

**STUDIES ON TREE-SOIL INTERACTION ON DIFFERENT
SPECIES IN ARBORETUM**



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**MASTER OF SCIENCE IN FORESTRY
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT**

**FACULTY OF FORESTRY
BIRSA AGRICULTURAL UNIVERSITY
RANCHI-834006 (JHARKHAND)**

2018

**STUDIES ON TREE-SOIL INTERACTION ON DIFFERENT
SPECIES IN ARBORETUM**

**THESIS
SUBMITTED TO THE
BIRSA AGRICULTURAL UNIVERSITY
RANCHI, JHARKHAND**

By
Anju Runda
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**IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

**MASTER OF SCIENCE IN FORESTRY
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT**

**FACULTY OF FORESTRY
BIRSA AGRICULTURAL UNIVERSITY
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2018

Dedicated
To
My Beloved Parents

BIRSA AGRICULTURAL UNIVERSITY

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Dated

CERTIFICATE

This is to certify that thesis entitled “**Studies on Tree-Soil Interaction on different species in Arboretum**” submitted in partial fulfillment of the requirement for the **Degree of Master of Science in Forestry with specialization in (Natural Resource Management)** of Post Graduate Studies, Birsa Agricultural University, Kanke, Ranchi (Jharkhand). It is the record of bonafide research work carried out by **Miss Anju Runda** under the supervision and guidance. No part of the thesis has been submitted for any other Degree or Diploma.

It is further certified that such help or information received during the course of investigation and preparation of the thesis has been duly acknowledged.

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ACKNOWLEDGEMENT

I express my deep sense of gratitude to my Major Advisor, Dr. S.K. Singh, University Professor-cum Chief Scientist & Chairman, Department of Natural Resource Management, Faculty of Forestry, Birsa Agricultural University, Kanke, Ranchi (Jharkhand) for his inspiring guidance, valuable suggestions, constant supervision and encouragement throughout the course of my investigation and inspiration of the manuscript.

I am highly thankful to Dr. D. Kaushal, Vice-Chancellor, BAU, Dr. Z.A. Haider, ORT-cum-Dean Post Graduate Studies, BAU; and Dr. N. Kudada, Registrar, BAU for their necessary help in academic as well as for providing financial assistance.

I also express my sincere thanks to Dr. M. Mahto, Dean Forestry for providing necessary facility.

I am extremely obliged and grateful to the members of Advisory Committee Dr. R.N. Singh, Chief Scientist, Soil Science, Faculty of Forestry BAU, Kanke, Ranchi for his constructive ideas, valuable guidance, technical advice and co-operation during my research work.

I am extremely obliged to acknowledge other members of Advisory Committee Sri. V. Shrivaji & Dr. A.K. Chakraborty for their generous encouragement, kindness, unreserved regard and inspiring guidance in the pursuit of this work.

Further, I express my greatness to Mrs. D. Turkey, Assistant Professor, Department of Natural Resource Management, Faculty of Forestry BAU, Kanke, Ranchi for encouragement and co-operation during the entire period of my studies.

I also express my sincere appreciation for help received from Dr. Jai Kumar, Sri V. Dhar, Dr. R.R. Oraon, Dr. Basant Chandra Oraon, Dr. R.B. Sah and other teachers of Faculty of Forestry for their valuable suggestion.

I would like to thank the non-teaching staff members of Faculty of Forestry for their help during entire study period.

I take privilege to express my thanks to my seniors Sibek Birua and Sunita Deogam for their help and kind co-operation during entire research work.

I thank whole heartedly to my friends Rashmi Bakhla and Mithlesh Kumar for their constant support and encouragement.

Where the heart is concerned, pen and paper meagerly fail to express my emotion; I heartedly thank to my parents for their constant support, their sacrifice remains as a source of inspiration that had kept me going ahead giving full spirit enabling to finish such holy work.

I am thanking each and every person who was behind the successful realization of thesis, as well as expressing my apology that I could not mention each personally.

Finally above all offers my heartfelt devotion to Almighty God for his blessing and grace to move the endeavour a great success.

Date.

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Place.

ABSTRACT

The present experiment entitled “Studies on tree-soil interaction on different species in Arboretum of Faculty of Forestry, Birsa Agricultural University, Ranchi planted in the year 2006. The experiment is planned with the objectives such as to study the physicochemical properties of soil in the selected tree species, growth parameter of different tree species, and to know the interrelationship between soil properties and tree growth. The plantation in the arboretum is about 11 years old planted in block. Since the blocks are not equal, random sampling method has been adopted to conduct the experiment. The five tree species like Mahogany (*Swietenia mahogoni*), Sheesham (*Dalbergia sisso*), Gamhar (*Gmelina arborea*), Jamun (*Syzygium cumini*) and Ber (*Ziziphus jujube*) have been selected in the present studies.

The physical properties of the soil like soil texture, bulk density, soil porosity, water holding capacity and particle density has been taken into consideration; whereas the chemical properties such as soil pH, soil organic carbon, available nitrogen, available phosphorous and available potassium have been analysed. Besides these, the growth parameter such as height, diameter and crown width have been recorded to find out the growth performance of the concerned trees.

The maximum value (1.66 gm cm^{-3}) of Bulk Density has been found in *Ziziphus jujube* followed by *Gmelina arborea*, *Syzygium cumini*, *Dalbergia sisso* and minimum (1.55 gm cm^{-3}) *Swietenia mahogoni*; whereas in case of Particle Density, the maximum value (2.68 gm cm^{-3}) was observed in *Syzygium cumini* followed by *Swietenia mahogoni*, *Dalbergia sisso*, *Gmelina arborea* and minimum (2.56 gm cm^{-3}) in *Ziziphus jujube*. In Soil Porosity, the maximum value (43.50%) has been shown in *Dalbergia sisso* followed by *Swietenia mahogoni*, *Gmelina arborea*, *Syzygium cumini* and minimum (35.42%) in *Ziziphus jujube*; while the maximum value (34.39 ml/100cm^3) of water holding capacity was recorded in *Dalbergia sisso* followed by *Gmelina arborea*, *Ziziphus jujube*, *Syzygium cumini*, and minimum (21.30 ml/100cm^3) in *Swietenia mahogoni*. Percentage of sand has been found maximally (54.67%) in *Syzygium cumini* followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni* and minimum (51.31%) in *Ziziphus jujube*; whereas the maximum value (25.3%) of silt has been found in *Swietenia mahogoni* followed by *Dalbergia sisso*, *Syzygium cumini*, *Gmelina arborea* and minimum (22.7%) in *Ziziphus jujube*; while percentage of clay has been found maximum (26.61%) in *Ziziphus jujube* followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni*, and minimum (22.74%) in *Syzygium cumini*.

Statistically bulk density has been shown significantly higher in *Gmelina arborea* followed by *Syzygium cumini*, *Swietenia mahogoni*, *Ziziphus jujube* and non-significant in *Dalbergia sisso*; whereas particle density has been observed significantly higher in *Syzygium cumini* followed by *Swietenia mahogoni*, *Dalbergia sisso*, *Gmelina arborea* and *Ziziphus jujube* has been found non-significant. The soil porosity has been found significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Ziziphus jujube* and *Dalbergia sisso*; while the water holding capacity has been observed significantly higher in *Gmelina arborea* followed by *Dalbergia sisso*, *Ziziphus jujube*, *Syzygium cumini* and *Swietenia mahogoni*; whereas in case of percentage of sand, silt and clay it has been found non-significant in all the

species. Thus, it indicates that the physical properties of the soil have been found improved in planted area.

The findings of the experiment indicated that Soil pH, Organic Carbon (OC), Available Nitrogen (N), Available Potassium (K) increased in planted areas than non planted areas while Available Phosphorous (P) has been found higher in unplanted areas than planted area. The maximum value (6.07) of soil pH has been observed higher in *Dalbergia sisso* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Syzygium cumini* and minimum (5.32) in *Ziziphus jujube*. The maximum value (0.45) in soil organic carbon has been found higher in *Gmelina arborea* followed by *Dalbergia sisso*, *Swietenia mahogoni*, *Syzygium cumini* and minimum (0.40) in *Ziziphus jujube*. The maximum value (496.64) of available nitrogen has been recorded in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and minimum (419.54) in *Swietenia mahogoni*; whereas maximum value (760.62) of available potassium has been shown in *Swietenia mahogoni* followed by *Syzygium cumini*, *Gmelina arborea*, *Ziziphus jujube* and minimum (714.38) in *Dalbergia sisso*. On contrary unplanted area has been found maximum value (15.22kg/ha) of available phosphorous in *Dalbergia sisso* followed by *Swietenia mahogoni*, *Ziziphus jujube*, *Gmelina arborea*, and minimum (14.5kg/ha) in *Syzygium cumini*. Overall, the nutrient status in all the species has been found in the sequential order as $K > N > P$. As per statistical analysis the soil pH, has been found significantly higher in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and *Swietenia mahogoni*; whereas soil organic carbon depicts significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Dalbergia sisso*, and *Ziziphus jujube*. Available nitrogen has been observed significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Ziziphus jujube*, *Dalbergia sisso* and *Swietenia mahogoni*; while Available phosphorous has been shown significantly higher in *Swietenia mahogoni* followed by *Syzygium cumini*, *Dalbergia sisso*, *Gmelina arborea*, and *Ziziphus jujube*. The Available potassium has been found significantly higher in *Syzygium cumini* followed by *Ziziphus jujube*, *Swietenia mahogoni*, *Dalbergia sisso* and *Gmelina arborea*.

As per the growth parameter of the tree is concerned, the both diameter and height have been found maximum (13.33 cm & 10.55 m respectively) in *Swietenia mahogoni*, which is a fast growing species. But, in case of diameter, it has been followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini* and minimally (9.23 cm) *Ziziphus jujube*; while in case of height it has been followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini*, and minimum (7.62 m) in *Ziziphus jujube*. The crown width has been recorded maximum (5.62m) growth in *Swietenia mahogoni* followed by *Dalbergia sisso*, *Syzygium cumini*, *Ziziphus jujube* and minimum (3.67m) in *Gmelina arborea*. Therefore it may be concluded from the present investigation that physical properties of soils was improved considerably in planted area than that of unplanted area; the Soil pH, Soil Organic Carbon (OC), available nitrogen (N) and available Potassium (K) were found significantly higher in planted area compared to unplanted area. On contrast, the available Phosphorous (P) showed reverse finding being significantly higher in unplanted area. The finding of the results show an increasing tendency in the soil pH which indicates conducive for the tree growth.

Among the natural resources, forest has an important place such as renewable natural resource. It plays very vital role as autotrophs generating oxygen gas as well to breathe the heterotrophs as a whole so, its role in ecological balance is well understood and documented. Unfortunately, the forest crops is dwindling day by day due to deforestation, illicit felling etc. and facing alarming condition and required much more attention, conservation and propagation. Such cases are more required in tropical countries where its condition is very much pitiable. The total forest area and tree cover presently is about 24.16% of the geographical area against the goal of 33.33% as set by National Forest Policy, 1988 (Anon.2015). Hence, it is essentiality of the hour to make up the gap by planting and growing more forest tree species for getting healthy and pollution-free environment. From ecological point of view, it is said that additional 300-600 million hectare area is required to brought under rapidly growing forest plantation on in the world sequester about 2.9 billion tones increment of carbon accumulating in the atmosphere through burning of fossil fuel and deforestation. Wood is considered as a universal and cheap source of energy amongst coal, oil, gas etc. for thousand of years, until the advent of other source of energy arise. Even presently also half of the world's consumption of wood is for fuel. It may be clearly said that wood is major source of domestic fuel in India and most of it is obtained from the forest.

The role of forest and wood in case of energy crisis can be understood from the fact that wood is the main product of forest contributing 68.5% as fuel sourcing in rural areas of the country. It is also estimated that about 30 MW of the power can be generated from wood produced by fast growing trees planted on 1,000 ha of land (Dayal, 1984-

1985). Now, due to energy crisis and rising in wood prices, it is realized to give emphasis for raising tree planting particularly fuel wood species and timber species.

Under ecosystem processes like carbon and nutrient cycling, decomposition and primary plant production are very much essential for functioning the ecological activities in both aquatic and terrestrial spheres (Chapin III *et.al.* 2002; Begon *et.al.* 2005). In the forest ecosystem, cycling of the nutrients and decomposition occur in the soil performing by soil organisms below the ground as decomposer, and by plants above the ground as producers. Such sub-systems which are below and above the ground are so closely linked which influence each other in the various ways and show the outcome in ecosystem processes (Wardley, 2002). In this manner; climate, organism, relief, topography and parent material interacting through time are the dominant factors controlling processes of soil formation and determine soil properties in the forest ecosystem. On the other hand, tree affects soil properties through several ways such as it alters input to the soil system by increasing capture of wet fall and dry fall and by adding of the soil nitrogen via nitrogen- fixation. They effect the morphological and chemical conditions of the soil. The chemical and physical nature of leaf, bark, branch and roots alter decomposition and nutrient availability through control on soil, water and litter breakdown. The lateral root systems of the tree scavenge soil nutrient and redistribute them beneath the tree canopy. Therefore growth of the trees depend upon various factors like genetic, climatic adaphic along with the biotic interference. They interact each-other and its cumulative effect matters a lot in growth and propagation of the plants. The soil beneath the tree canopy is important reserving local and regional nutrients which influence community structure in ecosystem. It is reported that plant interaction with soil biota can shift from negative to positive status following introduction to new region, and are relevant for understanding the success of some exotic forest plantation. (Michel J, *et.al.* 2013). Soil from beneath

the vegetation varies in pH, texture, nutrients, microbial biomass and physiological status; the seedlings grown in local soils have about 2.5 times greater survival than local soils as well as the height, number of leaves and leaf area are larger in local than non-local sites. Hence, variation in soil gradients acts as an important selective agents causing differential fitness and local adaptation in plants (Smith. D.S. *et.al.* 2011). Therefore, the understanding of species specific difference in tree-soil interaction is very much important (Rhoades, 1997). Forest floor mass generally differs about 20% for different species growing on the same site and litter fall mass and nitrogen content differ by 20-30% and larger differences are also found because net mineralization of soil nitrogen typically differs by 50% or more among the species which indicates very strong feedback possibilities (Binkley D, *et.al.* 1998). Tree species also influence soil mineralization and regulate over all nutrient cycle in forest ecosystem which may occur through their effect on substrate quality on soil physiochemical properties (Ushio, *et.al.* 2010). Thus, tree-soil interaction is an important aspect in ecological processes having interdependency in ecosystem at a particular area.

Like plants, soil is also a kind of renewable natural resource as an important resource on the planet earth and life cannot be imagined without it. Life supporting system depends upon the soil which is a component of lithosphere and biosphere. Its physical and chemical properties at a particular area reflect past and present condition (Robertson & Gross, 1994). The ability of land is limited to produce as per the condition of soil, climate and types of land. However the capacity of soil to produce is limited by intrinsic characteristic, agro-ecology setting and management (Anon, 1993 a).

It is established fact that the soil of a land which devoid of vegetation becomes degraded due to soil erosion resulting wasteland, known productive and so on. Such area is exposed to insulation, dries up and gets eroded by wind and water and water holding

capacity of soil is decreased along with downing and downing the ground water level. It is prevented by plant cover, litter, mixing of litter by movement of decimals and conversion to spongy humus by micro-organisms. Soil is not only a kind of natural resource but it is also a renewable natural resource. Man is dependent on agriculture for food, clothing, medicine and many other necessities. Land is also used for industrialization and urbanization. The surface of the earth is limited and so is its soil. Random and excessive cutting down of trees, currying for minerals and ores followed by heavy rains leads to washing away of the rich top soil necessary for plants leading to landslides and causing great damage to man. If plants do not grow on the land, soil tends to be washed away by rain and wind causing soil erosion. Hence, it is clear that land is good for agriculture purposes when it is fertile and land is fertile when it is covered with trees. Soil is a renewable resource only if it is protected from erosion and if sustainable amount of organic matter is added to time to time. Barren soil cannot renew itself as it remains exposed to natural forces which cause erosion. Therefore, soil tree interaction is a very important aspect playing vital role in providing life support systems or energy-nutrient cycle to the organisms as well as natural / environmental management and balancing the ecology or ecosystem. In general; it can be said that the soil, which is formed by weathering of rocks associated with organic matter and the living organism, is the most essential medium for the survival of plants and animals and therefore it is essential for the sustenance of any form of life. The plants of any place is the resultant of climate, soil, moisture and biotic factor of that very place. Hence, soil is one of the essential factor for the survival of plants and animals and their interactions is determining the kinds and growth of plants of a place.

Soil is an important and essential factor having vital role to determine the varieties and survival of flora and fauna both. It acts as an agent of Natural Selection fixing

differential fitness in genotypes and / or families of the same plant species more changes in soil such as variation in microbial communities may also act as the agent of Natural Selection. The properties of soil pertaining in different types of areas determine different types of plant to be grown in that very area being adopted through the Force Of Natural Selection to suit in that very area have to adopt for survival in that very area by eating and taking such plants to be assimilated in their bodies, which is also adopted by the force of Natural Selection and getting energy-flow and nutrient-cycle. In this way food-chains and food-webs are maintained through energy flow mechanism covering different zones and areas by checking and eliminating unwanted or excess population in Natural System, ultimately related to the survival or mankind who is a part and partial of that very system. Therefore, it is clear to say that soil as a adaphic factor, is the basic important factor playing key role in maintaining the natural-balance. So, to understand the physical and chemical properties of soil of a site is very much important with the aim to apprehend life-support-system and natural balance to fit for all living organisms and their further better management and growth.

Ecological balance is a must to conduct all kinds of system in the biosphere or may be set in the universe also. The nature do the system in balance and keep the whole environment in nice way providing life support systems / elements to the all flora and fauna for their existence and growth as well as propagation in better and better way. The system is so much fantastic and marvelous with such delicacy that a minor breakup in it creates major problems to not a single organism but in the whole linkage. Therefore, the food chains / food webs which is, for example, is a resultant showing such delicacy in which mankind is also a part and parcel of the system depending directly or indirectly for the existence as stated above. If such the systems become haphazard or zigzag, the survival and existence of mankind will come under question mark. That's why, the

nature has created so many different kinds of fauna and flora surviving and growing different kinds of environment, climate, food habits and so on. For instance, different types of animals having different and various kinds of food habits on the planet earth so that each and every organism may get sufficient food and shelter and other life supporting requirements for their proper growth and propagation depending, also upon each-other maintaining and conserving their races. This is the reason, that in flora and fauna both, there is categorization among them having dependency also among themselves such as autotrophs and heterotrophs majority: and further, among animals or heterotrophs, there are carnivores, herbivores, predators and preys, parasites, scavengers, decomposers etc. to keep the ecosystem etc. to keep the ecosystem and environment neat and clean plus balanced as well providing healthy and hygienic ways keeping each and every organism upto mark in population and communities to act in their niches freely.

The above categorization, created by the nature, enables the living organisms to live and grow peacefully and calmly in their niches avoiding intra and inter-specific struggles and competitions but depending each-other irrespective of population and community. Hence, it may be said that ecological-balance is very much essential getting sufficient requirements by the individuals/population/community including mankind playing their vital role on the earth planet.

Undoubtedly; the role of flora and fauna with soil along with their interactions cannot be ignored from aspects of eco-friendly and eco-balancing point of view.

The soil properties like pH texture, nutrient status, moisture and those related to parent materials are particularly important aspects in case of soil characteristic features. Soil texture is important from plant growth point of view. The granular structure have more volume of air and water than other types, superficially compact layers have poor penetration of soil, air, water and tree roots determine the plant growth (Dwivedi, 199).

As per as survival and growth of the plants are concerned, the respective factors govern markedly because the native vegetation is so much adopted and specialized in its native site. Certain species like *Euclyptus globulus* and *Cryptomeria japonica* in India and *Pinus petula* in South America and *Tectona grandis* in Java have shown atleast 4-6 times more growth than their native sites. It can be said that though original sites really capable of high productivity but due to some restrictive factors, the potential was not harvested (Champion and Seth, 1968).

Flora and fauna always try to adjust and adopt to the physical environment conditions and also try to modify them reducing the limiting factors of the locality. Such happenings occurs at both community and species levels. Trees have notable effects upon the soils on which they grow and upon the local climate (as micro climate) upto a certain extent. The continous deposition of leaf litters and debris create organic mulch on forest floor providing better field for soil micro-organism. Such activities and leaching of organic matter as well as decomposition of other products create much difference in physical, chemical and biological properties of soil. The salient addition to the forest soil is organic matter contributing influence in underlying mineral soil and associated micro-organism and soil animals including insects. The tree roots penetrate compact layers improving aeration, soil texture, nutrients and water infiltration and retaination providing capacity to the soil of forest cover. In this way, roots of trees exert the profiles reaching its deep and extracting bases and returned them to the surface and as litter fall. Hence, in forest ecosystem, it is necessary to find out forest soil properties for the practices to be applied in management. Soil with a forest cover under process of nutrient cycling provide a distinctive character and, hence, the close and integral relationship between soils and plant communities help in understanding the soil process. Thus, the forest growth which is linked with physical and chemical properties of soil and nutrient

status act as a tool in decision making policy in the field in the field of its management. In terrestrial flora; numerous factors in case of plants richness, soil plays major role affecting greatly on the composition and its structure. Niche is created with heterogeneity of their properties with specific conditions affecting spatial distribution of the relation between the plants. In this way soil properties are very important from production, ecological and environment point of view.

On the basis of the above view, the present work of tree-soil interaction studies has been taken in the Arboretum of Faculty of Forestry considering five tree species such as Mahogany (*Swietenia mahogoni*), Sheesham (*Dalbergia sisso*), Gamhar (*Gmelina arborea*), Jamun (*Syzygium cumini*) and Ber (*Ziziphus jujube*) with the soil properties like Soil pH, Soil Organic Carbon, Available Nitrogen, Available Phosphorus and Available Potassium with the objectives as mentioned below.

OBJECTIVES

The research experiment is carried out with the following objectives:

1. To study the physico-chemical properties of soil under each tree species.
2. To study the growth parameters of different tree species.
3. To study the interrelation between relevant soil properties and tree growth.

Tree growth of a place depends upon the status of the soil of that very place as well as its availability in that very soil. Therefore, fertility of the soil play an important role to determine the growth of the planted tree species and, hence, the success of the plantation is determined by the physical and chemical proportion of the soil. Thus, analysis of the soil characteristics such as physical and chemical properties is the key factor to understand ecological status of plant and forest growth including its quality and strongness.

To understand the relationship and interactions of the tree growth and soil properties with the aim to interpret the outcome of the studies in logical way, literature survey was made and the work studied relevant to the present investigation, is summarized under the following headings.

PHYSICO-CHEMICAL PROPERTIES OF SOIL

2.1 Bulk Density

Birua, B.(2014) has worked on tree-soil interaction in arboretum and found that the maximum value of bulk density in *Euclyptus tereticornis* followed by *Tectona grandis*, *Acacia catechu*, *Emblca officianalis* and *Pongamia pinnata*.

Zhang *et.al.* (2012) investigated effects of afforestation with *E.grandis* carrying out physicochemical and micro-biological properties of the soil in China and reported that soil bulk density significantly decreased.

Singh *et.al.* (2011) studied on ameliorative effect of multipurpose tree species grown in sodic soils in Indo-Gangetic Alluvial Plains of India. Comparing the impact of ten years old plantation of ten multipurpose tree species like *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*,

Prosopis alba, *Acacia nilotica*, *Eucalyptus tereticornis*, *Pithecellobium dulce*, and *Cassia siamea*. They studied on the growth biomass and physicochemical properties of sodic soil in major tract of Indo- Gangetic Plains of India consisting salt affected soils and observed reduction in the soil bulk density significantly.

Alemie (2009), experimented on the effect of Euclyptus on crop production and soil properties in Koga watershed in Amahara region in Euthopia and reported no prominent change in the soil bulk density in growing Euclyptus as hedgerow in farm land.

Bassett *et. al.* (2005) worked on effects of soil compaction on establishment and development in New Zealand in native species, generally used in restoration programme, *Cordyline australis* (Adavaceae) and *Leptosermun scoiparium* (Myrtaceae). They have reported that root and shoot growth species decreased with increasing soil bulk density; though the bulk density accounted for only a small amount of variation in root length due to greater variability in growth at low soil bulk density.

Froehlich *et. al.* (2003) studied the growth in height, diameter, and volume on 9 to 18 year old Ponderosa pine (*Pinus ponderosa*) and 10 to 13 year old Lodgepole pine (*Pinus contorts*) trees growing on or year compacted skid traits in the Yakima Indian Reservation in South Central Washington. He found three Ponderosa pine sites average bulk density on skid trails which was 15% greater than on adjacent undistributed soil and on a Lodgepole pine site soil on skid trails averaged 28% greater than bulk density than undistributed soil. He also found that for Ponderosa pine, mean significantly increase in soil bulk density was reduced to 5% and increase in soil bulk density was related to the growth of lodgepole pine.

Williamson & Nielseon (2003) pointed out proportional decrease in final mass of seedlings upto 25% and significantly greater restrictions of growth than that achieved

through compaction; when they studied in two glass house, where three *Euclyptus* species were grown for 110 days in soil from six forest sites in Tasmania and Australia. Finally they concluded that top soil displacement and profile disturbance was more significant of soil damage than compaction. In the same experiment, growth of *E. globulus* seedlings grown on disturbed soil averaged 30% of that on the undistributed bed sites.

Woodward, (1996) studied on the effect of soil compaction and top removal, growth of planted trees in an oil extraction project in tropical moist forest on typical Paleudult in Amazonial Ecuador. His result showed 70% increase in bulk density with 23% increase in subsoil compaction.

Hosur & Dasog (1995) conducted experiment on effect of tree species namely teak, sheesham and khair on soil properties and found decrease in soil bulk density.

Stuhrmann *et. al.* (1994) studied mineral nutrition, soil factor and growth rates of *Gmelina arborea* plantation in the humid lowlands of Northern Costa Rica to determine the factors which are responsible for clearly visible growth irregularities in *Gmelina arborea* stands by relating growth rates to soil and site properties. The variation in site and soil properties and tree growth rates was analyzed investigating 24 plots in eight different plantations and the best multiple regression models for tree growth rate in soil was found with variable bulk density.

The investigation on forest ecosystem with response to artificial induced soil compaction, soil physical properties and tree diameter growth stimulating intensive recreation and / or vericular traffic in harversting operations, plot within a *Querques alba* / *Q.velutina* / *Q.rubra* forest on loamy soil in N-W Vermont before and after application of bark mulch 2-3 times each year for 4 years ; was done by Donnelly & Shane (1986) and reported that soil bulk density increases significantly due to compaction ,

infiltration and radial growth of *Acer rubri* and *Q.velutiae* were reduced, whereas bark much after compaction did not reverse , bulk density changes in soil in 2 years after application.

Mishra & Nanda(1985) studied on available water holding capacity of soil texture classes and found that bulk density significantly influences the soil texture particularly water holding capacity.

2.2 Particle Density :-

Birua, B. (2014) has worked on tree soil interaction in arboratum and observed the maximum value of particle density in *Emblica officinalis* followed by *Acacica catechu* *Tectona grandis* and minimum in *Pongamia pinnata* .

Jordan *et.al.* (2003) experimented in a green house on the effects of soil compaction and forest leaf litter on growth and nitrogen uptake in Oak . They reported that soil compaction decreased seedling height significantly and dry matter production. Compaction also significantly affected microbial activity by reducing acid phosphates and also the acute soil compaction resulted decreased young tree growth and reduced uptake of nitrogen.

2.3 Soil Porosity :-

Birua, B. (2014) in his experiment on tree soil interaction in arboretum has found soil porosity maximum in *Emblica officianalis* followed by *Euclyptus tereticornis*, *Acacia Catechu*, *Pongamia pinnata*, *Casuariana equisetifolia*, *Prosopis alba*, *Acacia nilotica*, *Eucalyptus tereticornis*, *Pithecellobium dulce* and *Cassia siamea* and minimum in *Tectona grandis*.

Singh *et. al.* (2011) did work on Ameliorative effect of multipurpose tree species growing on sodic soils of Indo-Gangetic Alluvial plains of India comparing 10 years old

plantation among 10 multipurpose trees like *Terminalia arjuna*, *Azadirachta indica* , *Prosopis juliflora* , *Pongamia pinnata* , *Casuarina equisetifolia* , *Prosopis alba* , *Acacia nilotica* , *Eucalyptus tereticornis* , *Pithecellobium dulce* and *Cassia siamea*. On tree growth and physicochemical properties of sodic soils and found significant increase in soil porosity under tree plantation.

Woodward, (1996) carried out the experiment on the effects and soil compaction and top soil removal covering physical and chemical properties of soil and growth of planted trees on and oil extraction project in tropical moist forest in a typic Paleudult in Amazonial Ecuador and observed significant decrease in soil porosity. The both compaction and top soil removal resulted reduction in water availability and porosity.

2.4 Water Holding Capacity

Birua, B. (2014) studied on tree soil interaction in arboretum has found water holding capacity is maximum in *Tectona grandis* followed by *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and minimum in *Emblia officinalis* .

Zang *et.al.* (2012) have conducted worked on effects of afforestation with *Eucalyptus grandis* on soil physiochemical and microbial properties and carried out soil physiochemical and microbiological properties were measured across a range of *E.grandis* plantation across a range of *E. grandis* plantation ages (1-10 years) in south western china to determine whether and how Eucalyptus afforestation of agricultural land affected the soil fertility and found that water holding capacity increased significantly with time .

Alemie, (2009) experimented on the effects of Eucalyptus production and soil properties in the Koga watershed , western Amhara region in Ethiopia and indicated significant effect on holding capacity in the undergrowth.

Cogliastro *et.al.* (2003) worked on hardwood tree species, planted over five different soil types on abandoned farmland of southwestern Quebec which were free from competition for light and soil resources. They observed seven years for identifying soil properties with growth of the tree. Their observation revealed that red oak growth (height/diameter) reduced with a higher soil water content; mean soil water content positively associated with stem growth of red ash and black walnut while negatively associated to the total white ash growth.

Ogaya *et.al.* (2003) studied on elucidation of the drought growth sperms of *Quercus ilex L.*, *Phillyrea latifolia L.*, *Arbutus unedo L.*, and other accompanying woody species of Mediterranean Holm Oak forest in Prades Mountain (N.E Spain) to a two year experimental drought where soil water availability was reduced to about 15% plastic strips. The reduction in growth was noticed markedly in the larger trees and 15% reduction in the upper soil moisture resulted 42% reduction in the biomass increment.

Sheffield *et.al.* (2003) in his experiment observed significant difference in above ground net primary productivity (AMPP) along a soil moisture gradient in mature long leaf pine-wire grass ecosystems. Cessation was also found in shoot growth significantly at the earlier whereas in needle growth in later stage. Other scientist like Wall & Heiskanen (2003) carried out work on the water retention character bulk density, organic matter concentration and particle size distribution in soil of afforested agriculture land in western Finland. Their result indicated that high water table level associated with the predomination of fine pore in the soil lead to potential risk of restricted aeration as well as reduction in forest growth.

Alavi, (2002) studied on relationship between free growth and water availability of Norway Spruce stand for 22 years period in a forest of Southern Sweden. He

concluded that short age of soil water has a strong effect on tree growth with the high precipitation.

Calder *et.al.* (1993) conducted in his experiment in Karnataka, India and found that in the dry zone of southern India; water availability is the principle limiting factor on growth, but nutrient limitations become important the availability of water. However result also showed fivefold increase in volume for the first year of growth in case of removal of the both water and nutrient.

Mishra & Nanda (1985) who worked on water holding capacity of soil texture classes ranging from sand to clay and reported that texture, organic matter and bulk density influenced water holding capacity.

2.5 Soil Texture :-

Birua, B. (2014) has worked on tree-soil interaction in arboretum and observed maximum value of percentage of sand in *Pongamia pinnata* followed by *Eucalyptus tereticornis*, *Emblica officinalis*, *Tectona grandis* and minimum in *Acacia catechu*; while the maximum value of percentage silt was found in *Acacia catechu* followed by *Eucalyptus tereticornis*, *Tectona grandis* and minimum in *Pongamia pinnata* whereas in percentage of clay, the maximum value has been reported in *Tectona grandis* followed by *Acacia catechu*, *Eucalyptus tereticornis*, *Pongamia pinnata* and minimum value in *Emblica officinalis*.

Alemie, (2009) focused his work on the effect of Eucalyptus production and soil proportion in koga watershed, western Amhara region in Ethiopia and observation no proportional change in soil texture .

Graciano *et.al.* (2005) reported from the responses from *E. Grandis* seedlings to drought affected by soil type and fertilization with nitrogen and phosphorus, that water stress tolerance strategies altered by fertilization depending on soil properties and

fertilization with phosphorus is recommend in black soil even if a moderate drought is likely to occur, but on sandy soil fertilization is recommended only under good water supply in given .

Szwaluk & Strong (2003) compared physical and chemical properties of forest floor humus and the uppermost 10 cm of the mineral soil zone and under storey plant species (42 native *Pinus contorts*) located in the lower Borel-Cordilleral eco- region of South Western Alberta of the tree stand ranged from 70 and 146 years age. These stands were stratified into 3 site index (SI 50) classes representing productivity gradient in terms of height growth. In their result, they found that the amount of explained variance among these equations differed by the type of variable : soil physical (maximum of 22%) < soil chemical (29%) < plant species (45%) plant growth form(63%) = humus form (67%) variables.

Plotnikoff *et.al.* (2002) tested operational landing rehabilitation programmes in three forest districts of interior British Coloumbia (BC) such as wind subsoiling grass / legume seedling followed by planting of lodgepole pine (*Pinus contorta* var. *latifolia*) generally resulted in successful re-establishment in forest cover and landings. They concluded that landings with >20 % clay had lower stocking densities, tree heights and probe depths compared to landings with <20% clay content. In the landings with >20% clay content had shorter trees growing on them when compared to tree heights on landings with 20% clay.

An experiment was conducted by Henery (2001) in dry tropical region of Western Venezuela on *Gmelina arborea*, *E. euophylla* and *E.grandis* plantations to find out soil properties. He reported that soil texture to be a significant predictor of tree growth for all the three species.

O'Halloral *et.al.* (1995) studied on the spatial variability of soil phosphorus (0-15cm) and its relationship with management and texture was examined on an on going crop rotation located on a Brown Chernozemich loam soil at Swift Current, Saskatchewan. The soil phosphorus was less variable than either the total inorganic (PI) or organic (PO) phosphorous fractions. The same was found for the sodium bicarbonate extractable P (Bicarb-P) fraction, though they were more variable. Upto 90% of variability in P could be accounted for by changes in texture. Organic P was negatively co-related to sand content.

Mishra & Nanda 1985 reported on his work done on available water holding capacity of three soil textured classes from sand to clay that available water holding capacity co-related significantly with silt+clay fraction, within the textured groups, was more closely related to silt+clay in coarse and moderately coarse textured, and to the proportion of silt to clay in fine textured soils. Besides, water retaintation was found greatly influenced by the nature of the dominant clay mineral of the soil.

2.6 Soil pH :-

Birua, B. (2014) has worked and found in his result the soil pH increased in planted area than unplanted area.

Zhang *et.al.* (2012) worked on effects on afforestation of *E.g* on soil physiochemical and micro-biological properties in *E.g* plantation a.z 1 to 10 year in South Western China to determine the effects of Eucalyptus afforestation on agricultural land particularly in soil fertility and their result showed soil pH in *E.g* plantation did not change the soil significantly.

Singh *et.al.* (2012) conducted the experiment on Amoleorative effect of multipurpose tree species grown on sodic soil on Indo-Gangetic Alluvial Plains of India comparing the impact of 10 years old plantation of 10 multipurpose tree species like

Terminalia arjuna, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Prosopis alba*, *Acacia nilotica*, *Eucalyptus tereticornis*, *Pithecellobium dulce* and *Cassia siamea*. They reported to be significant improvement in soil pH under tree plantation.

Alemie, (2009) studied on the effects of Eucalyptus on crop production and soil properties in Koga, Western Amhara region in Ethiopia and found no prominent change in soil pH.

Velarde *et.al.* (2005) have reported that in 20 years after establishment of *Prosopis juliflora*, soil pH changed from 10.4 to 8.0 as evidenced while Indian workers.

Coglistro *et.al.* (2003) carried out work on seven heart wood tree species planted in 5 different soil types in abundant farm land of South Western Quebec which were free from competition especially for light and soil. They found that the best red oak and bur oak “live stem growth” (height and diameter of surviving tree only occurred on soil derived from – dolomitic parent material viz. less alkaline).

Szwaluk & Strong (2003) carried out compilation on physical and chemical properties of forest floor humus and uppermost 10cm of the mineral soil zone and understory plant species abundance for 42 native *Pinus contorta* located in lower Boreal-Cordilleran eco- region of South Western Alberta stand ranged from 78-146 years in age. The stands were stratified into three site index (SI 50) classes representing productivity gradient in terms of height growth, pH was positively associated and also observed increasing SI 50.

Prevost, *et.al.* (1999) worked in peatland in Quebec, Canada and found higher nutrient content of peat soil water by drainage including that drainage also enhanced pH of the soil.

Binkley and Giardina (1998) conducted on plant-soil interaction and found that plant species have significant impacts on soil physiochemical properties like soil water content and pH. Binkley and Menyailo, (2005), worked on tree species effects on soil and found potential effects of tree species on soil properties associated with plant-soil interactions providing important feedbacks that regulate ecosystem processes. Almost similar observation have been reported by Kulmatiski, *et.al.* (2008) Porazinska,*et.al.* (2003), Pallant and Riha (1990), France *et.al.* (1989), Zinke (1962); whereas Ushio, *et.al.* (2008), Bartelt *et.al.* (2005), Porazinska, *et.al.* (2003), have observed that plant species have significant impact not only on soil physiochemical properties but also on the composition of soil microbial community.

Changes was found in topsoil chemical properties after a 20 month experiment in an Agroforestry system in the Philippines using three multipurpose tree legumes (*Gliricida sepium*, *Acacia auriculiformis* and *A. mangium*) intercropped with upland rice and mung bean (*Vigna radiata*) resulting positive change in fertility except soil pH (Anon 1997).

Hosur & Dasog (1995) experimented on effect tree species like teak, sheesham and Khair on soil properties and reported that pH decreased while; organic matter and calcium increased with slight change in nutrient status of the soil due to tree plantation.

Zech & Dreched (1991) worked in 5 to 11 years old teak plantation Glaro & Cavalla and Bomichinn, Hillchin, Liberia and found considerable variation in growth and variability of the trees. The deficiency symptoms indicates that difference in growth intensity was related to top soil acidity and status of calcium infoliage.

Narayan & Singh (1985) performed studies on nitrogen status of three kinds of forest soil under Sal forest E.Coppice regrowth, and mixed brushwood at Selakui, Dehradun. Higher nitrate concentration was found in the top 20cm with the decrease in

the deeper layers; whereas highest in Sal forest followed by E. and brushwood. Maximum nitrates were found in February followed by September and June.

Hoyt & Nilsen (1985) worked on effect of soil PH of 5 to 10 years old plantation in apple trees planted in orchard and indicated that size of delicious, tyed-man and Rome beauty cultivars was positively co-related with soil pH.

Sharmen *et.al.* (1985) made an investigation on soil properties under 5 stands of *Alnus nepalensis* a.z. from 7 to 56 years in Eastern Himalayas and reported increament soil pH down the profile and slow in the surface soil. Fractionation of inorganic phosphates was observed on representative sites of North-Eastern China in the studies done by Ye and Bang (1984) indicating maximum adsorption negatively co-related with soil pH.

Nair, (1984) experimented on soil productivity in Agroforestry and found alteration of chemical, physical and biological properties of soil through the trees showing impact on energy and nutrient fluxes into, out of and within the ecosystem. Almost similar observation have been found by Young (1989), Suncher (1998) and Breman & Kesslser (1995).

Jose & Koshy (1972) studied on physiochemical properties of soil influenced by teak vegetation and reported changes in physical and chemical properties of soil results by teak crop. They also observed that natural forest and 120 years old teak having somewhat similar surface horizon rich in organic matter. Though the physical properties of soil from 120 years plantation where similar to that of natural forest there was considerable compactness in second rotation plantation.

Gersper & Holowaychuk (1970) conducted in his studies to observe the effects of stem from the forest coppice tress on chemical properties of soil and reported that subtle variation in soil properties may alter the balance of competitive interaction among the

trees. They also observed clear mechanism through which dominant plants can alter properties of soil beneath their crown. This raises the potentiality for complex feedback loops between canopy tree occupancy and soil properties . Crozier *et.al.* (1986), Anderson (1991), Boerner *et.al.* (1989) have also conducted such work observing almost similar findings.

2.7 Soil Organic Carbon

Birua, B. (2014) has worked on and found that organic carbon increased in planted area than unplanted area. The soil organic carbon was observed maximum in *Acacia catechu* and *Pongamia pinnata* followed by *Tectona grandis* and *Emblica officinalis* and minimum in *Eucalyptus tereticornis*.

Singh *et.al.* (2011) carried out experiment on Ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Plains of India. Comparing impact of ten years old plantation of multipurpose tree species such as *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Acacia nilotica*, *Prosopis alba*, *Eucalyptus tereticornis*, *Pithecellobium dulce* and *Cassia siamea* on tree growth and physicochemical properties of sodic soil. They reported significant improvement in organic carbon under tree plantation soil than fallow of the nature.

Watanabe *et. al.* (2010) worked on teak plantation and observed site factor influence on organic carbon reporting significant correlation with the site factors; whereas Evans.J (1976) conducted investigation on plantation productivity finding that without proper soil management practices, clear felling of natural or planted forest and teak may result in soil deterioration depending on soil conditions, topography, climate and management practices.

Merino *et.al.* (2004) studied the effects of highly mechanised site preparation involving the removal of organic residue (humus,

layer and slash) on soil properties and tree growth in pine plantation growing on steep forest land in Northern Spain. They found that in 9 years the mean annual increment of timber decreased and calculated leaving logging residues on sites avoid soil compaction favouring nutrients uptake in trees and maintaining soil biological properties.

Swami *et.al.* (2003) observed in his result of the work that growth parameters like diameter, height and number of branches significantly varied due to age and site quality; while quantity of nutrients including soil organic carbon increased with age showing differences within the year. Likewise, Tomar *et.al.* (2003) experimented filled trial taking 31 trees species for nine years on a calcareous soil in semi-arid area of North West India and, found the soil to be enriched with organic carbon in upper 30 cm depth under tree species in order of satisfactory performance like *Tamarix articulata*, *Accacia nilotica*, *Prosopis juliflora*, *Eucalyptus tereticornis*, *Acaccia tortis*, *Cassia sameia*, *Melia azadirachta* and *Acaccia farnesia* whereas in tree species like *Acaccia auriculiformis*, *Bahunia bovirata*, *Cassia gloca*, *Szyium cumini*, *Crassensia alata*, *Samenia saman* and *Terminalia arjuna* were observed early growth satisfactorily.

In an agroforestry system conducted in Phillipines, changes in top soil chemical properties were found in twenty months in experiment in which three multiple purpose tree of legumes viz. *Gliricidea sepium*, *A. auriculiformis*, *Accacia mangium* were incorporate with upland rice and moong bean (*Vigna radiate*). The experiment showed positive variation in agroforestry and monoculture tree treatments, and in increase in organic carbon was found (Annon, 1997).

Binkley & Giardiana (1998) studied on plant-soil interactions. Their results revealed that the plant species exerts significant impact on soil quality for carbon concentration. Almost similar work has been done by Binkley & Menyallo (2005) on sand reporting potential effects of tree species on soil properties resulted by plant-soil

interactions keeping important feedbacks regulating ecosystem processes. Further; likely similar observations have been found by Kulmatiski et.al (2008), Porazinska *et.al.*(2003), Pallant & Rihea (1980), France *et.al.* (1989), Zinke (1962), and Ushio *et.al.*(2008) reporting that plant species show significant impact not only on soil physicochemical properties and substrate quality but also more directly on the composition of microbial organisms of the soil.

Sharma *et.al.*(1985) concluded his experiment by studying soil properties under five stands of *Alnus nepalensis* bearing age from 7-56 years in Eastern Himalayas. Their result revealed that organic carbon contents was high, decreasing with increasing profile depth, and increasing with increasing stand age.

Narain & Singh (1985) studied on nitrogen status of three types of forest types in Sal forest, Euclyptus coppice regrowth and mixed brush wood Selaquie, Dehradun. Higher nitrate concentration was found in top 20 cm decreasing in the deeper layers. The highest was found in sal forest followed by eucalyptus and then brush wood; maximum nitrates were found in February followed by September and June. Apart from these, correlation was found among nitrous concentration, organic carbon and moisture in surface layer of the soil.

Nair (1984) studied on soil productivity in case of agroforestry and concluded that trees alter chemical, physical and biological soil properties showing impact on energy and nutrients fluxes into, out, and within the ecosystem. The almost similar observations have been reported by Young (1989), Suncher (1998), Breman & Kesslser (1995).

Joshe & Koshy (1972) conducted work on morphological and physicochemical characteristics of soil influenced by teak vegetation and reported changes in physical and chemical properties of soil. As a result of teak crop, because rotation progresses by

recuperation in some of the properties. They also reported that natural forest and 120 years old teak plantation have rich horizons in organic matter. However, physical properties of soil from 120 years old plantation were similar to that of natural forest and considerable compactness in second rotation plantation.

Gersper & Holowaychuk (1970) did their experiment on effect of stem from forest canopy tree on chemical properties of soil properties of soil resulting variation in soil properties altering the balance of competitive interaction among the tree species, the mechanism by which dominant plants alter the properties of soil beneath their crown and, this raises the potential for complicated feedbacks looks between canopy tree occupancy and soil properties. Almost similar results have been found by Crozier *et.al.* (1986), Anderson (1991), Boerner *et.al.*(1989) who studied such work on the different sites and species.

2.8 Soil available Nitrogen:-

Birua B (2014) conducted the experiment to find out interactions between soil and tree species like *Tectona grandis*, *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and *Embllica officinalis* and reported about available nitrogen to be increased in planted area in respect of unplanted area. It was found maximum in *Tectona grandis* followed by *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and maximum in *Embllica officinalis*.

Zang *et.al.* (2012) found no significant effect on total nitrogen contents in their studies of afforestation with *Euclyptus grandis* on physicochemical and microbiological properties by measuring across 1-10 years plantation in South- Western China. They also reported that the requirements of the trees, understorey micro-environmental condition, allelopathic effects might play important roles in dynamic changes of soil physicochemical and microbiological properties.

Singh *et.al.* (2011) investigated ameliorative effect of multipurpose tree species grown on sodic soil of Indo-Gangetic Alluvial Plains of India by comparing impact of 10 years old plantation of 10 multipurpose tree species like *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Acacia nilotica*, *Prosopis alba*, *Eucalyptus tereticornis*, *Pithecellobium dulce* and *Cassia siamea* on tree growth biomass yield and physicochemical properties of sodic soils representing major tract of salt affected soil of Indo-Gangetic Alluvial Plains of India. Their result showed significant improvement in available nitrogen under tree plantation area than the natural fallow.

Watanabe *et.al.*(2010) studied on teak plantation and observed site factors influence reporting significant correlation of available nitrogen with the site factors. Similarly Evans (1976) worked on plantation productivity reporting that without proper soil management practices, clear felling of natural or plantation forest of continuous teak cropping may result in soil deterioration depending upon initial soil conditions, topography, climate, management practices as well; however, in rotation in tree crop like teak, soil properties may recuperate by stabilizing the properties provided there is no drastic disturbances of the site.

Alemie (2009) made his studies on the effect of eucalyptus on crop production and soil properties in Koga watershed and Western Amhara region in Euthopia and found significant effect in total nitrogen in undergrowth.

Swami *et.al.* (2004) studied chromosequence of *Gmelina arborea*, Roxb. , stands ranging from 1-6 years old to find out changes in growth, biomass and nutrient (N,P,K) contents for three red lateritic sites in Chhattisgarh, India; and observed that quantity of nutrients increased with the age. At the soil depth 0-20cm, 21-40 cm, and 41-60 cm after

six years of plantation, the available nitrogen was found to be enhanced by 14.58%, 11.98% and 11.25% respectively.

Cogliastro *et.al.*(2003) investigated seven hardwood tree species planted over five different soil types on abandoned farmland sites of South-western Quebec, and free of competition for light and soil resources, (at 7 years) in order to identify soil properties associated with their successful establishment and growth. Analysis of white ash indicated that highest “total tree diameter” (diameter weighted to include mortality) was positively associated with soil nitrification.

Williamson & Nielson (2003) have done assessment in two glass house having three eucalyptus species grown for 110 days in soil from six forest sites in Tasmania, Australia. The seedlings site of above ground was found strongly correlated with soil total nitrogen but poorly correlated with other micronutrients. But when it was added with phosphorous and nitrogen and with undisturbed sites growth showed seven times average than that of unfertilized seedlings depicting deficit of available phosphorous and nitrogen.

Binkley & Giardina (1998) studied on plant soil interactions they found in their result that the plant species have significant impact on soil quality for nitrogen substrate of nitrogen concentration. Binkley & Menyailo (2005) assessed on tree species effects on soil sand and reveled that there is potential effects of tree species on soil properties associated with plant soil interactions exerting important feedbacks which regulates ecosystem processes. Likewise, almost similar observations has been reported by Kulmatiski *et.al.*(2008), Porazinska *et.al.*(2003), Pallant and Riha, (1990), France, *et.al.*(1989), Zinke, (1962); whereas Ushio, *et.al.*(2008), Bartelt, *et.al.*,(2005), Porazinska, *et.al.*(2003), pointing out that plant species have significant impact not only

on physicochemical properties of soil but also on the composition of soil microbial components.

An experiment was conducted for 20 months in an Agroforestry system in Philippines consisting three multipurpose leguminous tree (*Gliricidia sepium*, *Acacia auriculiformis*, and *A. mangium*) intercropped by upland rice and mung bean (*Vigna radiata*); and found positive variation in agroforestry and monoculture tree treatment. An increase was also found in total nitrogen by 11.6%, while soil chemical properties did not vary much (Anon,1997).

Fife & Nambiar (1997) studied on response of *Pinus radiata* trees to nitrogen nutrition as the stand grew from canopy closure to first thinning stage to study the nature and the longevity of the growth response to applied nitrogen. They observed that the size of needles elongated when nitrogen was applied and, significant correlation was also observed between nitrogen and chlorophyll concentrations. Soil mineral nitrogen returned to pre-application levels within a year for further uptake from the soil. The elevated foliage nitrogen concentration and increment in stem growth continued for further two years, leading to increase in basal area over five years from nitrogen application upto 45% above the control. Thus, nitrogen application increase productivity primarily by increasing photosynthetic activity of the foliage, and increasing foliage production later on.

Woodward (1996) found effects of soil composition and top soil removal of physical and chemical properties of the soil and growth of planted trees in tropical moist forest on a typic Paleudult in Amazonian Ecuador denoting significant increase of nitrogen content.

Drechsel & Zech (1994) made an investigation on the site variable controlling teak yield (*Tectona grandis* Linn.fil.) and establishing guidelines for the selection of high

productivity site in Benin, Liberia, Nigeria and Togo. They found that between 70-90% of the variation in tree growth (Site Index, S.I) depending on age of the tree, soil region are due to supply of nitrogen, root-available soil depth and precipitation.

Sturhrmann *et.al.* (1994) worked on mineral nutrition, soil factors and growth rates of *Gmelina arborea* in plantation in humid low land of Northern Costa Rica to determine the factors responsible for visible growth irregularities in tree stands by relating growth rates to the soil and site properties. The variation in site and soil properties and tree growth rates was evaluated in 24 plits in 8 different plantations. It was observed by them that foliage reveled that tree growth is highly dependent on the supply by N,P,K & S indicating that poor growing trees suffer from a multiple nutrient disorder. All saturation uptake 80% in brown soil inhibits nutrient uptake, especially phosphorous and nitrogen.

Cromar *et.al.* (1993) studied fertilizer and irrigation treatment applied in factorial combination to four seed lots of *Euclyptus grandis* planted near Gynpie Queensland. After three years, they found that fertilizer treatment has significant effect in increasing height and basal area of the tree whereas; irrigation has no response this respect. Trees in fertilized plots where two and half times taller and have five times more basal area than that of unfertilized plots. Mean annual increment in fertilized plots at the age of three years reached 34.2 m³/ ha/year which is the highest growth rate in Australia at this young age of the tree.

Narian & Singh (1985) experimented on nitrate and nitrogen status of three kinds of forest soil in sal forest, Euclyptus coppice regrowth and mixed brushwood at Selakui, Dehradun. They observed higher nitrate concentration in top 20 cm with a decrease in the deeper layers. It was the highest in sal forest followed by eucalyptus and then brushwood. Maximum nitrates were found in February following September and June.

Correlation were found between nitrate concentration and soil pH, organic carbon and moisture status in surface layers of the soil.

Sharma *et.al.*(1985) in their studies on soil properties under five stands of *Alnus nepalensis*, having age from 7-56 years in Eastern Himalayas; found total nitrogen contents very high, decreasing with increasing profile depth and increasing with increasing stand age.

Nair (1984) assessed soil productivity aspect of agroforestry and observed that trees alter chemical, physical and biological properties of the soil through impact on energy and nutrient fluxes within the ecosystem. Similar observations have been reported by Suncher,(1995); Breman and Kesslser,(1995).

Joshe & Koshy (1972) carried out studies on morphological, physical and chemical properties of soil influenced by teak trees. They reported that there may be changes in physical and chemical properties of soil as the consequence of teak crop and as the rotation progresses there may be recuperation in some of the properties. Besides these, they also observed that the natural forest and 120 years old teak plantation have almost similar surface horizons having rich organic matter; but physical properties of soil of 120 years old plantation are similar to those of natural forest.

Gersper & Holowaychuk (1970) experimented on the effect of stand from forest canopy trees on chemical properties of soil and observed that subtle variation in soil properties may alter the balance of competition and interactions among the tree species. They also noticed clear mechanisms by which dominant plants can alter properties of soil beneath their crown. This raises the potential for complex feedback loops between canopy tree occupancy and soil properties. Likewise, Crozier *et.al.*(1986), Andersson (1991) and Borner *et.al.*(1989) also made investigations of such works on different sites and species reporting almost similar findings.

2.9 Soil available phosphorous:-

Birua, B.(2014) did the experiment on interactions between soil and tree species like *Tectona grandis*, *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and *Embllica officinalis* and reported in case of available phosphorus that it is more in unplanted area than planted area except *Euclyptus tereticornis*. It was maximum in Euclyptus tereticornis followed by *Embllica officinalis*, *Tectona grandis* and minimally in *Pongamia pinnata*.

Zhang *et.al.*(2012) studied on effects of afforestation with *Eucalyptus grandis* on soil physicochemical and microbiological properties measuring in tree ages being 1-10 years old in South Western China to determine affect on soil fertility. They reported that *E.grandis* afforestation of aerable soil has no significant effects on tptal phosphorous and and available phosphorous contents. Under storey micro environmental conditions, the requirements of tree and allelopathic effects play an important role in dynamic changes in soil physicochemical and microbiological properties.

Singh *et.al.* (2011) carried on studies on ameliorative effects of multipurpose tree species grown on sodic soil of Indo-Gangetic Alluvial Plains of India comparing the impacts of 10 years old plantation of 10 multipurpose tree species such as *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Acacia nilotica*, *Prosopis alba*, *Eucalyptus tereticornis*, *Pithecellobium dulce* and *Cassia siamea*. They found that there was significant improvement in available phosphorous under tree plantation than natural fallow.

Alemie (2009) reported significant effect of available phosphorous in undergrowth when he studied on the effect on Euclyptus on crop production and soil properties in Koga watershed, Western Amhara, Euthopia.

Graciano *et.al.* (2005) found responses of *E.grandis* seedlings to drought as affected by soil types and fertilization with nitrogen or phosphorous. For the purpose seedlings were planted in pots with two different types of soils like sandy soil and clay (black) soil. The red sand soil under drought was found unaffected by applying fertilizers; in black soil the plants fertilized with phosphorous showed moderate growth increase under drought in comparison to non fertilized plant. Water Use Efficiency (WUE) increased with phosphorous fertilization in well-watered plant in the sandy soil. In this way, they concluded that water stress tolerance strategies were altered by fertilization depending on soil properties and thus fertilization with phosphorous was recommended in black soil and on sandy soil fertilization it was recommended only under good water supply.

Velarde *et.al.* (2005) in their their experiment, Viz. field trial in Argentina on three years *Prosopis alba* growing in pH 8.5 soil to identify mineral nutrients to determine corelation among the nutrients randomizing the treatments containing sulphur, phosphorous and macro nutrients; found 42% significant biomes increase as well as positive growth corelation with leaf levels in decreasing order of potassium, sulphur, phosphorous and zinc.

Swami *et.al.* (2004) conducted a studies on chromo sequence of Gmelina arborea, *Roxb.* stand ranging from 1-6 years old plants and measured to documented changes in growth biomass and nutrient (N, P, & K) contents for three red lateritic sites in Chhattisgarh, India. They reported significant improvement in the organic matter and nutrients of the soil after 6 years of plantation. However available phosphorous decline 26%, 23% and 20% at soil depth of 0-20, 21-40 and 41-60 cm respectively.

Driessche *et.al.* (2003) worked in asper seedlings (*Populus tremuloides*) at Weyerhaeuser Tree Improvement Centre at Drayton Valley Alta, Canada to find out the

effects fertilization and irrigation with the objective to improve establishment and early growth of as per seedlings. Their results depicts that fertilization without irrigation had no effect on growth and also decreased 17% survival in comparison to the control. Foliage analysis indicated that the main growth response was to the phosphorous supplied by the fertilizer, foliage concentration and content of phosphorous increased by irrigation. Besides, seedling nutrient status increased over the second year, possibly due to larger seedling exploited the soil more extensively or because of more natural precipitation.

Ndufa *et.al.* (1999) carried out their work on the effect of phosphorous application on growth, nutrient uptake and dry matter in portioning in young trees of *Calliandra calothyrsus*, *Cedrela serrulata*, *Eucalyptus grandis*, *Grevillea robusta*, *Markhamia lutea*, *Senna spectabilis*, and *Sesbania sesban* on a P- deficient soil (Kandiudalfic Eutrudox, bicarbonate-EDTA extractable P=1 mg/kg) in western Kenya. Relative response to phosphorous was more strongly correlated with shoot growth rate per unit root length among species than with shoot growth rate alone. Apart from these, additional phosphorous increased nitrogen and phosphorous content as well.

Binkley & Giardiana (1998) worked on plant-soil interactions and found that plant species have significant impact on soil quality in case of phosphorous concentration. Binkley & Menyailo (2005) also investigated effects of tree species on soil sand reveling potential effects tree species on soil properties related with plant-soil interactions and also providing important feedbacks that regulate ecosystem processes. By Kulmatiski *et.al.* (2008); Porazinska *et.al.* (2003); Pallant & Riha (1990); France *et.al.*(1989); Zinke (1962), almost similar observations have been reported while while Ushio *et.al.* (2008); Bartelt *et.al.* (2005); Porazinska *et.al.* (2003) have reported in their work that plant species have significant impact not only on soil physicochemical

properties and substrate quality but there is direct impact on the composition of microbial community.

Positive variation has been reported in Agroforestry and monoculture tree treatments and changes in top soil chemical properties after twenty month experiment in this system. In the Phillipines using three multipurpose leguminous trees (*Gliricidea sepum*, *Acacia auriculioformis*, *Acacia mangium*) intercropped with upland rice and mung bean (*Vigna radiate*). An increase in phosphorous by 11.2% in soil chemical properties was also found which did not vary much across or along the tree rows (Anon.1997).

Woodward (1996) studied the effects of soil compaction and top soil removal of soil physical and chemical properties and growth of planted trees in tropical moist forest conducting in an oil extraction project on a typic Paludult in an Amazonian Ecuador reporting significant decrease in soil phosphorous content.

Cline *et.al.* (1986), investigated that dry biomass was related to root tissue levels of N, P, K, Ca, Na, Mg, Mn, Fe, Zn and Cu and soil pH. It was found that phosphorous was the element for most limiting growth whereas micro-nutrient addition produced little change in biomass at the lower lying level but at the higher lying levels. They increased biomass in the phosphorous abundant plants and a significant negative co-relation between phosphorous and zinc tissue concentration occurred indicating that phosphorous can be reduced zinc uptake in Prosipis.

Sharma *et.al.*(1985), made an on soil properties under five tree stands of *Alnus nepalensis*, ranging from 7-56 years of ages in Eastern Himalayas. They observed that available phosphorous content was the greatest at the depth of 40-60 cm and increased with stand is upto 46 years.

Nair (1984) in his studies on soil productivity aspect of Agroforestry suggested that tree alter chemical, physical and biological soil properties by giving impact on energy and nutrient fluxes into out of, within the ecosystem. Young (1989), Suncher (1998), Breman and Kesslesler (1995) observed almost similar results.

Jose & Koshy (1972) carried out experiment on morphological, physical and chemical characteristic of soil influenced by teak trees reporting that changes in physical and chemical properties of soil may be recuperation, as the rotation progresses, in some of the chemical properties of soil. They also observed that the natural forest and 120 years old teak plantation have somewhat similar surface horizons being rich in organic carbon matter; though the physical properties of soil of 120 years plantation are similar to the natural forest; While considerable compaction in second rotation plantation was also observed.

Gersper & Holowaychuk (1970) conducted their work on effect of stem from forest canopy trees on chemical properties of soil and concluded that subtle variation in soil properties may alter the parents of competition interaction among tree species. They also reported that there are mechanisms while which dominant plants can alter properties of soil beneath their crown raising the potential for complex feedback loops between canopy tree occupancy and soil properties. In this connection, Crozier *et.al.*(1986), Andersson (1991), Borner, *et. al.*(1989) also observed almost similar result.

O'Halloran, *et. al.* (1985) studied on the special variability of soil (P 0-15 cm) and its relationship with management and texture was examined on an ongoing crop rotation studies located on a Brown Chernozemic loam soil at Swift Current, Saskatchewan and found that soil phosphorous was less variable than either the total inorganic (P.I) or organic (PO). The similar result was found by the sodium bicarbonate extractable (P) (bicarb-P) fractions although they were more variable. Upto the 90% of

the variability in phosphorous could be accounted for by changes in texture. The organic phosphorous was negatively correlated to the soil content.

2.10 Soil available potassium

Birua, B. (2014) made an investigation on experiment on interactions between soil and tree species like *Tectona grandis*, *Acacia catechu*, *Eucalyptus tereticornis*, *Pongamia pinnata* and *Emblica officinalis* and reported in case of available potassium observed maximum value in *Pongamia pinnata* followed by *Eucalyptus tereticornis*, *Tectona grandis*, *Emblica officinalis* and minimum in *Acacia catechu*. He also observed increased potassium in planted area than planted area than unplanted area.

Singh *et.al.*(2011) worked on ameliorative effect of multipurpose tree species grown on sodic soil of Indo-Gangetic Alluvial Plains on India to compare the impact of 10 year old plantation of 10 multipurpose tree species like *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Acacia nilotica*, *Prosopis alba*, *Acacia nilotica*, *Eucalyptus tereticornis*, *Pithecellobium dulce*, and *Cassia seimea* on tree growth, biomass yield, and physicochemical properties of sodic soil representing major tract of salt affected soil of Indo-Gangetic Alluvial Plains of India. Their result reveled significant improvement in available potassium under tree plantation than the natural.

Velarde *et.al.*(2005) studied field trial in Argentina on three year old *Prosopis alba* growing in pH 8.5 soil with the purpose to identify mineral nutrients which was most limiting to growth and determining co-relation among this nutrient. In their experiment, they found that growth was positively co-related with leaf levels and decreasing order of potassium, sulphur, phosphorous and zinc. The leaf potassium, having the highest positive co-relation with growth, was highly significantly positively

correlated leaf with sulphur, Phosphorous, Nitrogen and Zinc are highly significant but negatively correlated with leaf calcium, Magnesium and manganese.

Swami *et.al.*(2004) conducted the experiment on growth parameters of *Gmelina arborea* like DBH, total height and number of branches and reported to be varied significantly in age and site quality. The quantity of nutrients was also found increasing with the age and available potassium was found enhanced by 10%, 9.13% and 10.63% at the soil depth 0-20 cm, 21-30 cm and 41-60 cm respectively.

An experiment was done on changes in top soil and chemical properties in a 20 month old Agroforestry system in Philippines in taking 3 multipurpose leguminous trees (*Gliricidea sepeium*, *Acacia auriculiformis*, *Acacia mangium*) intercropped with upland rice and mung bean(*Vigna radiata*) observed positive variation in Agroforestry and monoculture treatments. An increase in exchangeable potassium by 10.6% was found with the indication that *Glicricidea sepeium* to be the best species building soil fertility (except for exchangeable potassium). *Acacia auriculiformis* was found intermediate (but best in exchangeable potassium); while *Acacia magium* was found the least favourable. In case soil properties no much variation was found (Anon,1997).

Nadufa *et.al.*(1991) conducted experiment on effect of phosphorous application on growth, nutrient uptake, dry matter partitioning in young trees of *Calliandra calothyraus*, *Cedrela serrulata*, *E.grandis*, *Graveria robusta*, *markhamia lutea*, *Senna*, *Spectabilis*, and *Sesbania sesban* on p-deficient soil (Kandiudalfic-Eutrudox, bicarbonate-EDTA extractable P=1 mg/kg) in Western Kenya. It was found that potassium addition increased in N and P content but decreased final shoot potassium content in sesbania and calindra having little effect on other species.

Sharma *et.al.*(1985), studied soil properties under five tree stands of *Alnus nepalensis*, ranging from 7-56 years of ages in Eastern Himalayas finding decreasing

exchangeable potassium with soil depth particularly in the older stand; though no consistent relationship between exchangeable potassium or calcium content and stand age was found.

Nair (1984) studied on soil productivity in Agroforestry suggesting that trees alter chemical, physical and biological soil properties through their impact on energy and nutrient fluxes into, out of, and within the ecosystem. Almost similar observation have been reported by Young (1989), Suncher (1998), Breman and Kesslesler (1995).

Jose & Koshy (1972) worked on morphological, physical and chemical characteristic of soil influenced by teak plantation. Their result showed that changes in physical and chemical properties of soil due to teak plants may be due to recuperation in some of the properties as the rotation progresses. They observed that the natural forest and 120 years old teak plantation have somewhat similar surface horizons rich in organic matter, however, the physical properties of soil was found similar in both the cases of natural and planted conditions forest except considerable compaction was found in second rotation plantation of teak crop.

Gersper & Holowaychuk (1970) carried out studies on effect of stem from forest canopy trees on chemical properties of soil. They observed that subtle variation in soil properties may alter the balance of competition and interaction among tree species. They also found clear mechanism by which dominant plants and the alter properties of soil beneath their crown, raising the potential feedback loops between canopy trees occupy and soil properties. Crozier *et.al.*(1986), Anderson (1991), Borner *et.al.*(1989) who also carried out such experiment finding almost similar results.

Tree growth parameters

Plant Height

Birua, B.(2014) studied on interactions between soil and tree species like *Tectona grandis*, *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and *Emblica officinalis* and in case of height found maximum in *Eucalyptus tereticornis* which is the fast growing exotic species followed by *Tectona grandis*, *Pongamia pinnta*, *Emblica officinalis* and minimum in *Acacia catechu*.

Swami *et.al.* (2004) conducted a chonosequence experiment of *Gmelina arborea* Rox. ranging the stands from 1-6 years old aiming to document changes in groth biomass nutrient (N, P & K) contents for three lateritic sites at Chhattisgarh, India. In their experiment, they found that the stand density, their survival and growth parameter like total height varied significantly with their age as well as site.

Froehlich *et.al.*(2003), studied the growth in height, diameter and volume in 9-18 years old Ponderosa pine (*Pinus ponderosa*) and 10-13 years old Lodgepole pine (*Pinus contorts*) trees growing on or near compacted skid trails in the Yakima Indian reservation in South Central Washington. They observed total height reduction by 8% in *P.Ponderosa* and increased in *P.controts* which was significantly related to trees and the percentage of soil organic matter.

Swami *et.al.*(2003) reported on the basis of his experiment that growth parameter like total height to be varied significantly due to difference in age site quality. Quantity of nutrients increased with the age and soil organic carbon increased within the years.

Driessche *et.al.*(2003) studied in asper seedling (*Populus tremuloides*) in 2x2 factorial experiment at the Weyrhaeuser Tree Improvement Centre at Drayton Valley Alata, Canada with the objectives of improving establishment of early growth of the asper seedlings, effects of fertilization and irrigation. Their result showed that fertilizer

interacted strongly with irrigation revealing effects on both experiments applied together increasing mean height by 19% and stem volume 92% after three growing seasons of the experiment.

Woodward (1996) worked on effects of soil compaction and top soil removal on soil physical and chemical properties and growth of planted trees on an oil extraction project in tropical moist forest on a typic Paleudult in an Amazonian Ecuador and his result revealed reduced height growth in all the species and most consistently the height reduced in compacted sub-soil with top soil removal compared with undisturbed soil.

Plant Diameter

Chima *et.al.*(2016) evaluated soil properties in the rhizosphere and growth of *Gmelina arborea*, *Tectona grandis*, *Nauclea diderrichii* and *Khaya grandifolia* in a four year old arboretum to determine the influence of soil properties in exotic species. They reported the salient differences in height, crown and diameter of the trees among exotic and indigenous species.

Likewise Das C *et.al.*(2016) also studied the nutrient release pattern due to decomposition of litter fall in *Shorea robusta* and *Tectona grandis* and found that decomposed leaf litter was higher in comparison to *Shorea robusta*.

Birua, B.(2014) has studied on interactions between soil and tree species like *Tectona grandis*, *Acacia catechu*, *Eucalyptus tereticornis* , *Pongamia pinnata* and *Emblia officinalis* and in case of diameter found maximum in *Eucalyptus tereticornis* followed by *Tectona grandis*, *Pongamia pinnta*, *Emblia officinalis* and minimum in *Acacia catechu*.

Froehlich *et.al.*(2003) made their experiment to study the growth in height, diameter and volume in 9-18 years old Ponderosa pine (*Pinus ponderosa*) and 10-13

years old Lodgepole pine (*Pinus contorts*) in or near compacted skid trails in the Yakima Indian Reservation in South Central Washington. They found that the diameter reduced by 20% *P.ponderosa* whereas increased in *P.controts* showing significant relations with the trees and the percentage of soil organic matter.

Swami *et.al.*(2003) conducted the work on growth parameter like diameter and reported significant significant variation in diameter due to difference in age and site quality; whereas quantity of the nutrients increased with the age and soil organic carbon increased from 8.46-14.02 kg/ha within the years.

Woodward (1996) reported in his investigation on the effects of soil compaction and top soil removal in soil physical and chemical properties as well as growth of planted trees on an oil extraction project in Tropical moist forest on a typic Palaudult in Amazonian Ecuador and found reduction in diameter only in *Cedrelinga conteniformis*.

Donnelly & Shane (1986) carried on investigation on forest ecosystem responses to artificially induced soil compaction, soil physical properties and tree diameter growth to simulate intensive recreation and / or vehicular traffic in harvesting operation plots within a *Quercus alba* / *Q.velutina* / *Q. rubra* forest on loamy sand in NW Vermont before and after application of bark mulch 2-3 times each year for 4 years. They reported that the application of before compaction tempted to reduce the changes in soil properties in diameter increment and hence showing intensive effect on the growth of the tree.

The present experiment entitled “Tree-Soil interaction on different species in Arboretum” has been conducted in the Arboretum of Birsa Agricultural University, Kanke, Ranchi, District of Jharkhand state during the year 2016-17. The material methods used in this investigation are as below.

EXPERIMENTAL SITE

The research area of the experiment in Arboretum which was established in the year 2006 by the faculty of Forestry of Birsa Agricultural University, Kanke, Ranchi, (Jharkhand) India. The experimental site is located at 23° 26' 0" North latitude and of 85° 19' 0" East latitude. The arboretum is divided into 9 blocks of 100x100 plants in each block. Spacing was kept minimum of 1m. The Arboretum was created keeping in view to serve multifarious use with the basic objective of research, study, and conservation of the species including demonstration as well. It is spreaded over an area of 2 hectares possessing 5 compartments of valuable species like timber, fruit, medicinal, industrial and ornamental trees. Besides these, a plot has been kept reserved for the lesser known tree species.

CLIMATE AND SOIL

The location of the experimental site belongs to sub-zone V of Jharkhand region as per Agroclimatic Zone Classification. The general climate of this region is classified as sub-humid megathermal and the region has characteristics of three distinct seasons such as summer, rainy and winter. However, the general climate of the region is subtropical with mean daily temperature of about 22.8°C. It is characterized by hot summer and cold winter with mid May (hottest month) temperature of 39.3°C mid

January (coldest month) temperature dropping down to 01.8⁰C. The maximum temperature ranges from 21⁰C to as high as 42.8⁰C and minimum temperature from 2.6⁰C to 21.8⁰C. The mean annual temperature ranges from 16.8⁰C to 25.4⁰C. The mean relative humidity is about 64% in the area. The annual rainfall varies from 900-1400 mm making favorable condition for subtropical dry deciduous forest.

The soil of this region is of acidic nature and the pH ranges from 4.5-6.7 with temperature variation from 30-42⁰C.

DESCRIPTION OF PLANTS

1. *Swietenia mahogoni* (Mahogany):-

Swietenia mahogoni belongs to the family Meliaceae. It is a medium to large-sized evergreen tree with a buttressed base. It is exotic to India. It is timber species. It is a deciduous or semi-deciduous attaining a height of 18-24m. It grows mostly in valleys at lower elevations. The small and inconspicuous but scented flowers appear in April-May soon after the new flowers appeared. The wood is hard, reddish-brown and moderately heavy. The timber considered superior throughout the worked for furniture and cabinet work.

2. *Dalbergia sissoo* (Sheesham):-

Dalbergia sisso belongs to the family Leguminosae. It is a medium to large sized gregarious and deciduous tree having thick, rough grey bark, with shallow broad longitudinal fissures exfoliating in irregular woody strips and scales. The species occurs throughout the sub- Himalayan tract and outer Himalayan valleys from the Indus to Assam, usually upto 900-1500m. The trees shed its leaves from Nov-Dec to Jan-Feb when the new leafing starts continuing upto April. It is valuable timber species, strong and very elastic and extremely durable. It is used in wooden flooring and paneling, furniture, railway sleepers, trucks and lorry bodies, musical instruments and walking sticks.

3. *Gmelina arborea* (Gamhar):-

Gmelina arborea belongs to the family Verbenaceae. It has timber value which is valuable in market and extremely used in furniture. It is a kind of deciduous tree that attains large dimensions on favourable sites, giving clear boles. The largest tree occurs in moist mixed forest of Assam, West Bengal, Bangladesh and Burma. Leaves shed in February- April and the new foliage appears in April- May. It is a strong light-demander, though it can stand some shade in its early stages. It is a durable timber both under cover and when placed in contact with water. It is also used in construction, furniture, boat buildings, agricultural implements etc.

4. *Ziziphus jujube* (Ber):-

Ziziphus jujube belongs to the family Rhamnaceae. It is a famous fruit tree in India. It has moderate sized almost evergreen tree with short bole, spreading rounded crown of dark green foliage, drooping slender branches armed with stipular prickles. It is found growing naturally in hotter parts of northern and peninsular India and also in Deccan but absent from the very humid areas of the north-east India. The old leaves shed in about March-April and new leaves appear almost simultaneously. Its wood is used for agricultural implements, boot and shoe-lasts etc.

5. *Syzygium cumini* (Jamun):-

Syzygium cumini belongs to the family Myrtaceae. It is a fruit tree which is large, evergreen tree with a dense irregular crown of dark-green shining foliage and short trunk. It is one of the most widely distributed trees of India occurring in the major forest groups except those in the very arid regions. The wood is pale reddish-grey or reddish brown. The wood is extensively used for beams, door-frame panels, heavy packing cases etc. Its fruit and especially seed is widely used for medicinal purposes.



Swietenia mahagoni



Dalbergia sissoo



Gmelina arborea



Ziziphus jujube



Syzygium cumini

METHODOLOGY

The plantation in the arboretum has been done row wise in blocks. Since the blocks are not equal in size random sampling methods has been applied in the present work in taking soil samples in each tree species. Five tree species like Mahogany (*Swietenia mahogoni*), Sheesham (*Dalbergia sissoo*), Gamhar (*Gmelina arborea*), Jamun (*Syzygium cumini*) and Ber (*Ziziphus jujube*) have been taken in the current investigation to study tree-soil interaction in Arboretum.

In each tree species at least 10 soil samples (0-30cm deep) has been collected from 10 trees (treating as Planted Area) by Random Selection method and accordingly corresponding to them 10 soil samples were collected from just opposite of such selected trees about 5m distance away having no vegetation (treating as Unplanted Area). Further, from the same randomly selected trees in each species; height, diameter and crown- width have been also recorded to assess growth performance of the species.

Methodologies as per objectives are:

1. Analysis of the soil sample for different nutrient present in the soil.
2. Estimate the diameter, height and crown width for the growth parameter.
3. Statistical analysis of the soil for nutrient status of the soil.

SOIL PHYSICAL PROPERTIES

1. Bulk Density (Core Method):-

Bulk Density (BD) of a soil is the ratio of the mass (M) of oven-dried soil to its Bulk volume (BV), which includes the volume of the soil particles and the voids (pore spaces) between the particles. Bulk density is a kind of dynamic soil properties, altered by cultivation, compressed by animals and machinery, weather, and loss of organic matter. Generally, it increases with depth of the soil profile and normally varies from 1.0

to 1.7 g cm^{-3} . It means, higher the number shows more compactness of the soil being more difficult for roots to penetrate. The most simple method as well as useful for measuring it is cut out a cylindrical core of soil of known volume and find the mass of the dried soil. Hence, bulk density is the ratio of the mass to the bulk of macroscopic volume plus space expressed in gram cm^{-3} or it is the oven dried mass divided by the filled volume of the sample.

Calculation of BD by the following formula:-

$$\text{BD (g cm}^{-3}\text{)} = \frac{\text{Weight of over-dry soil in grams [(c) - (a)]}}{\text{Volume of core in cm}^3}$$

2. Particle density (Blake, 1965):-

It denotes the density of the solid particles of the soil expressed as the ratio of the total mass of soil particles to their total volume, excluding pore space between the particles. In general, the units are grams per cubic centimeter. The formula for calculation given by Blake (1965) is as follows:-

$$D_p = \frac{d_w(W_{ps} - W_{pa})}{(W_{ps} - W_{pa}) - (W_{psw} - W_{pw})}$$

Where:

D_p = Particle density

D_w = density of water at observed temperature

W_{ps} = weight of empty pycnometer

W_{pa} = weight of pycnometer with soil + sample collected at oven dry condition

W_{psw} = weight of pycnometer with soil and water

W_{pw} = weight of pycnometer filled with water at observed temperature

3. Soil porosity:-

It is estimated by the formula as below:-

$$\text{Soil porosity (\%)} = [1 - (\text{Bulk Density} / \text{Particle Density})] \times 100$$

4. **Water Holding Capacity (WHC):-**

It is defined as the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially ceased. (Veihmeyer & Hendrickson, 1931). The stage of field capacity is attained in the field after 48 to 72 hours of saturation which is the upper limit of plant available soil moisture.

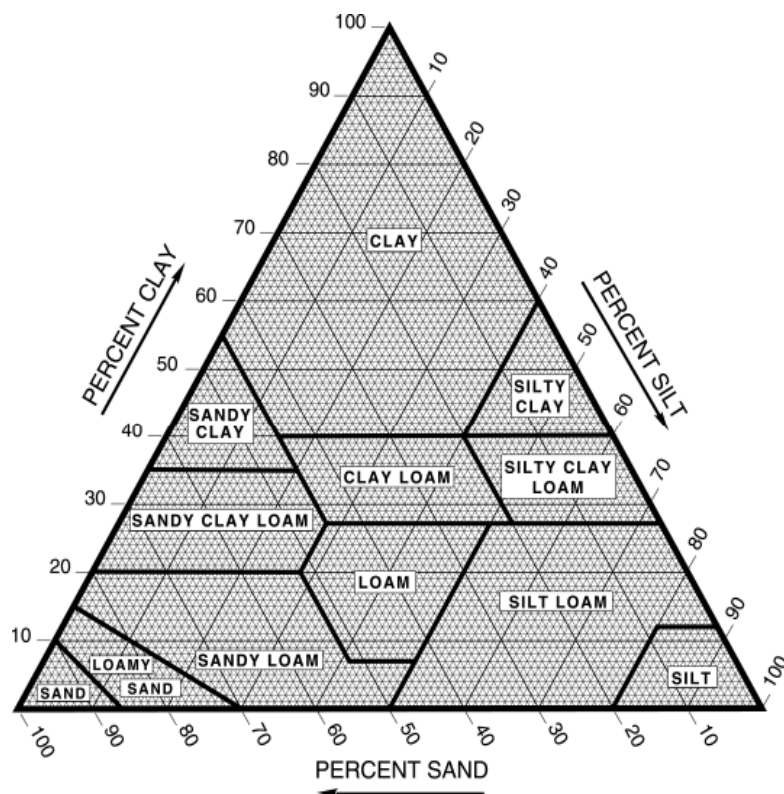
It is the amount of moisture in a soil when its total pore space both macro and micro is completely filled with water. This happens when a thin layer of soil is allowed to absorb water from a free water surface. It is expressed in the form of the formula as below:

$$\text{Water holding capacity} = \frac{\text{Maximum water absorbed}}{\text{Oven dry weight of soil}} \times 100$$

5. **Soil Texture:-**

Soil texture is the major characteristics of the soil being used for describing the size distribution of particle in the soil such as sand, silt, and clay. It is calculated by Bouyoucos Hydrometer Method.

The calculated percentage of sand, silt and clay on the basis of data sheet, the textural class of the soil has been determined by Diagram for USDA Soil Textural Triangle.



USDA SOIL TEXTURAL TRIANGLE

SOIL CHEMICAL PROPERTIES

6. Soil pH:-

It was measured by pH meter following the procedure as mentioned below-

1. Setting the pH meter by using 2 buffer solutions, one should be the buffer with neutral pH (7.0) and the other with chosen based on the range of pH in the soil.
2. The buffer solution was taken in the beaker. The electrode was inserted alternately in the beakers containing 2 buffer solutions to adjust the pH. And now the instrument indicating pH as per the buffers is ready to test the samples.
3. 10.0g of soil sample into 100 ml beaker was taken and add 25ml of distilled water.
4. By stirring the suspension for 30 minutes, pH was recorded as on the calibrated pH meter.

7. Soil organic carbon:-

It is calculated by the following formula postulated by Walkley & Black (1934) known as Volumetric Method:

$$\text{Percent organic Carbon (X)} = \frac{10 (S - T) \times 0.003}{S} \times \frac{100}{\text{Wt. of soil}}$$

Since one gram of soil is used, this equation simplifies to:

$$\frac{3(S - T)}{S}$$

Where,

S = ml FeSO₄ solution required for blank

T = ml FeSO₄ solution required for soil sample

3 = Eq. W of C (weight of C is 12, valency is 4, hence Eq. W is 12÷4 = 3.0)

0.003 = weight of C (1 000 ml 0.1667M K₂Cr₂O₇ = 3 g C).

Organic Carbon recovery is estimated to be about 77%. Therefore, actual amount of organic carbon (Y) will be:

$$\text{Percent value of organic carbon obtained} \times \frac{77}{100}$$

Or Percentage value of organic carbon x 1.3

Percent Organic matter = Y x 1.724 (organic matter contains 58 % organic carbon, Hence 100/58 = 1.724)

8. Soil available Nitrogen

It has been calculated by Subia and Asija Method (1956) described as follows:-

Volume of acid used to neutralize ammonia in the sample = A – B ml

N content in the test sample = (A – B) x 0.56mg

Percent Nitrogen (A – B) x 0.56 x 5

Where,

A = Volume of 0.02M H₂SO₄ used in titration against ammonia absorbed in boric acid.

B = Volume of 0.02M sulphuric acid used in blank titration. 1 ml of 0.02M sulphuric acid = 0.56 mg N (1 000 ml of 1M H₂SO₄ = 14 g Nitrogen). Wt. of soil sample = 20 g. Thus, factor for converting into % Nitrogen = 100/20 = 5

9. Soil available Phosphorus:

Calculation by Bray's Method No. 1 for acid soils (Bray and Kurtz, 1945) by help of the Formula:-

$$P \text{ (kg / ha)} = \frac{A}{1000000} \times \frac{50}{5} \times \frac{4.5 \times 10^6}{5} = 9A$$

Where,

Available phosphorous = P

Weight of the soil taken = 5 g

Volume of the extract = 50 ml

Volume of the extract taken for estimation = 5 ml

Volume made for estimation (dilution = 5 times) = 25 ml

Amount of P observed in the sample on the standard curve = A (μg).

Wt. of 1 ha of soil upto a depth of 30 cm is taken as 4.5 million kg.

9. Soil available Potassium: -

Calculation was followed by Flame photometric method (Toth and Prince, 1949) which is well-accepted method, by the Formula such as:-

$$K \text{ (Kg/ha)} = A \times \frac{25}{5} \times \frac{4.5 \times 10^6}{1000000} = 22.5 A$$

Where,

K = Available Potassium

A = Content of K in the sample, as read from the standard curve: weight of 1 ha of soil up to 30cm is approx. 4.5 million kg.

MEASUREMENT OF TREE PARAMETERS

From growth performance point of view of the tree species, the following parameters were considered to find out the same.

- (I) Measurement of diameter of the tree species.
- (II) Measurement of the height of the tree species.
- (III) Measurement of the crown width of the tree species

10. Measurement of tree Diameter:-

The diameter of the tree was measured at the breast height (which is defined as almost universally adopted standard height for measuring the girth, diameter and basal area of the standing tree). The measurement of diameter at D.B.H (Diameter at Breast Height) was taken by the help of the calliper.

11. Measurement of tree Height:-

Height of standing tree was measured, which is the straight line distance from the tip of the leading shoot (or from the highest point of the crown where tree has no leader) to the ground level. Usually it is measured on slopes from the uphill side of the tree. The measurement of height was taken by the instrument namely Hypsometer which gives direct height of the tree when a horizontal stick of fixed length kept at the base of tree is exactly covered with the selected measuring base.

13. Measurement of tree Crown width:-

Crown width is the maximum spread of the crown along its widest diameter. It was estimated by measuring the shadow of the crown of tree in east-west and north-south direction.

STATISTICAL ANALYSIS

A paired t-test is used to compare two population means where you have to sample in which observation in one sample can be paired with observations in the other sample.

(a) Procedure for carrying out a paired t-test

Suppose a sample of n pair soil will be given a diagnostic test before studying a particular module and then again after completing the module. We will be found out if, in general, it leads to improvements in soil condition. We can use the results from our sample of soil to draw conclusions about the impact of this module in general.

Let x = Nutrient status before the module, y = Nutrient status after the module.

To test the null hypothesis that the true mean difference is zero, the procedure is as follows:

1. Calculate the difference ($d_i = y_i - x_i$) between the two observations on each pair, making sure you distinguish between positive and negative differences.
2. Calculate the mean difference, $\bar{d}$.
3. Calculate the standard deviation of the differences, s_d , and use this to calculate the standard error of the mean difference, $SE(\bar{d}) = \frac{s_d}{\sqrt{n}}$

$$s_d^2 = \frac{1}{n-1} (\sum d_i^2 - n\bar{d}^2)$$

HO: difference in nutrient status of each pair is same.

H1: difference in nutrient status of each pair is different.

4. Calculate the t-statistic, which is given by $t = \frac{\bar{d}}{SE(\bar{d})}$

Under the null hypothesis statistic, follows a t-distribution with n-1 degrees of freedom.

5. Use tables of the t-distribution to compare your value for t to the tn-1 distribution.

This will give the p-value for the paired t-test.

(b) Procedure for carrying out interaction between tree growth and soil

To find out the interaction between tree growth and soil, Pearson Correlation Method has been followed to get statistical value as per the data found in the results.

The experiment was conducted on different tree species in arboretum in respect of tree-soil interaction to find out the extent of influence of soil properties related to the growth of five tree species with ten soil parameters along with three growth parameters. The results coming after statistical analysis are as follows under following heads :-

PHYSICAL PROPERTIES OF SOIL

4.1 Bulk Density

In the result of the present experiment, the bulk density of the soil has been found higher in unplanted area than planted area in all the species. It has been observed highest in *Ziziphus jujube* in unplanted area followed by *Gmelina arborea*, *Syzygium cumini*, *Dalbergia sisso*, and minimum in *Swietenia mahogoni*. It has been statistically significantly higher in *Gmelina arborea* followed by *Syzygium cumini*, *Swietenia mahogoni*, *Ziziphus jujube* and non-significant in *Dalbergia sisso*. (Table 4.1)

Table-4.1: Showing bulk density of different tree species

Name of species	Unplanted (gm cm ⁻³)	Planted (gm cm ⁻³)	t-test value
<i>Swietenia mahogoni</i>	1.55	1.52	3.31**
<i>Gmelina arborea</i>	1.64	1.55	19.08**
<i>Dalbergia sisso</i>	1.58	1.55	NS
<i>Ziziphus jujube</i>	1.66	1.62	2.73**
<i>Syzygium cumini</i>	1.59	1.51	16.58**

t (9)0.05=2.262

** Highly significant

4.2 Particle Density

As per the data recorded in experimental work, the particle density of the soil has been found higher in planted area than unplanted area in all the species. The particle density is found highest in *Syzygium cumini* in planted area followed by *Swietenia mahogoni*, *Dalbergia sisso*, *Gmelina arborea* and lowest in *Ziziphus jujube*. Statistically it

has been found significantly higher in *Syzygium cumini* followed by *Swietenia mahogoni*, *Dalbergia sisso*, *Gmelina arborea* and *Ziziphus jujube* is non-significant. (Table 4.2)

Table-4.2: Showing Particle density of different tree species

Name of species	Unplanted (gm cm ⁻³)	Planted (gm cm ⁻³)	t-test value
<i>Swietenia mahogoni</i>	2.59	2.62	12.01**
<i>Gmelina arborea</i>	2.54	2.59	6.25**
<i>Dalbergia sisso</i>	2.54	2.60	6.26**
<i>Ziziphus jujube</i>	2.52	2.56	NS
<i>Syzygium cumini</i>	2.58	2.68	13.32**

t (9)0.05=2.262

** Highly significant

4.3 Soil Porosity

The recorded data of the experiment showed porosity of the soil higher in planted area than unplanted area. The highest value of soil porosity in *Dalbergia sisso* followed by *Swietenia mahogoni*, *Gmelina arborea*, *Syzygium cumini* and minimum in *Ziziphus jujube*. Statistical analysis shows it is highly significant in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Ziziphus jujube* and *Dalbergia sisso*. (Table 4.3)

Table-4.3: Showing Soil Porosity of different tree species

Name of species	Unplanted (%)	Planted (%)	t-test value
<i>Swietenia mahogoni</i>	34.12	38.26	42.79**
<i>Gmelina arborea</i>	30.34	36.43	45.02**
<i>Dalbergia sisso</i>	35.40	43.50	38.85**
<i>Ziziphus jujube</i>	31.03	35.42	41.45**
<i>Syzygium cumini</i>	32.13	33.57	45.68**

t (9)0.05=2.262

** Highly significant

4.4 Water Holding Capacity

The water holding capacity of soil has been found higher in planted area than unplanted area. Showing highest value of water holding capacity was found higher in *Dalbergia sisso* followed by *Gmelina arborea*, *Ziziphus jujube*, *Syzygium cumini* and

minimum in *Swietenia mahogoni*. From statistical point of view it is found significantly higher in *Gmelina arborea* followed by *Dalbergia sisso*, *Ziziphus jujube*, *Syzygium cumini* and *Swietenia mahogoni*. (Table 4.4)

Table-4.4: Showing Water Holding Capacity of different tree species

Name of species	Unplanted (ml /100 cm ⁻³)	Planted (ml /100 cm ⁻³)	t-test value
<i>Swietenia mahogoni</i>	18.59	21.30	24.54**
<i>Gmelina arborea</i>	23.83	27.83	48.91**
<i>Dalbergia sisso</i>	28.93	34.39	48.06**
<i>Ziziphus jujube</i>	24.39	26.35	40.06**
<i>Syzygium cumini</i>	22.34	24.24	31.47**

t (9)0.05=2.262

** Highly significant

4.5 Soil Texture

4.5 a. Sand

In the present experiment, as per the recorded data, the percentage of sand has been found higher in unplanted area than planted area in all the species. The highest value of percentage of sand was found in *Syzygium cumini* followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni* and minimum in *Ziziphus jujube*. Statistically it is found non- significant in all the species. (Table 4.5.a.)

Table-4.5.a.: Showing percentage of Sand in different tree species

Name of species	Unplanted (%)	Planted (%)	t-test value
<i>Swietenia mahogoni</i>	52.47	51.12	NS
<i>Gmelina arborea</i>	54.46	52.94	NS
<i>Dalbergia sisso</i>	54.26	52.74	NS
<i>Ziziphus jujube</i>	51.31	50.69	NS
<i>Syzygium cumini</i>	54.67	53.96	NS

4.5.b. Silt

The percentage of silt has been observed higher in planted area than unplanted area in all the species. The percentage of silt was found highest in *Swietenia mahogoni* in planted area followed by *Dalbergia sisso*, *Syzygium cumini*, *Gmelina arborea* and lowest in *Ziziphus jujube*. From statistical point of view it is found non-significant in all the species. (Table 4.5.b.)

Table-4.5 b: Showing percentage of silt in different tree species

Name of species	Unplanted (%)	Planted (%)	t-test value
<i>Swietenia mahogoni</i>	24.8	25.3	NS
<i>Gmelina arborea</i>	21.4	22.8	NS
<i>Dalbergia sisso</i>	22.1	23.4	NS
<i>Ziziphus jujube</i>	22.1	22.7	NS
<i>Syzygium cumini</i>	22.7	23.3	NS

4.5.c. Clay

In case of clay percentage of the soil, it has been found higher in planted area than unplanted area as per the recorded data of the result. The percentage of clay is found higher in *Ziziphus jujube* in planted area followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni*, and minimum in *Syzygium cumini*. Statistically it has been found non-significant in all the species. (Table 4.5.c.)

Table-4.5.c.: Showing percentage of Clay in different tree species

Name of species	Unplanted (%)	Planted (%)	t-test value
<i>Swietenia mahogoni</i>	22.73	23.58	NS
<i>Gmelina arborea</i>	24.14	24.26	NS
<i>Dalbergia sisso</i>	23.64	23.86	NS
<i>Ziziphus jujube</i>	26.59	26.61	NS
<i>Syzygium cumini</i>	22.63	22.74	NS

CHEMICAL PROPERTIES OF SOIL

4.6 Soil pH

The soil pH has been found higher in planted area than unplanted area in all the species. The highest value of soil pH was found in *Dalbergia sisso* in planted area followed by *Gmelina arborea*, *Swietenia mahogoni*, *Syzygium cumini* and minimum in *Ziziphus jujube*. Statistically, it is found highly significant in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and *Swietenia mahogoni*. (Table 4.6 & Fig.1)

Table-4.6: Showing Soil pH in different tree species

Name of species	Unplanted	Planted	t-test value
<i>Swietenia mahogoni</i>	5.33	5.68	4.32**
<i>Gmelina arborea</i>	5.51	5.72	5.21**
<i>Dalbergia sisso</i>	5.85	6.07	8.45**
<i>Ziziphus jujube</i>	5.13	5.32	6.43**
<i>Syzygium cumini</i>	5.50	5.65	7.28**

$t_{(9)0.05}=2.262$

** Highly significant

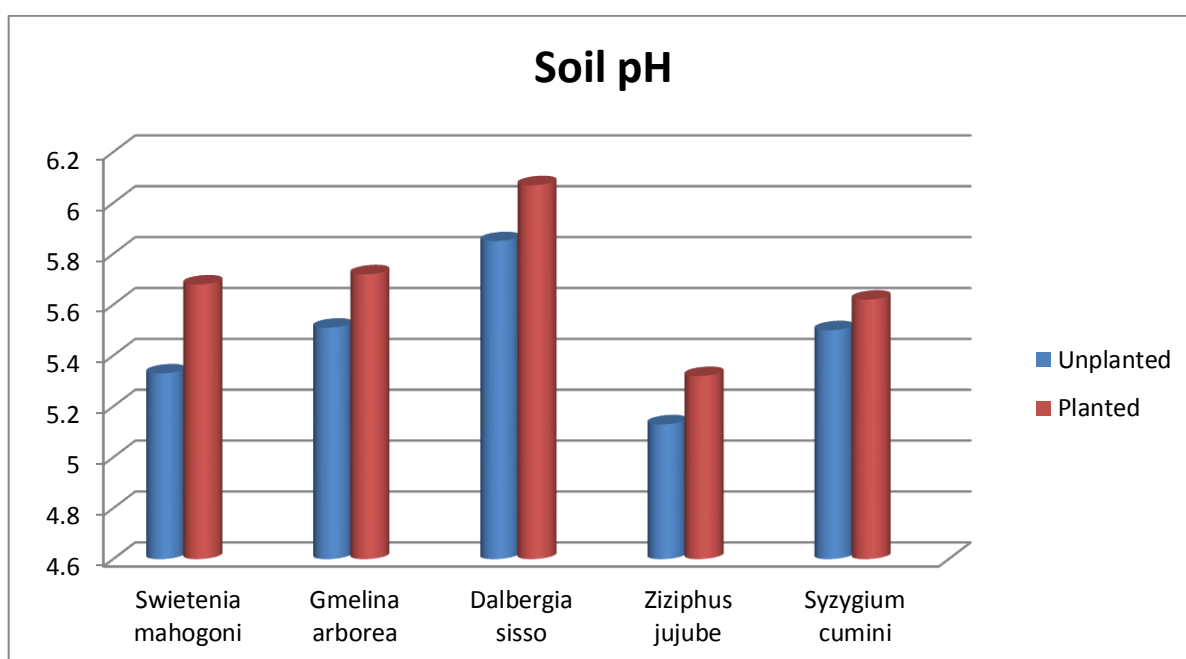


Fig-1: Showing Soil pH of different tree species

4.7 Soil Organic Carbon

The soil organic carbon has been observed higher in planted area than unplanted area in all the species. The highest value of soil organic carbon was found in *Gmelina arborea* in planted area followed by *Dalbergia sisso*, *Swietenia mahogoni*, *Syzygium cumini* and minimum in *Ziziphus jujube*. In statistical point of view it is found statistically higher in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Dalbergia sisso* and in *Ziziphus jujube*. (Table 4.7 & Fig.2)

Table-4.7: Showing Soil Organic Carbon in different tree species

Name of species	Unplanted (%)	Planted (%)	t-test value
<i>Swietenia mahogoni</i>	0.32	0.43	2.360**
<i>Gmelina arborea</i>	0.31	0.45	4.330**
<i>Dalbergia sisso</i>	0.30	0.44	2.345**
<i>Ziziphus jujube</i>	0.32	0.40	2.288**
<i>Syzygium cumini</i>	0.33	0.41	4.780**

t (9)0.05=2.262

** Highly significant

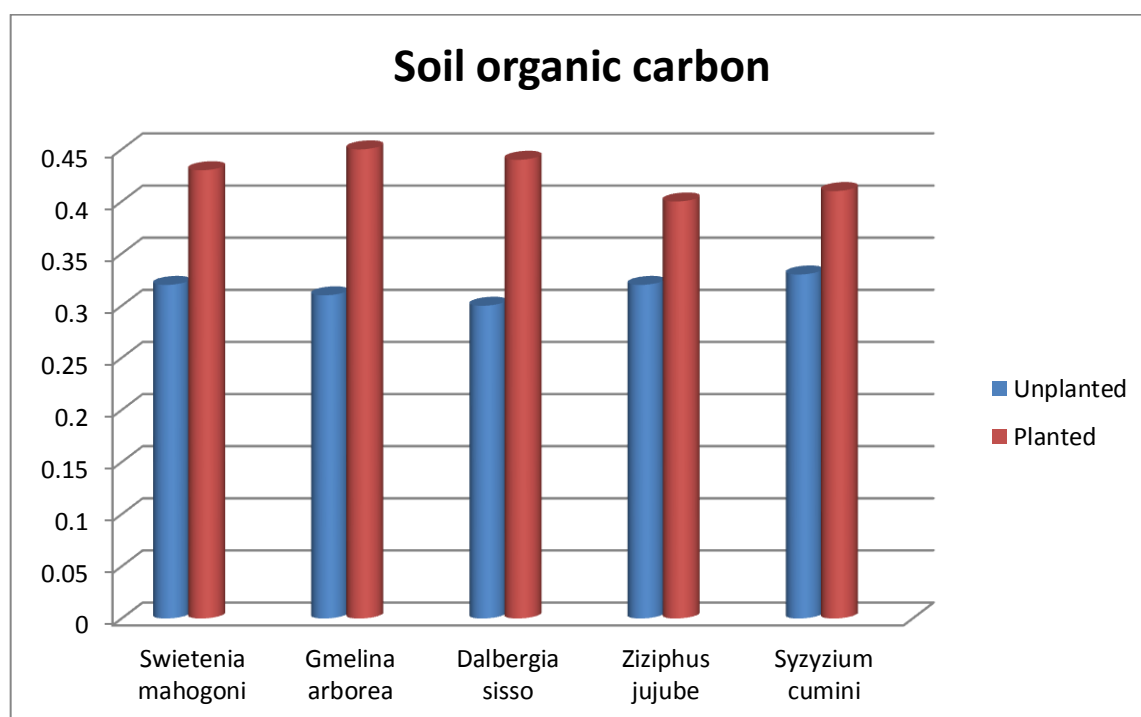


Fig-2: Showing Soil organic carbon of different tree species

4.8 Soil available Nitrogen

The soil available nitrogen has been found higher in planted area than unplanted area in all the species. The highest value of soil available nitrogen was found in *Dalbergia sisso* in planted area followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and minimum in *Swietenia mahogoni*. In statistical point of view, it is found higher in *Syzygium cumini* followed by *Gmelina arborea*, *Ziziphus jujube*, *Dalbergia sisso* and minimum in *Swietenia mahogoni*. (Table 4.8 & Fig.3)

Table-4.8: Showing soil available Nitrogen in different tree species

Name of species	Unplanted (kg/ha)	Planted (kg/ha)	t-test value
<i>Swietenia mahogoni</i>	380.82	419.54	29.72**
<i>Gmelina arborea</i>	370.58	433.2	32.69**
<i>Dalbergia sisso</i>	389.02	496.64	30.28**
<i>Ziziphus jujube</i>	393.24	436	31.54**
<i>Syzygium cumini</i>	405.64	447.06	35.32**

t (9)0.05=2.262

** Highly significant

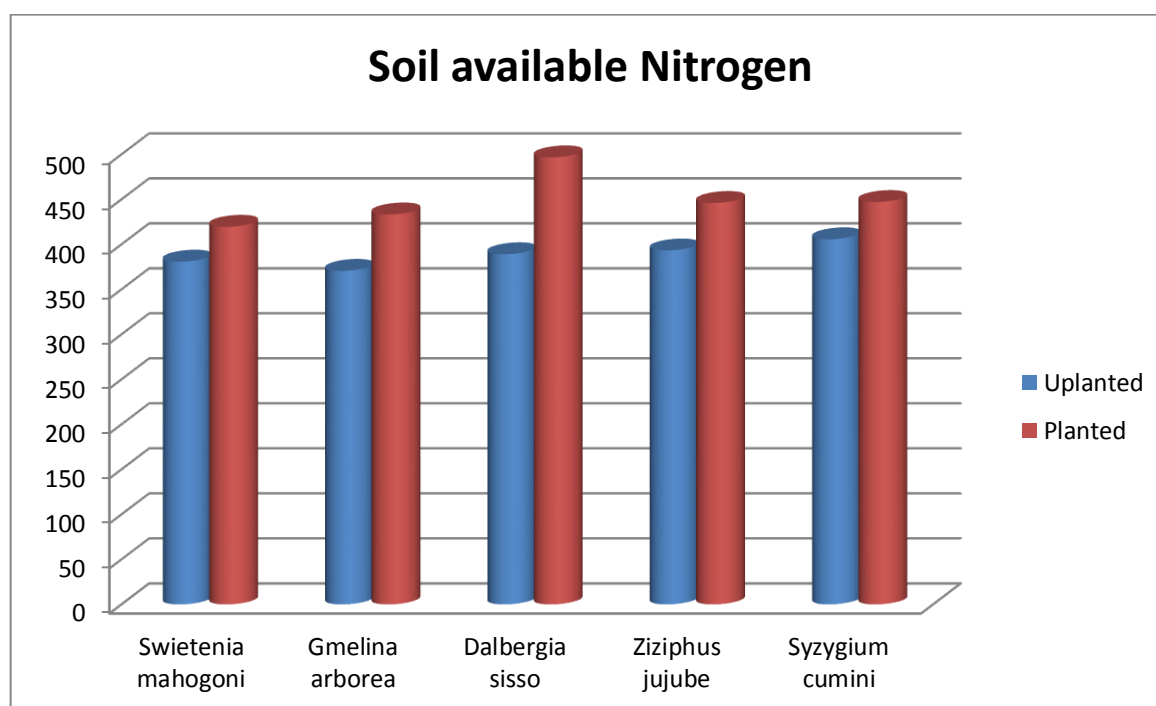


Fig-3: Showing soil available Nitrogen in different tree species

4.9 Soil available Phosphorous

The available phosphorous of soil has been found higher in unplanted area than planted area in all the species. The highest value of soil available phosphorous is found maximum in *Dalbergia sisso* in unplanted area followed by *Swietenia mahogoni*, *Ziziphus jujube*, *Gmelina arborea* and minimum in *Syzygium cumini*. From statistical point of view it was found significantly higher in *Swietenia mahogoni* followed by *Syzygium cumini*, *Dalbergia sisso*, *Gmelina arborea* and minimum in *Ziziphus jujube*. (Table 4.9 & Fig.4)

Table-4.9: Showing soil available Phosphorous in different tree species

Name of species	Unplanted (kg/ha)	Planted (kg/ha)	t-test value
<i>Swietenia mahogoni</i>	15.08	14.26	8.25**
<i>Gmelina arborea</i>	14.64	13.74	6.48**
<i>Dalbergia sisso</i>	15.22	14.04	7.65**
<i>Ziziphus jujube</i>	14.78	13.86	6.34**
<i>Syzygium cumini</i>	14.5	13.48	7.82**

t (9)0.05=2.262

** Highly significant

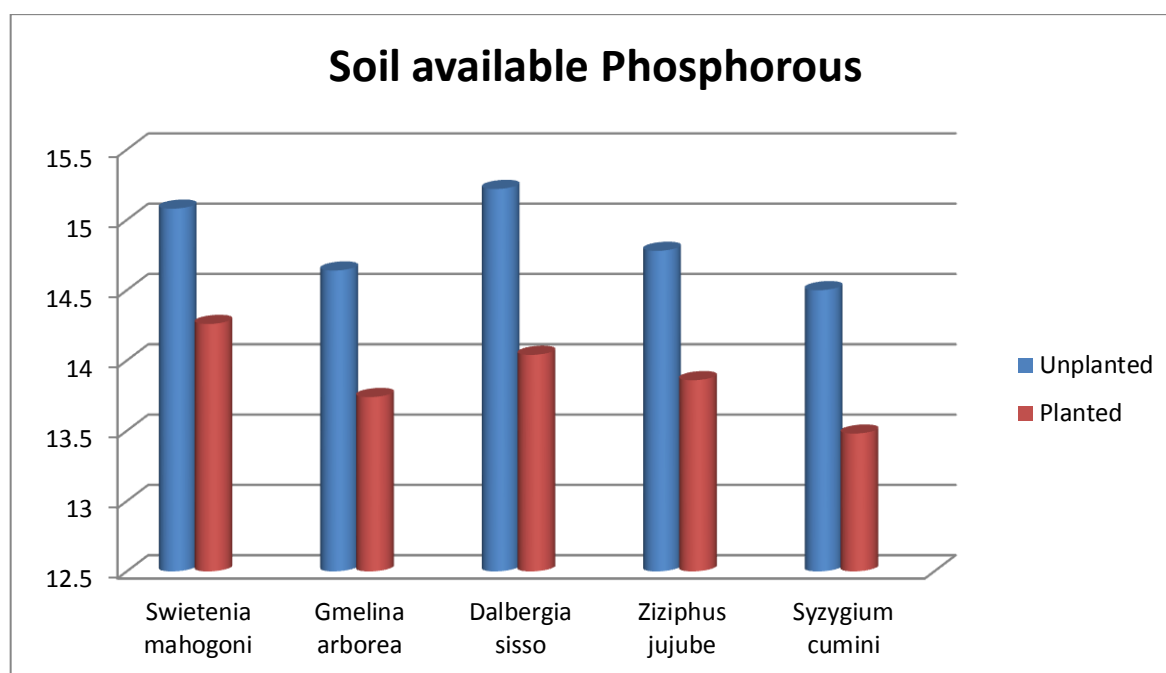


Fig-4: Showing soil available Phosphorous in different tree species

4.10 Soil available Potassium

The available potassium of soil has been found higher in planted area than unplanted area in all the species. The highest value of soil available potassium is found higher in *Swietenia mahogoni* followed by *Syzygium cumini*, *Gmelina arborea*, *Ziziphus jujube* and minimum in *Dalbergia sisso*. In statistical point of view it was found significantly higher in *Syzygium cumini* followed by *Ziziphus jujube*, *Swietenia mahogoni*, *Dalbergia sisso* and minimum in *Gmelina arborea*.(Table 4.10 & Fig.5)

Table-4.10: Showing soil available Potassium in different tree species

Name of species	Unplanted (kg/ha)	Planted (kg/ha)	t-test value
<i>Swietenia mahogoni</i>	619.92	760.62	22.54**
<i>Gmelina arborea</i>	614.07	745.50	21.35**
<i>Dalbergia sisso</i>	598.08	714.38	21.63**
<i>Ziziphus jujube</i>	626.36	723.24	23.39**
<i>Syzygium cumini</i>	638.26	751.96	25.54**

t (9)0.05=2.262

** Highly significant

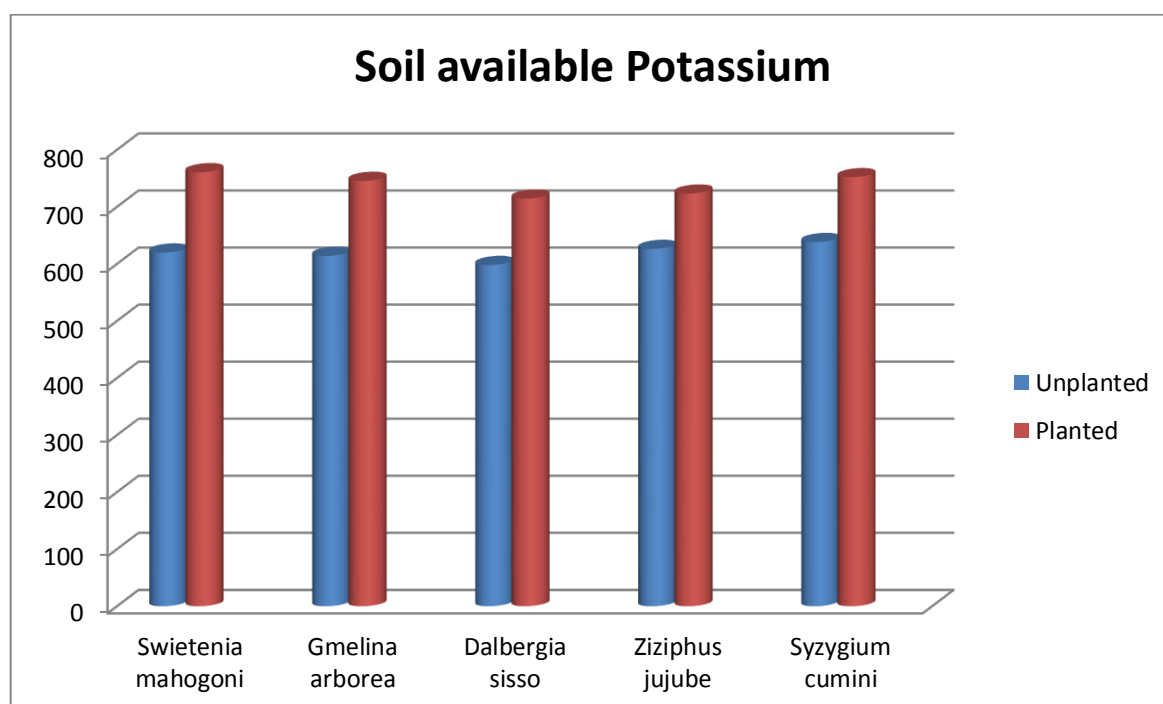


Fig-5: Showing soil available Potassium in different tree species

GROWTH DIAMETER

4.11 Diameter

The diameter in the studied species has been observed maximum in *Swietenia mahogoni* followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini* and minimum in *Ziziphus jujube*. (Table 4.11& Fig. 6)

Table-4.11: Showing Mean Diameter in different tree species

Name of species	Mean Diameter(in cm)
<i>Swietenia mahogoni</i>	13.33
<i>Gmelina arborea</i>	10.91
<i>Dalbergia sisso</i>	10.47
<i>Ziziphus jujube</i>	9.23
<i>Syzygium cumini</i>	10.12

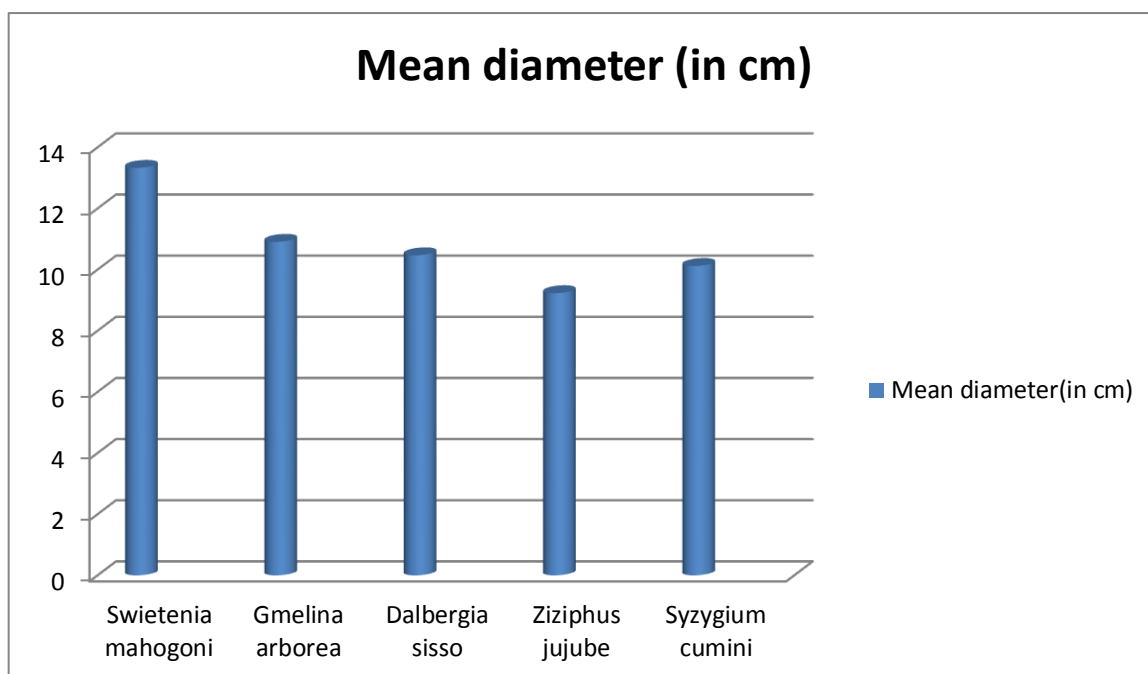


Fig-6: Showing Mean Diameter in different tree species

4.12 Height

The present experiment showed trend of height among the species as maximum in *Swietenia mahogoni* followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini* and minimum in *Ziziphus jujube*. (Table 4.12 & Fig. 7).

Table-4.12: Showing Mean Height in different tree species

Name of species	Mean Height (in m)
<i>Swietenia mahogoni</i>	10.55
<i>Gmelina arborea</i>	9.62
<i>Dalbergia sisso</i>	8.45
<i>Ziziphus jujube</i>	7.62
<i>Syzygium cumini</i>	8.39

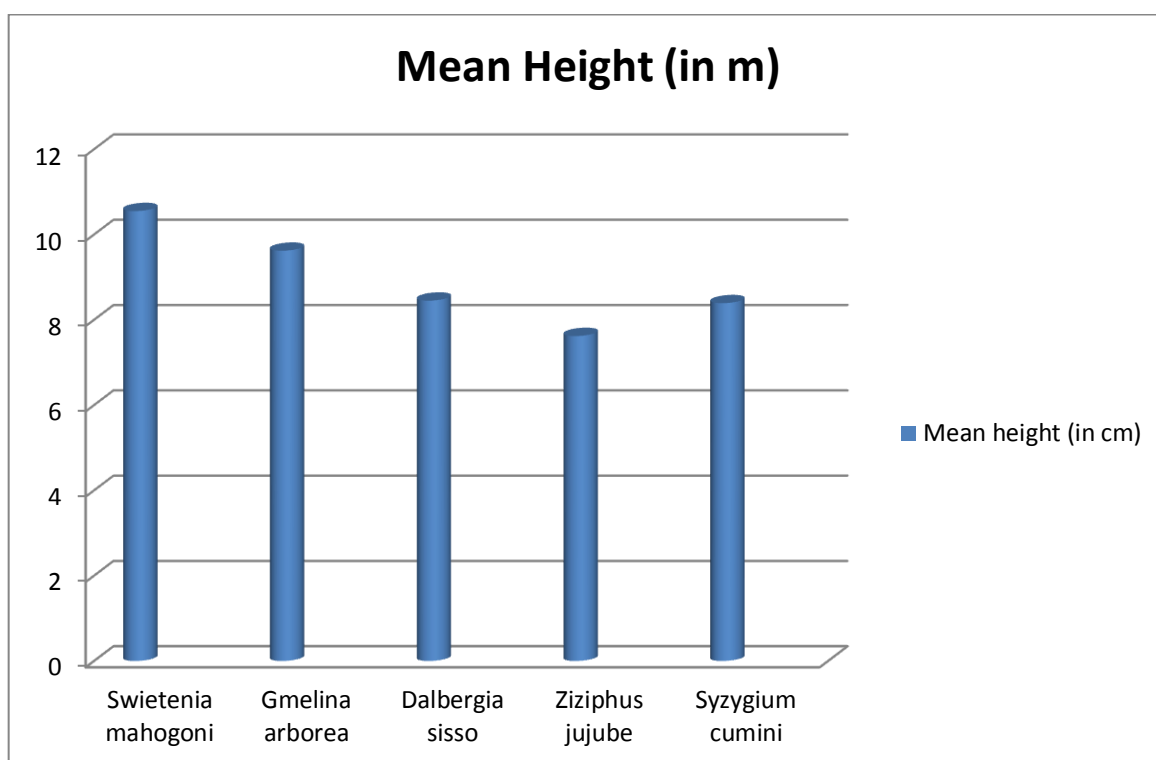


Fig-7: Showing Mean Height in different tree species

4.13 Crown Width

The crown width among the species studied has been calculated maximum in *Swietenia mahogoni* followed by *Dalbergia sisso*, *Syzygium cumini*, *Ziziphus jujube* and minimum in *Gmelina arborea*. (Table 4.13 & Fig.8)

Table-4.13: Showing Mean Crown width in different tree species

Name of species	Mean Height (in m)
<i>Swietenia mahogoni</i>	5.62
<i>Gmelina arborea</i>	3.67
<i>Dalbergia sisso</i>	5.53
<i>Ziziphus jujube</i>	4.85
<i>Syzygium cumini</i>	5.52

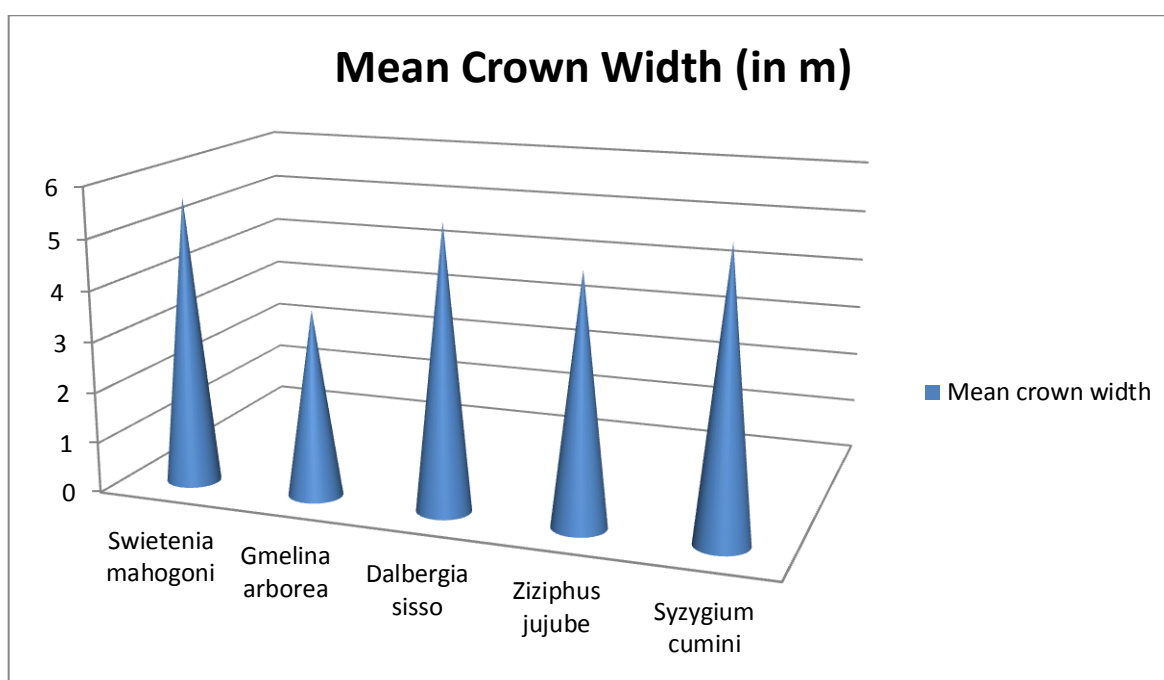


Fig-8: Showing Mean Crown Width in different tree species

4.14 Interrelationship between plant growth and soil

As far as interrelation between tree growth and soil is concerned correlation studies was made in order to find out the linear relationship. Statistically, none of them has been found significant except one which is between Water Holding Capacity and Available Nitrogen. The Degree of Freedom is 3 and, hence, high and low value has been observed significant as well as non-significant. Further, influence of Available Nitrogen shows significant relation with Water Holding Capacity having positive relationship. (Table 4.14)

Table-4.14: Correlation matrix of different physico-chemical properties of soil on growth parameters of tree species

	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂
V ₁	1.000	-0.858 ^{NS}	-0.158 ^{NS}	0.280 ^{NS}	-0.524 ^{NS}	-0.429 ^{NS}	0.010 ^{NS}	0.063 ^{NS}	-0.674 ^{NS}	-0.532 ^{NS}	-0.597 ^{NS}	-0.352 ^{NS}
V ₂	-0.858 ^{NS}	1.000	-0.103 ^{NS}	-0.352 ^{NS}	0.235 ^{NS}	-0.077 ^{NS}	0.011 ^{NS}	-0.416 ^{NS}	0.579 ^{NS}	0.882 [*]	0.169 ^{NS}	0.484 ^{NS}
V ₃	-0.158 ^{NS}	-0.103 ^{NS}	1.000	0.701 ^{NS}	0.863 ^{NS}	0.516 ^{NS}	0.790 ^{NS}	0.558 ^{NS}	-0.497 ^{NS}	-0.375 ^{NS}	0.089 ^{NS}	0.389 ^{NS}
V ₄	0.280 ^{NS}	-0.352 ^{NS}	0.701 ^{NS}	1.000	0.622 ^{NS}	0.622 ^{NS}	1.000	0.720 ^{NS}	0.892 [*]	0.002 ^{NS}	-0.849 ^{NS}	0.217 ^{NS}
V ₅	-0.524 ^{NS}	0.235 ^{NS}	0.863 ^{NS}	0.622 ^{NS}	1.000	0.700 ^{NS}	0.720 ^{NS}	0.558 ^{NS}	-0.497 ^{NS}	-0.375 ^{NS}	0.089 ^{NS}	0.389 ^{NS}
V ₆	-0.429 ^{NS}	-0.077 ^{NS}	0.516 ^{NS}	0.251 ^{NS}	0.700 ^{NS}	1.000	0.700 ^{NS}	0.516 ^{NS}	-0.103 ^{NS}	0.235 ^{NS}	-0.103 ^{NS}	0.235 ^{NS}
V ₇	0.010 ^{NS}	0.011 ^{NS}	0.790 ^{NS}	0.892 [*]	0.720 ^{NS}	0.105 ^{NS}	1.000	0.105 ^{NS}	-0.011 ^{NS}	0.004 ^{NS}	-0.462 ^{NS}	0.300 ^{NS}
V ₈	0.063 ^{NS}	-0.416 ^{NS}	0.558 ^{NS}	0.002 ^{NS}	0.242 ^{NS}	0.435 ^{NS}	0.105 ^{NS}	0.435 ^{NS}	0.011 ^{NS}	-0.011 ^{NS}	0.012 ^{NS}	0.332 ^{NS}
V ₉	-0.674 ^{NS}	0.579 ^{NS}	-0.497 ^{NS}	-0.849 ^{NS}	-0.195 ^{NS}	0.186 ^{NS}	1.000	-0.065 ^{NS}	1.000	0.379 ^{NS}	1.000	0.332 ^{NS}
V ₁₀	-0.532 ^{NS}	0.882 [*]	-0.375 ^{NS}	-0.304 ^{NS}	-0.075 ^{NS}	-0.455 ^{NS}	0.004 ^{NS}	-0.740 ^{NS}	0.379 ^{NS}	1.000	1.000	0.332 ^{NS}
V ₁₁	-0.597 ^{NS}	0.169 ^{NS}	0.089 ^{NS}	-0.437 ^{NS}	0.267 ^{NS}	0.751 ^{NS}	-0.462 ^{NS}	0.501 ^{NS}	0.718 ^{NS}	-0.244 ^{NS}	1.000	-0.066 ^{NS}
V ₁₂	-0.352 ^{NS}	0.484 ^{NS}	0.389 ^{NS}	-0.126 ^{NS}	0.217 ^{NS}	-0.288 ^{NS}	0.300 ^{NS}	0.310 ^{NS}	0.012 ^{NS}	0.332 ^{NS}	-0.066 ^{NS}	1.000

Where V₁ – Bulk density of soil, V₂ – Particle density of soil, V₃ – Soil porosity, V₄ – Water holding capacity of soil, V₅ – Soil pH, V₆ – Soil organic carbon %, V₇ – Available nitrogen in soil, V₈ – Available phosphorus in soil, V₉ – Available potassium in soil, V₁₀ – DBH of tree species, V₁₁ – Crown width of tree species, V₁₂ – Plant height of tree species

As per the findings found in the result on the basis of the data and statistical analysis, the present investigation may be interpreted and discussed as follows in different heads :-

PHYSICAL PROPERTIES OF SOIL:-

5.1. BULK DENSITY

According to the result found in the present experiment, the bulk density of soil has been observed higher in unplanted area than planted area. Further, the difference between unplanted and planted areas has been found significantly higher in *Gmelina arborea*, *Syzygium cumini*, *Swietenia mahogoni*, *Ziziphus jujube* and non significant in *Dalbergia sisso*.

Almost similar result has been recorded by Birua, B. (2014) in all the species who worked on physicochemical studies of soil in arboretum taking into account the species like in *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblia officianalis* and *Pongamia pinnata*. The findings reported by Zhang *et.al.* (2012) has similarity with the present findings who studied on the effects of afforestation with *Eucalyptus grandis* on soil physicochemical as well as microbiological properties planted by *Eucalyptus grandis* (1-10 years of age) in South-Western China to find out soil fertility.

Singh *et.al.* (2011) who investigated on ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Alluvial Plains of India comparing the impact of 10 years old plantation of 10 multipurpose tree species and reported significant reduction in density, which is at par with the present findings.

The findings of Alemie (2009) is almost alike with the present investigation who studied the effect of eucalyptus on crop production and soil properties in the Koga

watershed, Western Amahara region in Ethiopia and had reported that there were no pronounced changes in soil bulk density.

The findings of bulk density in the present studies is similar to the investigation of Hosur & Dasog(1995) who observed effect of tree species like teak, sheesham and khair on soil properties in decreased status in case of trees.

An investigation was made by Mishra & Nanda (1985) worked on water holding capacity on soil texture pointed out that bulk density influences significantly water holding capacity of a soil texture,; whereas the present experiment depicts decreased bulk density in the planted area and increased status of water holding capacity.

1.2 PARTICLE DENSITY

The recorded data of the present experiment showed that particle density of soil is higher in planted area than unplanted area.

Birua, B.(2014) who has studied on the tree species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata* in arboretum and has reported the particle density found to be higher in planted area than unplanted area; which has the similarity of the present findings. Jordan *et.al.* (2003) has observed soil particle density significantly decreased the seedling height and dry matter production because soil particle significantly affected microbial activity by reducing acid phosphates and nitrogen fertilizer uptake.

5.3 SOIL POROSITY

Soil porosity, in the present studies, has been found higher in planted area than unplanted area which is at par with the findings of Birua, B. (2014) as well as Singh *et.al.* (2012); who studied to find out tree-soil interaction in the arboretum consisting five species such as *Euaclyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica*

officinalis and *Pongamia pinnata* and, on ameliorative effect of multipurpose tree species grown on sodic soil of Indo-Gangetic Alluvial Plains of India respectively.

Woodward (1996) worked to investigate the effects of soil compaction and top soil removal of soil physical and chemical properties who observed significant decrease in total porosity. He also pointed out that both compaction and top soil removal resulted decrease in micro porosity of the sub soil and reduced water availability as per the experimental data recorded.

5.4 WATER HOLDING CAPACITY

The result obtained in the present investigation, it has been found that the water holding capacity of soil is higher in planted area than unplanted area. Birua, B. (2014) who has studied on tree-soil interaction in different species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Embllica officianalis* and *Pongamia pinnata* in Arboretum and has reported the similar result as found in the present investigation.

Almost similar result has been reported by Zhang *et.al.*(2012) who studied on effects of afforestation with *Eucalyptus grandis* on the soil in Southwestern China to determine its affect on the soil fertility of agricultural land and observed that water holding capacity in such area increased significantly.

Alemie (2009), working on the effect of eucalyptus on crop production and soil properties in Koga watershed of Ethiopia, has reported significant affect on water holding capacity in the undergrowth region. Alavi (2002) studied relationship between tree growth and water availability Norway spruce stand during 22 years period of a forest in Southern Sweden. He has suggested that short age of soil water has strong effect on tree growth in an area of Southern Sweden with the high precipitation in general.

The result of the present studies indicated that water holding capacity increased in the planted area; whereas Mishra & Nanda (1985), who worked the available water

holding capacity of the soil textural classes, have observed that water holding capacity is influenced by bulk density, texture and organic matter.

5.5 SOIL TEXTURE

In the present experiment, the percentage of sand has been found higher in unplanted area than planted area in all the species; while the percentage of silt and clay has been found higher in planted area than unplanted area in all the species.

The result of Birua, B. (2014) also showed almost alike result except certain species like *Pongamia pinnata* & *Eucalyptus tereticornis*, *Embluca officianalis* & *Pongamia pinnata*, and *Euclyptus tereticornis* in cases of percentage of sand, silt and clay respectively who has studied on tree-soil interaction in arboretum taking the experimental trees such as *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Embluca officianalis* and *Pongamia pinnata*.

Alemie (2009) has also found almost similar result in his experiment working on the effect of eucalyptus on crop production and soil properties in the Koga watershed, Ethiopia stating that there was no pronounced change in soil texture due to eucalyptus of his experimental area.

In the studies of the present investigation, the result indicated that there is increase of particle density, soil porosity, and water holding capacity in planted area; while it is decreased in case of bulk density. Such finding is almost at par with the findings of Mishra & Nanda (1985) who have worked on available water holding capacity of three soil textured classes from sand to clay pointing out that bulk density influenced significantly water holding capacity of the soil texture.

CHEMICAL PROPERTIES OF SOIL:-

5.6 SOIL pH

The pH in the present studies has been found higher in planted area than unplanted area in all the species. The difference between planted and unplanted areas has been depicted significantly higher in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea*, *Swietenia mahogoni*. The result is comparable with the findings of Birua, B. (2014) who worked on tree- soil interaction in arboretum focusing the trees like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Embllica officianalis* and *Pongamia pinnata*. The similar result has also found by Singh *et.al.* (2011) who studied on ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Alluvial Plains of India comparing the impact of 10 years old plantation of 10 multipurpose tree species observing significant improvement in soil pH under planted areas.

The investigation of Alemie (2009) concerning effects of eucalyptus on crop production and soil properties in Koga watershed, Western Amahara region in Ethiopia and found that there was no pronounced change in soil pH due to growing eucalyptus as hedgegrow in farmland. The report is almost alike with the present result.

Prevost *et.al.* (1999) in their experiment in Peatland of Eastern Quebeck, Canada reported that nutrient content of peat soil water was enhanced by drainage which showed pH increase of one unit, a result attributed to increased runoff from the upland part of the treated watershed.

Binkley & Giardina (1998) who conducted the experiment on plant soil interactions and reported that plant species have significant impacts on soil physicochemical properties including pH. Such result is in accordance with the finding of the present studies; whereas Hosur & Dasog (1995) who studied on the effect of tree

species on soil properties in red loam soil and found decreased pH in the planted area of teak, sheesham and khair.

An experiment was conducted by Sharma *et.al.* (1985) on soil properties of *Alnus nepalensis* from 7-56 years old tree species in the Eastern Himalayas. They reported that soil pH increased slowly in the surface soil, which is alike with the present investigation.

5.7 SOIL ORGANIC CARBON

In case of soil organic carbon, the result of the present investigation has shown that it is higher in planted area than unplanted area in all the species. The result has similar resemblance with the finding of Birua, B.(2014) who has studied on tree-soil interaction in the arboretum taking into account five tree species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata*. the findings of the present studies has also alike characteristic with the result of Singh *et.al.*(2011) who investigated ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Alluvial Plains of India reporting that significant improvement in organic carbon has come under tree plantation than natural fallow. Watanbe *et.al.*(2010) have done experiment on teak plantation and observed that site factors influence organic carbon with significant correlation.

Tomar *et.al.* (2003) studied on a field trial with tree species over 9 years period on a calcareous soil in a semi arid part of North west India and reported the soil to be enriched with organic carbon (> 0.4% in upper 30 cm) under the promising tree species which are in order of persistence and performance like *Tamarix articulata*, *Acacia nilotica*, *Prosopis juliflora*, *Eucalyptus tereticonis*, *Acacia tortilis*, *Cassia seamiea*, *Melia azadirachta* and *Acacia farnesiana*. The finding found in the tree species like *Acacia auriculiformis*, *Albezia lebeck*, *Bauhinia variegata*, *Cassia glauca*, *Syzygium*

cumini, *Crescentia alata*, *Samanea saman* and *Terminalia arjuna*; is comparable with the finding of the present studies.

The experiment conducted by Binkley & Giardana (1998) on plant soil interaction point out that plant species have significant impact on quality in respect to carbon concentration; shows almost similar to the present finding. The result of the present studies is also almost at par with the findings of Coote & Ramasay (1983); Sharma *et.al.*(1995); and Lav Bhushan (1998) who have reported that the high value of organic carbon content in the soil is caused to the lower bulk density in the soil, and the higher soil organic carbon value in upper layers of the soil profile then the other profiles may have resulted from the dilution of soil matrix with lesser denser material and amelioration in soil aggregation as well as improvement in aggregation encourages a fluffy and porous condition in soil due to increase in soil organic carbon.

5.8 SOIL AVAILABLE NITROGEN

The available nitrogen in the soil has been found higher in planted area than unplanted area in on the species as per the data recorded in the present investigation. Birua, B.(2014) who has carried out work on tree-soil interaction in the arboretum taking into a account five tree species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Embluca officianalis* and *Pongamia pinnata*, has also reported the similar finding in his result. Again Singh *et.al.*(2011), who worked on ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Alluvial Plains of India comparing impact of 10 years old plantation of 10 multipurpose tree species, have also reported alike finding with the present experiment stating that significant improvement has been found in available nitrogen under tree plantation and hence it is similar with the present result. Watanabe *et.al.*(2010) who made an investigation on teak plantation and found significant correlation with site factors influencing available nitrogen.

Acomparable result has been reported by Swami *et.al.*(2004) investigated on chronosequence of *Gmelina arborea* varying from 1-6 years old plant and reported that available nitrogen in the soil and significantly ameliorated due to plantation.

The finding of Binkley & Giardiana(1998) has similarity with the finding of the present experiment who conducted studies on plant soil interaction concluding that plant species showed significant impact on soil quality in case nitrogen concentration. An experiment related with top soil chemical properties in an Agroforestry systems in the Philippines was conducted choosing three multipurpose tree legumes (*Gliricidia sepium*, *Acacia auriculiformis*, and *A. mangium*) intercropped with upland rice and mung bean (*Vigna radiate*) with the finding of positive variation in Agroforestry and monoculture tree treatments showing increase in total nitrogen by 11.6% while soil chemical properties did not show much variation across or alone the tree rows(Anon,1997). Woodward (1996) studied on soil compaction and top soil remover effect on soil properties and seedling growth in Amazonial Ecuador with the result showing significant decrease in nitrogen content in the soil. Likewise Naraian & Singh (1985) worked on nitrogen status of three kinds of forest soils under sal forest, Eucalyptus coppice regrowth, and mixed brushwood at Selaqui, Dehradun observing higher nitrate concentration in top 20 cm soil.

Hosur & Dasog (1995) conducted an experiment on effect of tree species on soil properties in red loam soil observing the result showing that nutrient status was followed the sequential order $K > N$ which indicates almost similar result with the present experiment planted in sandy loam soil especially in potassium and nitrogen property.

5.9 SOIL AVAILABLE PHOSPHOROUS

The available Phosphorous (P), on contrast has been found higher in unplanted area than planted area in all the species. Birua,B.(2014) who has worked on different

who has studied on tree-soil interaction in the arboretum taking into account five tree species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata* which is almost comparable with the result of present studies.

Singh *et.al.*(2011) has conducted an experiment on ameliorative effect of multipurpose tree species grown on sodic soils of Indo-Gangetic Alluvial Plains of India compared impact of 10 years old plantation of 10 multipurpose tree species like *Terminalia arjuna*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Prosopis alba*, *Acacia nilotica*, *Eucalyptus tereticornis*, *Pithecellobium dulce*, and *Cassia siamea* and found significant in available Phosphorous under tree plantation than natural fallow. The finding is similar with the present studies.

Alemie (2009) made investigation on effect of Eucalyptus on crop production and soil properties in Koga watershed and Western Amahara region in Ethiopia and reported that there is significant effect of available Phosphorous in underground which is alike with the present result.

A studies on choronosequence of *Gmelina arborea* stand aging from 1-6 years was conducted by Swami *et.al.*(2004) and found that Phosphorous in the soil improved significantly after plantation. Such result is comparable with the present studies. Binkley & Giardiana (1998) in their studies on plant soil interaction reported that plant species have significant impact on soil quality for Phosphorous concentration. Woodward (1996) who conducted an experiment on soil compaction and top soil removal effect on soil properties and seedling growth in Amazonian Ecuador and reported significant decrease in Phosphorous in the soil; which is similar to the result found in present studies.

5.10 SOIL AVAILABLE POTASSIUM

The available Potassium of soil in present studies has been found higher in planted area than unplanted area in all the species. Similar findings has been reported by Birua,B.(2014) who has studies on tree soil interaction on the species *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata*; and the experiment done by Singh *et.al.*(2011) has also the resemblance in his finding with the present investigation who conducted to find out ameliorative effect of 10 years old multipurpose tree species grown on sodic soil of Indo-Gangetic Alluvial Plains of India indicating significant improvement in available Potassium under tree plantation.

Swami *et.al.*(2004) studied on choronosequence of *Gmelina arborea* stand from 1-6 years old plants and observe that available soil Potassium improved significantly after plantation which is comparable with the present finding.

According to Sharma *et.al.*(1985) who investigated on soil properties of *Alnus nepalensis* in the trees aging from 7-56 years old in Eastern Himalayas and reported that its exchangeable Potassium showed decreasing tendency with the soil depth particularly in older tree stands as well as low consistent relationship between exchangeable Potassium/ Calcium content and stand age was observed.

II. TREE GROWTH PARAMETERS

5.11 TREE DIAMETER

In the present investigation, the trend of diameter in the species has been found maximum in *Swetenia mahogoni* followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzugium cumini* and minimum in *Ziziphus jujube*.

Chima *et.al.*(2016) studied to evaluate soil properties determining tree growth influencing exotic and indigenous species like *Gmelina arborea*, *Nauclea didrerrichii* and *Khaya grandifoliola* in a 4 year old arboretum. The found significant variation in

diameter at breast height between *Gmelina arborea* and the indigenous species but no significant difference between *Tectona grandis* and indigenous species.

The result of Birua, B.(2014) who has studied to investigate tree-soil interaction in the species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata* and reported the maximum diameter in *Eucalyptus tereticornis* (the only fast growing species); which is comparable with the present investigation in which the maximum diameter has been found in *Swietenia mahogany* (the only fast growing species). Likewise, the finding of the present investigation has resemblance with the finding of Swami *et.al.*(2003) who studied on chronosequence of *Gmelina arborea* (1-6 years old) to find out growth parameter in accordance with the site quality.

The experiment done by Tomar *et.al.*(2002) indicated that the girth of the tree species in the term of diameter at breast height was found equivalent to the gain in their height in 9 years old plantation. The result of the present investigation depicts the similar finding showing maximum diameter in fast growing *Swietenia mahogoni* species than the others.

5.12 TREE GROWTH

The trend of height, in the present investigation, among the species has been observed maximum in *Swietenia mahogoni* followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini* and minimum in *Ziziphus jujube*.

Chima *et.al.*(2016) who worked to evaluate soil properties determining tree growth influencing exotic species and indigenous species like *Gmelina arborea*, *Nauclea didrerrichii* and *Khaya grandifoliola* and reported that height varied significantly between exotic and indigenous species.

Birua, B.(2014) who conducted experiment on tree soil interaction in 7 years old arboretum tree species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Emblica officianalis* and *Pongamia pinnata* and found maximum in *Eucalyptus tereticornis*(the only fast growing species) which is comparable with the present result showing maximum height in mahogany which is also the only fast growing species in the experiment.

Swamy *et.al.* (2004) conducted an experiment on chrono sequence of *Gmelina arborea* stands ranging from 1-6 years old plantation to find out changes in growth, biomass and nutrient(N, P & K) contents for three red laterictic soil in Chattisgarh, India observing that the height significantly varies as per the site quality. Further, Swamy *et.al.* (2003) also studied on growth, biomass, carbon storage and nutrient distribution in *Gmelina arborea* stands on red laterite soil in Central India with the conclusion that the growth parameter like height varies significantly on the basis of age and site quality.

Woodward (1996) conducted the experiment to find out the effects of soil compaction and top soil removal on soil physical and chemical properties, and growth of planted trees on an oil extraction project in tropical moist forest on a typic Paleudult in Amazonian Ecuador. He has pointed out that height growth reduced in all the species and prominently in compacted sub soil with top soil removal in comparison with the undisturbed soil.

Troup (1986) as reported that *Eucalyptus tereticornis* which is comparatively fast growing exotic tree species than other species, as shown maximum height. It is comparably with the present studies as the finding of the present result shows that mahogany which is comparative fast growing species in experiment, has obtained maximum height.

5.13 TREE CROWN WIDTH

The present experiment has indicated maximum crown width in *Swietenia mahagoni* followed by *Dalbergia sissoo*, *Syzygium cumini*, *Ziziphus jujube* and minimum *Gmelina arborea*.

Chima et.al (2016) who worked to evaluate soil properties determining tree growth influencing exotic and indigenous species like *Gmelina arborea*, *Nauclea didrerrichii* and *Khaya grandifoliola* and pointed out that *Nauclea didrerrichii* attained maximum crown diameter but did not vary significantly with that of the exotic species while, it varies significantly *Khaya grandifoliola*. Birua, B. (2014) who has conducted experiment in arboretum in tree-soil interaction in the species like *Eucalyptus tereticornis*, *Tectona grandis*, *Acacia catechu*, *Embllica officianalis* and *Pongamia pinnata* getting maximum crown width in *Pongamia pinata* followed by *Eucalyptus tereticornis*, *Tectona grandis*, *Embllica officianalis*, *Acacia catechu*.

In their experiment, Fife & Nambiar (1997) following the response of *Pinus radiate* trees to nitrogen nutrification in the growing stands from the canopy closure to first thinning stage for the purpose of studying the nature and the longevity of the growth respond to applied nitrogen. On the basis of their observation, they reported that the size of the needles were elongating when nitrogen was applied increased with an increase in foliar nitrogen, and it was found that there was a significant correlation between nitrogen and chlorophyll concentration. However, elevated foliar nitrogen concentration and greater increment in stand growth continued for further two years leading to an increase in basal area over the five years interval from nitrogen application of upto 45 % above the control. It was also reported that nitrogen application increased productivity in the initial stage by increasing photosynthetic efficiency of the foliage, and later on it is enhance through increased foliage production in the plant.

As per statistical correlation analysis between parameters of tree growth and soil, the linear relationship shows that none of them is significant except between Water Holding Capacity and Available Nitrogen expressing significant positive influence/relationship.

The present experiment has been carried out to investigate growth of the tree raised in arboretum which are 11 years old namely Mahogany (*Swietenia mahogoni*), Sheesham (*Dalbergia sisso*), Gamhar (*Gmelina arborea*), Jamun (*Syzygium cumini*) and Ber (*Ziziphus jujube*) as well as underneath soil characteristics to find out influences on the growth of the planted tree species by soil.

The soil of the experimental area is sandy-loam in nature. The effects on physical properties of soil like Bulk Density, Water Holding Capacity and Soil Texture. The effects on chemical properties like Soil pH, Soil Organic Carbon, Available Nitrogen, Available Phosphorous and Available Potassium have been growth studies to carried out the correlation between soil properties. The findings of the result has been summarized and concluded as follows:-

SUMMARY

Physical properties of soil

The Bulk Density has been found higher in unplanted area than planted area; while Particle Density, Porosity and Water Holding Capacity are higher in planted area than unplanted area. The sand percentage has been found higher in unplanted area than planted area in all the species. The clay percentage has been found higher in planted area than unplanted area; whereas silt percentage showed the same result. Hence, it appears the physical properties of soil in planted area show important.

Maximally Bulk Density was found in *Ziziphus jujube* followed by *Gmelina arborea*, *Syzygium cumini*, *Dalbergia sisso*, and minimally in *Swietenia mahogoni*. The highest value of particle density has been found in *Syzygium cumini* followed by *Swietenia mahogoni*, *Dalbergia sisso*, *Gmelina arborea* and minimum in *Ziziphus*

jujube. The maximum value of soil porosity has been found in *Dalbergia sisso* followed by *Swietenia mahogoni*, *Gmelina arborea*, *Syzygium cumini*, and minimum in *Ziziphus jujube*. Water holding capacity has been found maximum in *Dalbergia sisso* followed by *Gmelina arborea*, *Ziziphus jujube*, *Syzygium cumini*, and minimum in *Swietenia mahogoni*; while maximum value of percentage of sand has been observed in *Syzygium cumini* followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni* and minimum in *Ziziphus jujube*. The maximum value of percentage of silt has been recorded in *Swietenia mahogoni* followed by *Dalbergia sisso*, *Syzygium cumini*, *Gmelina arborea*, and minimum in *Ziziphus jujube*. The maximum value of percentage of clay has been found in *Ziziphus jujube* followed by *Gmelina arborea*, *Dalbergia sisso*, *Swietenia mahogoni*, and minimum in *Syzygium cumini*.

The Bulk Density has been recorded significantly higher in *Gmelina arborea* followed by *Syzygium cumini*, *Swietenia mahogoni*, *Ziziphus jujube* and it was non-significant in *Dalbergia sisso*; whereas Particle Density has been found significantly higher in *Syzygium cumini* followed by *Swietenia mahogoni*, and *Dalbergia sisso*, *Gmelina arborea* and it was non-significant in *Ziziphus jujube*. The soil porosity has been found significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Ziziphus jujube* and *Dalbergia sisso*. The water holding capacity has been found significantly higher in *Gmelina arborea* followed by *Dalbergia sisso*, *Ziziphus jujube*, *Syzygium cumini* and *Swietenia mahogoni*. As per data recorded, percentage of sand, silt and clay has been found non-significant.

Chemical properties of soil

In case of chemical properties; the Soil pH, Organic Carbon (OC), soil available Nitrogen (N), and soil available Potassium (K) had increased value in planted area than unplanted area in all the species; whereas soil available phosphorous (P) showed higher

value in unplanted area than planted areas in all the species. The detailed results may be summarized as follows:-

The maximum value of Soil pH has been recorded in *Dalbergia sisso* followed by *Gmelina arborea*, *Swietenia mahogoni*, *Syzygium cumini*, minimum in *Ziziphus jujube*. As far as organic carbon is concerned, it has been observed maximum in *Gmelina arborea* followed by *Dalbergia sisso*, *Swietenia mahogoni*, *Syzygium cumini*, and minimum in *Ziziphus jujube*. The Available nitrogen showed maximum value in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and minimum in *Swietenia mahogoni*; whereas the maximum value of Available potassium (K) has been observed in *Swietenia mahogoni* followed by *Syzygium cumini*, *Gmelina arborea*, *Ziziphus jujube*, and minimum in *Dalbergia sisso*; while in case of available phosphorous (P) has been found higher in unplanted area than planted area in all the species. Besides it, may also be noted that the result showed that nutrient content in all the species of planted area followed in increasing order showing the sequence as $K > N > P$.

In accordance with statistical analysis between unplanted and planted area, the Soil pH has been found significantly higher in *Dalbergia sisso* followed by *Syzygium cumini*, *Ziziphus jujube*, *Gmelina arborea* and *Swietenia mahogoni* ; whereas the soil organic carbon showed significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Swietenia mahogoni* *Dalbergia sisso*, and *Ziziphus jujube*. The available nitrogen has been observed significantly higher in *Syzygium cumini* followed by *Gmelina arborea*, *Ziziphus jujube*, *Dalbergia sisso* and *Swietenia mahogoni* ; whereas the available phosphorous has been found significantly higher in *Swietenia mahogoni* followed by *Syzygium cumini*, *Dalbergia sisso*, *Gmelina arborea* and *Ziziphus jujube*; while in case of Available potassium, it has been observed significantly higher in

Syzygium cumini followed by *Ziziphus jujube*, *Swietenia mahogoni*, *Dalbergia sisso*, and *Gmelina arborea*.

Growth parameter

Both height and diameter have been recorded maximum in *Swietenia mahogoni*, followed by *Gmelina arborea*, *Dalbergia sisso*, *Syzygium cumini*, and minimum in *Ziziphus jujube*. It may be assumed that *Swietenia mahogoni*, which is comparatively fast growing species, has attained maximum height and diameter than other species. The trend of crown width among the species has been observed maximum in *Swietenia mahogoni* followed by *Dalbergia sisso*, *Syzygium cumini*, *Ziziphus jujube*, and minimum in *Gmelina arborea*.

In case of interactions between tree growth and soil; the data of their parameters in correlation studies shows significant finding only between Water Holding Capacity and Nitrogen which indicates that influence of nitrogen has positive relationship with Water Holding Capacity.

Conclusion

1. The physical properties of soil were found to improve in planted area than that of unplanted area.
2. The chemical properties of soil like pH, Organic carbon, soil available Nitrogen, and soil available Potassium were found significantly higher in planted area compared to unplanted area.
3. In case of soil available phosphorous, the reverse trend was found, higher in unplanted area in comparison to planted area.
4. In all the species of planted area, the soil available major nutrients status were found in order of : Potassium > Nitrogen > Phosphorous

5. It appears from the result that the soil pH has an increasing tendency in the plantation area which is indicative of better tree growth.
6. Tree height, diameter and crown width have been found maximum in *Swietenia mahogoni* as compared to other species.

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