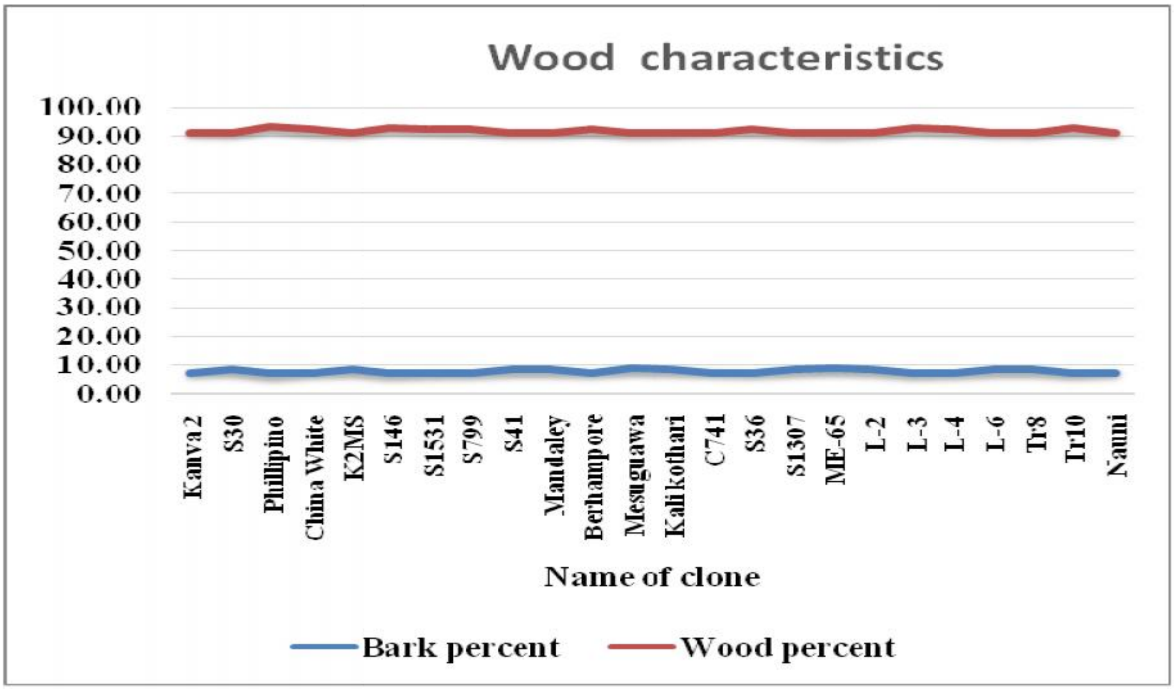


Figure 5: Variation in wood characters among different clones of *Morus alba*

iii. Moisture content (%)

The results relating to wood moisture content of various *Morus alba* clones are presented in Table-4.5. Results for different clones were found to be significant.The moisture content of the different clones ranged between 55.40-104.66 per cent with mean value of 89.25 per cent. The highest moisture content was observed in clone Kanva-2 (104.66%) which was statistically at par with clones Tr10 (104.49%), Mandaley (103.01%), S41 (102.56%), C741 (101.82%), Nauni (100.79%), Berhampore (98.14%), S1307 (97.83), China White (95.74%), S146 (93.26%), L-6 (93.18%), L-3 (90.20%), Mesuguawa (89.82%), S799 (89.56). However, minimum moisture content of 55.40 per cent was observed in clone 'ME-65'.

The hygroscopicity of wood depends on the wood cellular structure i.e. various cell types, their cell wall thickness and lumen size. In general the wood is denser, the moisture content of the wood is lower (Haygreen and Bowyer, 1996). In the present study there was significant difference in moisture content among clones. The moisture content ranged from 55.40 per cent to 104.66 per cent. Shottafer and Brackley (1982) also reported similar results in their study on the analysis of variation in moisture content in balsam fir (102.90 per cent). El-Baha (2002) also reported a maximum moisture content at *Leucaena leucocephala* of 119.32 percent.Sharma *et al*. (2014) reported significant variation in moisture content between promising willow clones ranging from 58.83 to 110.49 percent.Sharma (2016) found the highest moisture content of 91.09 percent in *Cedrus deodara*wood samples from Nankhari site in Himachal Pradesh,.

iv. Maximum moisture content (MMC %)

A critical analysis of the findings provided in Table-4.4 showed substantial variation in wood MMC (percentage) among different clones at 5 percent level of significance. The highest MMC (%) was found in clone L-3 (158.337 %) which was statistically at par with clones Tr10 (147.08%), L-6 (146.82%), S1531 (145.333%), C741 (145.242%), L-4 (142.162%) and Nauni (134.647%). While the lowest MMC (%) (95.909%) was recorded in 'Kali Kothari'.The moisture content at which the cell walls are completely saturated with bound water and free water in the structure is known as maximum moisture content (Choong and Achmadi 1991). Kilemwa (2010) while studying 21 willow clones,revealed significant variation in moisture content with a maximum moisture content of 110.49 per cent. Nicholls *etal*. (2003) have also reported a maximum moisture content of 149.7 per cent in *Tsuga heterophylla*.

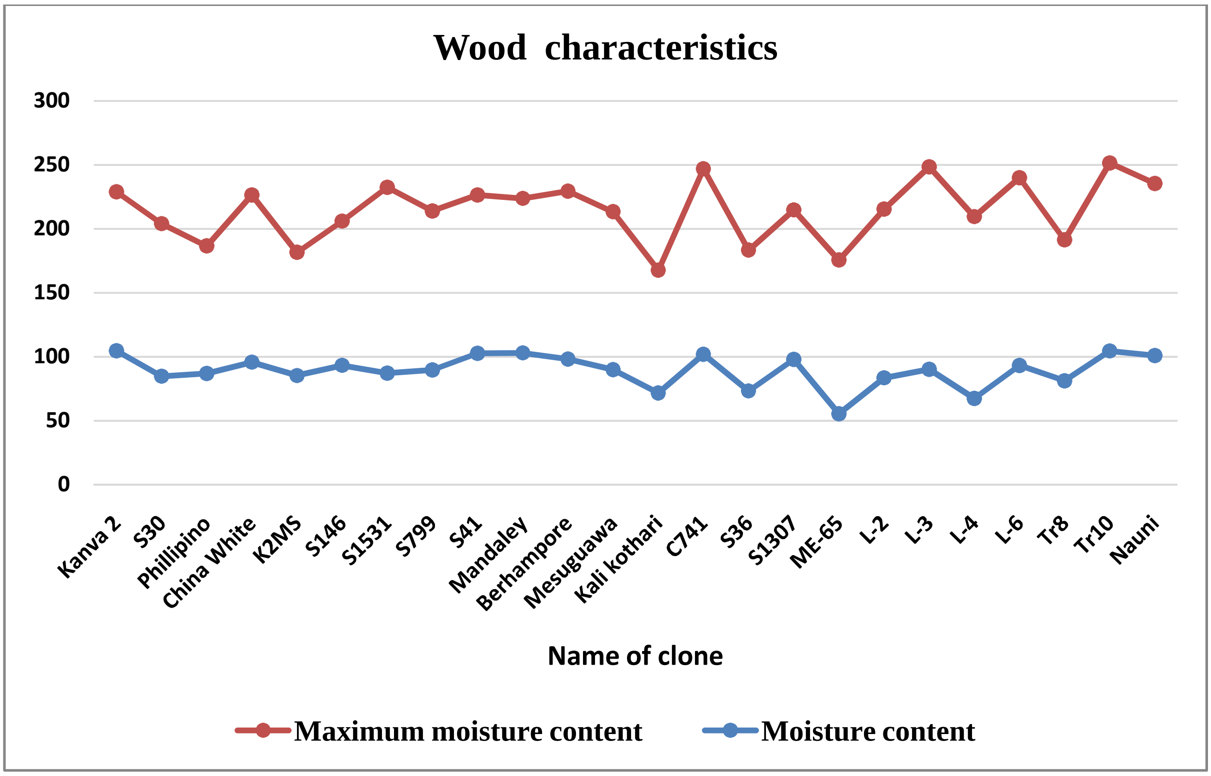


Figure 6: Variation in wood characters among different clones of *Morus alba*

v. **Specific gravity of wood**

The results pertaining to specific gravity of the wood (Table 4.4) showed significant variation among different cloneswith mean value of 0.54. The maximum specific gravity was reported in clone 'Kali Kothari' (0.620) which was statistically at par with clones 'K2MS' (0.619) 'Phillipino' (0.612), 'S36' (0.575),'Mesuguawa' (.574), 'Tr8'(.569), 'L-6' (.568), 'S146' (.566) The minimum specific gravity was observed in clone 'L-3' (0..451).

Specific gravity is the best single indicator of wood physical and mechanical behaviour (Panshin and de Zeeuw, 1980). The specific gravity shows the wood compactness depending on the thickness of the fiber wall, vessel lumen and parenchyma. The specific gravity of wood decreases with the fraction of the vessel, area of the vessel and density of the vessel affecting the amount of lumen space in wood (Preston *etal*). The findings of Stringer and Olsen (1987) in *Robinia pseudoacacia* Kumar (1996) in *Eucalyptus teritiornis* and Lekha (1999) in *Acacia catechu* also supporting the present results. Cox *et al*. (2001) noted the substantial difference in the specific gravity of wood at *Shorea accuminata*, *S. S. leprosula* and *Dryobalanops aromatica*, which have reported the inheritance of specific gravity and the difference between clones is due to the genetic makeup of clones. The present investigation are also in line with the study conducted by Monteoliva*et al*. (2005), who also reported significant difference in the specific gravity between different willow clones.

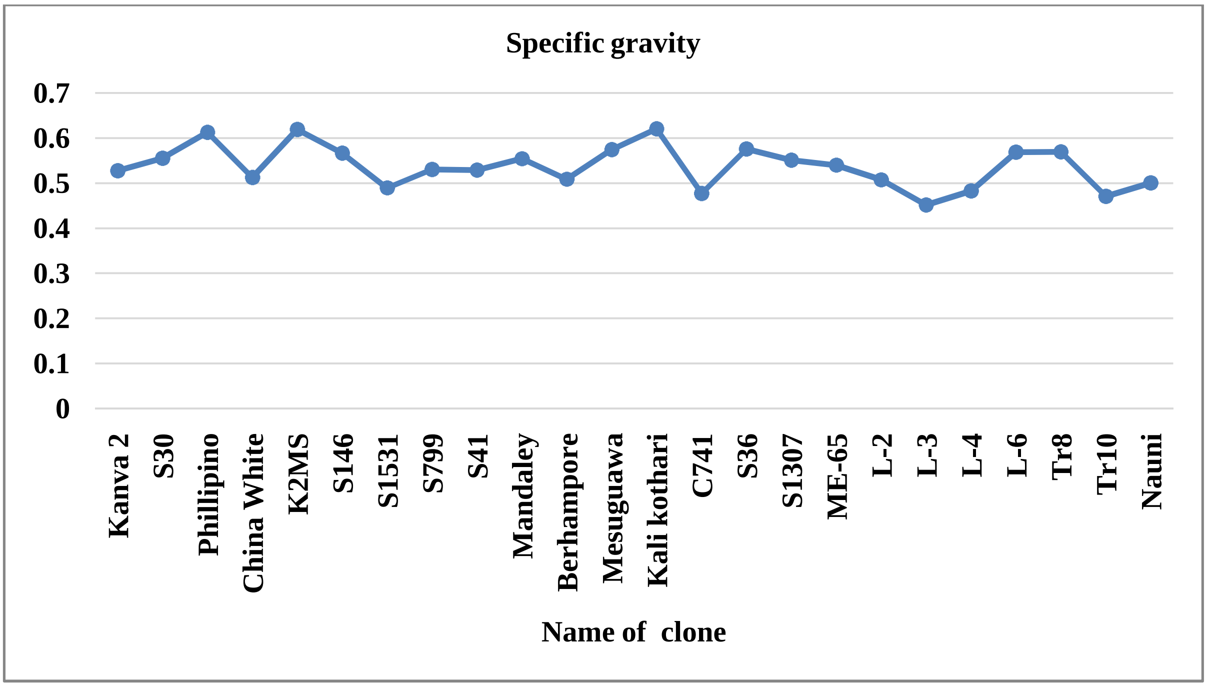


Figure 7: Variation in specific gravity among different clones in*Morus alba*

Table 4.5: Variation in Specific gravity, moisture content and maximum moisture content among different clones of *Morus alba*

Clone	Moisture content (%)	Maximum moisture content (%)	Surface gravity
Kanva 2	104.66	124.32	0.527
S30	84.78	119.29	0.555
Phillipino	86.98	99.62	0.612
China White	95.74	130.75	0.513
K2MS	85.30	96.29	0.619
S146	93.26	112.82	0.567
S1531	87.20	145.33	0.489
S799	89.56	124.37	0.530
S41	102.56	123.93	0.529
Mandaley	103.01	120.77	0.554
Berhampore	98.14	131.32	0.509
Mesuguawa	89.82	123.58	0.574
Kali Kothari	71.61	95.91	0.620
C741	101.82	145.24	0.477
S36	73.27	110.14	0.576
S1307	97.83	116.93	0.551
ME-65	55.40	120.18	0.540
L-2	83.51	131.86	0.507
L-3	90.20	158.34	0.451
L-4	67.36	142.16	0.483
L-6	93.18	146.82	0.568
Tr8	81.14	110.25	0.569
Tr10	104.49	147.08	0.471
Nauni	100.79	134.65	0.500
Mean	89.23	125.50	0.537
$C.D_{0.05}$	15.20	25.94	0.064

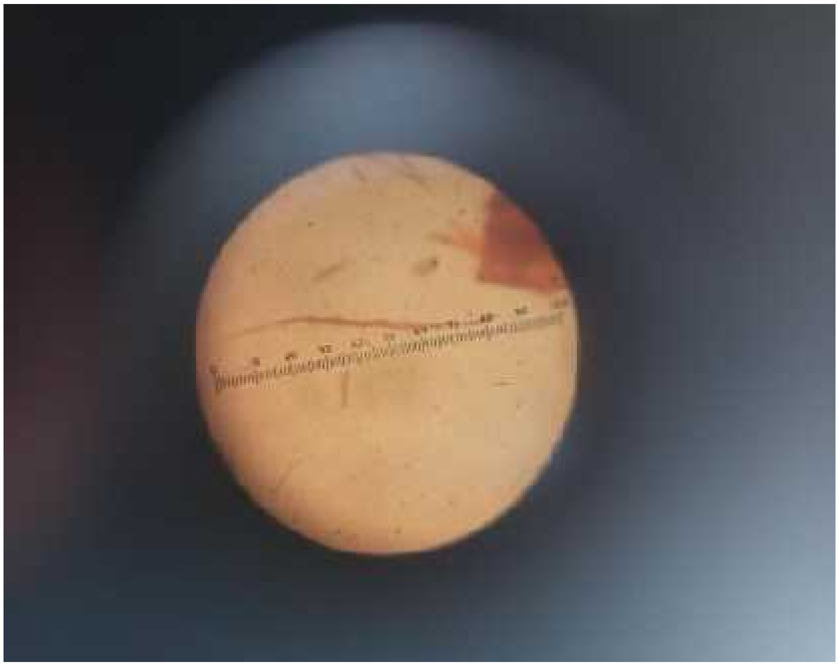
vi. Fibre length (mm)

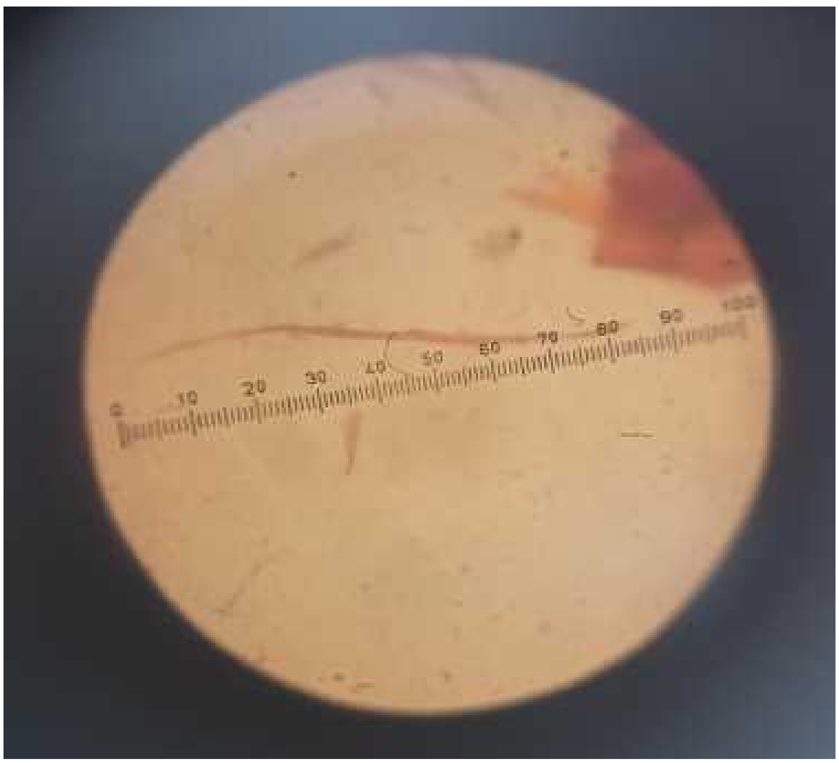
The mean fiber length data showed significant variation between clones as shown in Table-4.5. Fibre length ranged from 0.365 mm to 0639 mm with a mean average value of 0.504 mm. Clone 'L-4' recorded the shortest fiber length, while clone 'Kali Kothari' (0.639mm) showed the longest fiber length.

Table 4.6: Variation in fiber length and fiber diameter among different clones of *Morus alba* clones

Clone	Fiber length(mm)	Fiber diameter(mm)
Kanva 2	0.514	0.015
S30	0.449	0.014
Phillipino	0.482	0.015
China White	0.506	0.016
K2MS	0.538	0.012
S146	0.545	0.017
S1531	0.492	0.015
S799	0.536	0.013
S41	0.578	0.014
Mandaley	0.440	0.013
Berhampore	0.488	0.013
Mesuguawa	0.531	0.016
Kali Kothari	0.639	0.014
C741	0.521	0.013
S36	0.585	0.015
S1307	0.451	0.016
ME-65	0.401	0.013
L-2	0.425	0.013
L-3	0.439	0.017
L-4	0.365	0.018
L-6	0.582	0.013
Tr8	0.545	0.015
Tr10	0.553	0.016
Nauni	0.481	0.016
Mean	0.504	0.015
$C.D_{0.05}$	0.013	0.005

Fiber length defines whether the quality of raw material is appropriate for specific use in paper industry and also has its effect on paper characteristics such as strength, optical property and surface quality. Wani and Khan (2010) demonstrated substantial variability in the wood fiber length from different locations of trees of *Populusnigra*.Among 8-year-old Populus deltoides clones developing among plantations, Chauhan et al. (1999) have found major clonal variability in fiber-length. Sheng-Zuo and Wen Zhong (2003) also revealed





Photographs 7. Microscopic view of fiber length

substantial differences in fiber length between growth rings, which had a increasing tendency along the pith-to-bark direction and a decreasing trend with an increase in tree height.

vii. Fibre diameter (mm)

The data on average fiber diameter showed significant variation among clones of (Table-4.5). The maximum mean fiber diameter was recorded to be 0.018 mm in clone 'L-4' whereas, the minimum fiber diameter (0.012 mm) was observed in clone 'K2MS'.

Kramer (1964) advocateded that water stress reduces fiber dimensions that are required for cell enlargement due to the role of water in turgidity maintenance. Whereas (David *et al.*, 2009) stated that in response to decreased water supply the fiber diameter decreases. No significant difference in fiber diameter among 24 clones was observed in the present study.

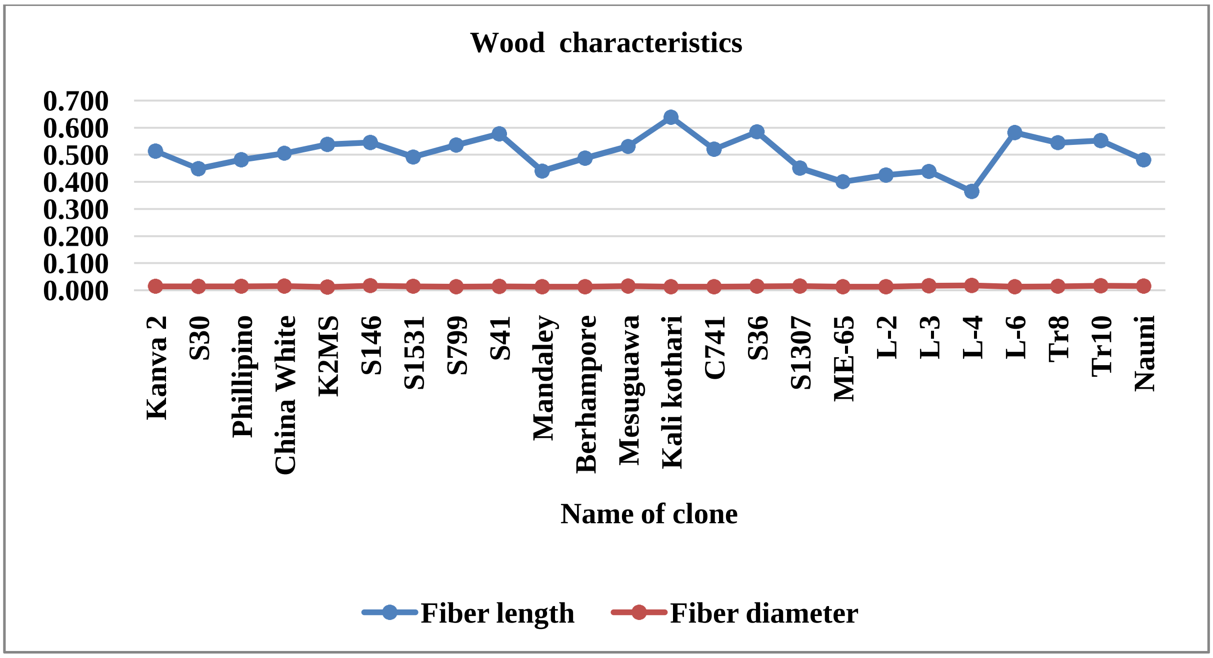


Figure 8: Variation in wood characters among different clones in*Morus alba*

4.2VARIABILITY ESTIMATES AND GENETIC PARAMETERS

Variability refers to the observed differences within population for a particular trait. These differences may be partly due to genetic causes and partly due to environmental trapping. The combined expression of both of these is the phenotypic effect. Observed value of an individual appraised trait is the phenotypic values of the individual. The relative magnitude of those components determines the genetic properties of any given species (Jain, 1982).The effective tree enhancement system therefore, depends on the extent and magnitude of the existing genetic variation and also the degree of transmission of the traits.

The quantitative trait variability was measured with respect to coefficient of mean, size, phenotypic and genotypic variability. In order to estimate heritability (broad sense), genetic advance, and genetic gain, genetic parameters for morphometric traits were estimated.

4.2.1 Morphometric traits

The results given in Table 4.7 showed the highest mean value for leaf area (76.80) followed by the diameter (12.69).Minimum value for petiole length was recorded (3.24) followed by number of primary branches (4.75).The area of the leaf showed maximum range (56.35-178.61) followed by length of the lamina (10.11-17.50).Minimum range for petiole length was observed (2.17-4.65) followed by number of primary branches (3.00-7.00).

The PCV and GCV were highest for crown area (54.78% and 53.90%) followed by leaf area (39.15% and 39.13%), respectively. However, minimum values for basal diameter of PCV and GCV (20.09 per cent and 15.13 per cent) were observed. For all morphometric parameters the values of PCV were higher than those of GCV.

The heritability acts as a partial measure of genetic gain that can be generated on any particular trait and thus allow the breeder concentrate on the properties that are under the tight genetic control. Johnson *et al*. (1955) and Burton (1952) proposed that GCV research and heritage estimate would provide the best picture of the progress to be made by selection.

The results in Table 4.12 revealed that heritability in general ranged between low and high.The maximum heritability value for the leaf area (0.99) was observed followed by lamina length (0.99) and green leaf yield (0.99) indicating that these traits were under strong genetic regulation influence. However, basal diameter (0.28) showed modest heritability.

The genetic advance for petiole length and leaf area ranged from 1.49 to 61.88, respectively. The highest genetic benefit was reported for crown area (109.25 percent) followed by leaf area (80.48 percent) indicating that additive genetic effects are important in deciding these characteristics and that selection should be successful for those characteristics. The lowest genetic benefit value for basal diameter was reported (23.48 per cent).Low heritability values and genetic gains suggest the expression of non-additive gene action and thus simple selection would be a limiting factor in improving it.

Table 4.7 Estimate of different genetic parameters for morphometric characters in different clones of *Morus alba*

Character	Mean ($\bar{X}$)	Range	GCV (%)	PCV (%)	H^2	Genetic advance	Gain
Lamina width	8.52	5.68-11.99	16.68	17.14	0.95	2.85	33.44
Lamina length	11.09	8.41-17.52	19.13	19.18	0.99	4.36	39.30
Petiole length	3.24	2.17-4.63	22.79	23.33	0.95	1.49	45.89
Leaf area	76.80	48.49-179.13	39.13	39.15	0.99	61.88	80.58
No. of primary branches	4.75	3.00-7.33	25.51	35.66	0.51	1.79	37.59
Basal diameter	12.69	8.91-17.84	15.13	20.09	0.57	2.98	23.48
Crown area	7.49	3.05-22.27	53.90	54.78	0.97	8.18	109.25
Green leaf yield	5.15	3.81-7.60	19.21	19.29	0.99	2.03	39.41

The above findings support the findings of Thakur and Chauhan (2008) who documented moderate to high genetic variation coefficient (GCV), heritability and genetic benefit for leaf yield, shoot height, shoot diameter and number of leaves in *Morus* spp's indicatingthat these characters can be effective for potential selection results. Wani (2012) also estimated coefficient of phenotypic and genotypic variation for different morphometric traits in *Bauhiniavariegata* and high heritability for different traits such as number of shoots per plant (0.99%), longest shoot (0.99%), total shoot length (0.98%), inter nodal distance (0.93%), lamina length (0.99%), lamina width (0.99%) ,lamina weight (0.98%), petiole weight(0.86%),petiole length(0.97%)and leaf yield per plant(0.99%). Wani (2014) reported significant variation between various *Morus alba* leaf characters. Bajpai *et al*. (2015) recorded high PCV for various growth characteristics such as leaf length, leaf width, small leaf length, leaf area, internodal distance, number of nodes, fruit length , fruit width and fruit weight in *Morus alba*.

4.3 CORRELATION ANALYSIS

4.3.1 Simple Correlation

The knowledge of relationship of various characters among themselves is most important for any programme of tree improvement. The expression of a character is the sum total of so many other characters' input and thus screening / selection should be performed on the basis of components that contribute to that character. The bio-metric tool to support this is 'correlation' which gives the nature and degree of association between different characteristics.

An appraisal of the results (Table 4.8) revealed that basal diameter showed positive and highly significant correlation with crown area (0.631), lamina length (0.635) and green leaf yield (.673), significant and positive correlation with number of primary branches (0.481). Crown area showed significant and positive correlation with green leaf yield (0.441). Lamina width exhibited highly significant and positive correlation with petiole length (0.607) and leaf area (0.614), significant and positive correlation with green leaf yield (0.425) and lamina length (.448). Lamina length revealed significant and positive correlation with leaf area (0.723), significant and positive correlation with petiole length (.494) and green leaf yield (.433). Petiole length recorded highly significant and positive correlation with leaf area (0.637), significant and positive correlation with green leaf yield (.512). While, rest of the correlation combinations were non-significant.

Table 4.8Estimate of simple correlation among morphometric traits of *Morus alba*

	Basal diameter	**Crown area**	**No of primary branches**	**Lamina width**	**Lamina length**	**Petiole length**	**Leaf area**	**Green leaf yield**
Basal diameter (cm)	1	.631**	.481*	0.087	.635**	0.32	0.261	.673**
Crown area (m^2)		1	0.205	0.154	0.298	0.117	0.169	.441*
No of primary branches			1	0.195	0.38	0.206	0.333	0.35
Lamina width(cm)				1	.448*	.607**	.614**	.425*
Lamina length (cm)					1	.494*	.723**	.433*
Petiole length (cm)						1	.637**	.512*
Leaf area (cm^2)							1	0.224
Green leaf yield kg/tree								1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Significant and positive correlation between different morphological and biomass characteristics indicates and underlines their use in indirect selection. The significant and positive correlation between one trait and another shows that development of one trait will be followed by change in another. Tikader and Kamble (2008) reported substantial correlation coefficient between leaf yield and other growth traits. In agreement with present study. Doss *et al*. (2012) reported that the yield of green leaf has shown significantly positive phenotypic and genotypic correlations with various growth traits. Wani *et al*. (2014) also advocated for the *Morus alba* leaves to have a significant and positive correlation between different leaf characters. Peris *et al*. (2014) observed the significant and positive correlations between leaf yield characteristics in *Morus alba* except in internodal distance and number of branches which were significant and negatively correlated.

Table 4.9Estimate of simple correlation among wood characters traits of *Morus alba*

	Bark (%)	Wood (%)	Moisture content	Specific gravity	Maximum moisture content	Fiber length	Fiber diamete
Bark (%)	1	-1	-0.207	0.234	-0.190	0.005	-0.498
Wood (%)		1	0.207	-0.234	0.1905	-0.005	0.498
Moisture content (%)			1	-0.284	0.304	0.209	0.055
Specific gravity (%)				1	-0.891	0.436	-0.328
Maximum moisture content(%)					1	-0.312	0.282
Fiber length (mm)						1	-0.187
Fiber diameter (mm)							1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

The appraisal of the results in Table 4.9 revealed that bark (%) had negative and highly significant correlation with wood (%). Specific gravity showed negative and significant correlation with maximum moisture content. However rest of correlation were found to be non-significant.

4.4 PRINCIPAL COMPONENTS ANALYSIS

In order to view the data in a more realistic way the number of variables needs to be reduced to a few interpretable linear variables combinations. Thus the main component analysis was used to decrease the observed variable into the number of main components which will account for much of the variance in observed variables.

Table 4.10: Eigen vectors of principal component analysis

Variables	PC1	PC2
Basal diameter	.739	.591
Crown area	.516	.584
No. of branches	.550	.228
Lamina width	.646	-.534
Lamina length	.825	-.076
Petiole length	.727	-.420
Leaf area	.737	-.488
Green leaf yield	.738	.284
Eigen values	3.829	1.529
%of variance	47.860	19.108

The SPSS software was used for principal component analysis of morphometric parameter. The key factor research result are presented in table 4.10. Table 4.10 showed that 2 out of 8 main components (PCs) had a value of their own greater than unity and therefore these two main components played a major role in the study. Hence, the study retained the first two main elements which clarified 66.968 percent of the overall variance. The first main variable had its own value of 3.829 and 47.860 percent of the overall variance. The highest value of 0.825 was revealed in lamina length followed by 0.739 for basal diameter, 0.738 for green leaf yield, 0.737 for leaf area, 0.727 for petiole length, 0.646 for lamina width, 0.550 for number of primary branches and 0.516 for crown area. The second main component heads its own value of 1.529 and described 19.108% of the overall variance.The highest value 0.591 was revealed in basal diameter followed by 0.584 for crown area, 0.284 for green leaf yield and 0.228 for number of primary branches.

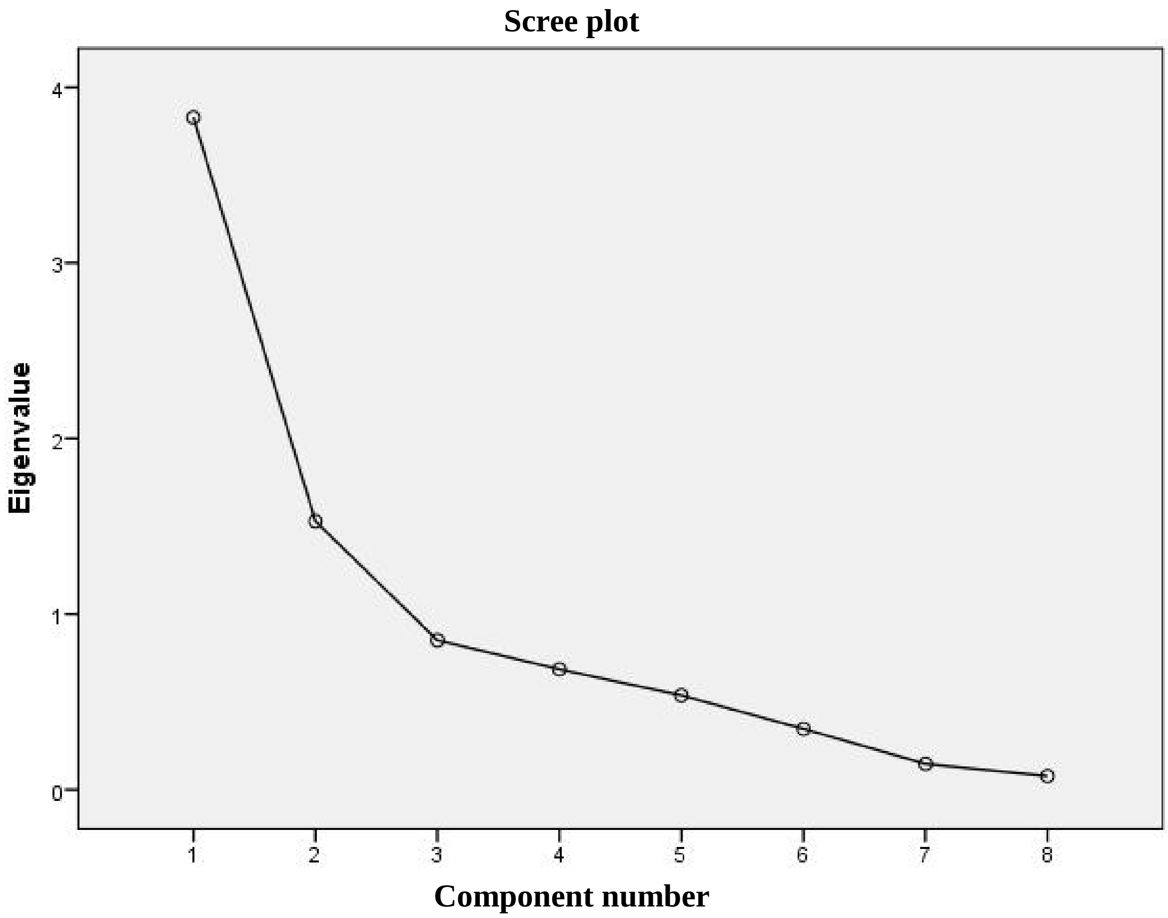


Figure 9: Scree plot showing eigen value of different principal components

Chapter-5

SUMMARY AND CONCLUSION

This study was carried out in the Department of Tree Improvement and Genetic Resources, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP), during 2018-2020 under the title "**Evaluation of *Morus alba* L.clones for morphometric and wood charactersitics**"to assess clonal variation for morphometric characteristics, wood characteristics, genetic parameters estimation, correlation and study of principal components analysis. A clonal evaluation trial of 24 clones (collected from different areas) was raised in Randomized Block Design with three replications in the department in the year 2008.

The data collected on various characters were analyzed as per the experiment's design. The field observations were recorded on basal diameter (cm), crown area (m2), number of primary branches, lamina width (cm),lamina length (cm), petiole length (cm), leaf area (cm^2), green leaf yield (kg/tree).Out of the 24 clones 6 have been observed to be better as compared to others based on growth performance .i.e.Kanva 2, S30, Phillipino, white China, S146, K2MS.Laboratory observations were recorded on bark (%), wood (%), moisture content (%), maximum moisture content (%), specific gravity, fiber length (mm), and fiber diameter (mm).Based on the results of the wood characteristics six were found to be better than other.i.e. Kali Kothari, S36, K2MS, Phillipino, Mesuguawa, Tr8.The study's significant findings are summarized as under:

The analysis of variance revealed highly significant differences among 24 clones for leaf area, crown area, lamina length, green leaf yield, lamina width and petiole length.

Among the morphometric characters viz; basal diameter (17.84 cm), crown area (22.27m^2), number of primary branches (7.33) and yield of green leaves (7.60) were remarkable for clone Tr10.In clones S146 the maximum values were recorded for lamina width (11.93 cm), lamina length (17.52 cm), leaf area (178.61cm^2). However outstanding petiole length (4.65 cm) was observed for clone Berhampore.

The significant differences for all of the parameters were observed among different clones except bark (%), wood (%), and fiber diameter(mm).The highest percentage of bark (8.79) and wood (93.03) was found respectively in clones 'ME-65' and 'Phillipino'.Clones Kali Kothari (0.620), Kanva-2 (104.66 %), and L-3 (158.33 %) reported the maximum specific gravity, moisture content, and maximum moisture content. The clones with high specific gravity recorded minimum high content of moisture (MMC %).The longest fiber length (0.639 mm) and fiber diameter (0.018 mm) were found in the clone 'Kali Kothari' and 'L-4' respectively.

In general morphometric traits, except for the number of primary branches, displayed high heritability.For leaf area (0.99) the highest heritability was observed followed by lamina length (0.99) and green leaf yield (0.99).The maximum heritability for number of primary branches was recorded (0.51).For crown area the highest phenotypic (54.78 %) and genotypic coefficient (53.90 %) of variation was observed. The maximum genetic gain was found for crown area (109.25 %) of all morphometric traits followed by leaf area (80.58 %) and minimum for basal diameter (23.48 %).

The simple correlation studies among various morphometric characters showed a highly significant and positive correlation of basal diameter with crown area (0.631), lamina length (0.635) and green leaf yield (0.673), lamina width with petiole length (0.607) and leaf area (0.614), lamina length with leaf area (0.723), petiole length with leaf area (0.637).

The correlation between different characters of wood revealed highly significant and negative correlation for bark (%) with wood (%) (-1.00).Specific gravity showed significant and negative correlation with maximum moisture content (-0.891).

CONCLUSIONS

- Clone Tr10 displayed better morphometric traits then others with highest (7.60 kg/tree) green leaf yield.
- High heritability for leaf area and crown area with high genetic gain was recorded, while high heritability with moderate genetic gain was observed for green leaf yield and lamina length.
- Significant and positive correlations among basal diameter, green leaf yield, lamina width, lamina length, petiole length and leaf area were found.
- Among the different clones the longest fiber was found in clone 'Kali Kothari'.
- Out of 8 components in PCA, 2 had eigen value greater than unity and contributed 66.98 of total variance.
- From the present investigation it can be inferred that wood of the clones 'Kali Kothari','K2MS' and 'Phillipino' have been showing better strength properties and also specific gravity, hence have desirable timber quality.

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ABSTRACT

The present investigation entitled "Evaluation of *Morus alba* L. clones for morphometric and wood characteristics" was carried out in the Department of Tree Improvement and Genetic Resources, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan during the year 2018-2020 to assess the variability among different clones for various morphometric and wood characters . The study revealed that different clones varied significantly with respect to morphometric traits and in wood characteristics except bark percentage, wood percentage and fiber diameter . The best performance was shown by clones Tr10, S146 and Mandaley with respect to various morphometric traits and Kali Kothari,S36 followed by K2MS for different wood characters. High estimates of heritability were recorded for leaf area , lamina length and green leaf yield. Significant and positive correlations were found among basal diameter, lamina width, lamina length, petiole length and leaf area. Petiole length and crown area also exhibited significant and positive correlation with green leaf yield. The specific gravity and maximum moisture content (MMC%) ranged from 0.451 -0.620 and 95.90-158.33 per cent. The maximum fiber length and fiber diameter was recorded in clones Kali Kothari (0.639mm) and L-4 (0.018mm), respectively.

Signature of Major Advisor **Signature of the Student**

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Scholarship/Stipend/ Fellowship : M.Sc. (University Merit Scholarship)

(Vipul Sharma)