ASSESSMENT OF TREE PRODUCTIVITY, PHYSICO-CHEMICAL PROPERTIES AND MICROFLORA OF SOIL UNDER *Hardwickia binata* Roxb.

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
FORESTRY
(SILVICULTURE AND AGROFORESTRY)
(AGROFORESTRY)

By

JAGTAP DEEPAK SURESH

DEPARTMENT OF FORESTRY
POST GRADUATE INSTITUTE, AKOLA

DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
KRISHINAGAR PO, AKOLA (MS) 444 104

Enrollment Number – PP-281 **2023**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation in the thesis entitled **"ASSESSMENT OF TREE PRODUCTIVITY, PHYSICO-CHEMICAL PROPERTIES AND MICROFLORA OF SOIL UNDER *Hardwickia binata* Roxb."** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola **(Jagtap Deepak Suresh)**

Date: / /2023 Enrolment No. PP-281

CERTIFICATE

This is to certify that thesis entitled **"ASSESSMENT OF TREE PRODUCTIVITY, PHYSICO-CHEMICAL PROPERTIES AND MICROFLORA OF SOIL UNDER *Hardwickia binata* Roxb."** submitted in partial fulfilment of the requirement for the degree of **Master of Science in Forestry (Silviculture and Agroforestry)** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **JAGTAP DEEPAK SURESH** under my guidance and supervision.

The subject of the thesis has been approved by the student's Advisory Committee.

Place : Akola
Date : / /2023

Shri. S. W. Choudhari
Chairman
Advisory Committee

Countersigned

Associate Dean
Post Graduate Institute
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

1.	Chairman	Shri. S. W. Choudhari	____________________
2.	Member	Dr. V. P. Mane	____________________
3.	Member	Dr. N. M. Konde	____________________
4.	Member	Dr. S. T. Ingle	____________________
5.	External Member	( )	____________________

ACKNOWLEDGEMENT

Traditional and formal words of acknowledgement will not project the picture of volcano of felling while expressing deep sense of gratitude to my many known and unknown hands which pushed and put me on right paths and enlightened me with their experience, knowledge and wisdom and shall ever remain grateful to them.

I consider myself to be extremely fortunate for an opportunity to work under the guidance of enthusiastic man Shri. S. W. Choudhari, Assistant Professor, Department of Silviculture and Agroforestry, Dr. PDKV, Akola. It is my proud privilege to take this opportunity to express my deep sense of gratitude and indebtedness to his for suggesting this research problem, for his valuable inspiring and scholastic guidance, keen criticism and unfailing interest during the course of this investigation.

It is of great pleasure for me to express my sincere thanks to my advisory committee member Dr. N. M Konde, Assistant Professor, Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola for his valuable comments and suggestions from time to time and for providing necessary facilities during the course of investigation.

I am equally indebted to other members of advisory committee Dr. V. P. Mane, Associate Professor, Department of Silviculture and Agroforestry, Dr. PDKV, Akola, Dr. S. T. Ingle, Associate Professor, Department of Plant Pathology, Dr. PDKV, Akola for their kind co-operation, valuable guidance and timely suggestions during the course of investigation.

My inexplicable gratitude goes to Dr. Y. B. Taide, Associate Dean, PGI, Dr. S. S. Harne, Associate Dean and HOD, College of Forestry, Dr. PDKV, Akola for kind help of administration during my degree program.

It is my privilege to record sincere thanks to Professors of my Department Shri. S. M. Khachane, Dr. H. K. Deshmukh, Dr. A. U. Nimkar, Shri. A. J. Deshmukh, Dr. V. B. Shambharkar and other academic faculty members for their inspiration and wholehearted support during my postgraduate study.

I gratefully acknowledge all authors whose literature has been cited in this thesis; I also place my gratitude to University Librarian Shri. A. B.

Bhosale and staff members of Computer Center for the facility and help rendered.

My family is my strength and source of motivation behind me. It seems one uses the choice would to measure the boundless love and fireless sacrifice of someone. I find no much measure in adequate quantity, for all that my beloved father Shri. Suresh Jagtap, mother Sau. Anita Jagtap and sister Ku. Punam Jagtap done for affection, moral support and me, whose love has no equivalent and everlasting source throughout my life.

I heartly thanks to my close friends Savi Nimbarte, Rushikesh Telang, Gaurav Meshram, Dnyanesh Desale, Manisha Uike, Aishwarya Deshmukh, Priyanka Tayade, Manohar P., Bhushan Khawale, Tushar Sarade, Snehal Shende, and my beloved juniors from College of Forestry, Dr. PDKV, Akola and College of Horticulture, Dr. PDKV, Akola for their timely co-operation and emotional support during course of my research work.

Above all, I bow my head before almighty Lord Hanuman, whose constant blessing enabled me to complete this endeavour successfully and gave me courage to stand all.

Place: Akola **(JAGTAP DEEPAK SURESH)**

Date: / /2023 Enrolment No. PP-281

Table of Contents

(A) List of Tables

(B) List of Figures

(C) List of Plates

(D) Abbreviations

%	:	Per cent
C	:	Carbon
^0C	:	Degree Celsius
@	:	At the rate
$^{-1}$ or /	:	Per
ABS	:	Adjacent barren site
Ca	:	Calcium
$CaCO_3$	:	Calcium carbonate
cfu	:	Colony forming unit
CO_2	:	Carbon dioxide
Conc.	:	Concentration
cm	:	Centimetre
dS m^{-1}	:	Deci-siemens per metre
EC	:	Electrical conductivity
e.g.	:	Exempli gratia (For example)
et al.	:	Et alia (and others)
etc.	:	Et cetera
E-W	:	East-West
Fig.	:	Figure
ha	:	Hectare
Hr.	:	Hour
i.e.	:	that is
In vitro	:	In laboratory
In vivo	:	In field
K	:	Potash
kg	:	Kilogram
L	:	litre
lbs	:	Libra pondo (a pound by weight)
m	:	Meter
km	:	Kilometre
Mg	:	Magnesium

Mg	:	Mega gram
mm	:	Millimetre
MSL	:	Mean sea level
N	:	Nitrogen
NA	:	Nutrient Agar
NLC	:	Non-Labile Carbon
No.	:	Number
N-S	:	North-south
OC	:	Organic carbon
P	:	Phosphorus
PDKV	:	Panjabrao Deshmukh Krishi Vidyapeeth
PDA	:	Potato Dextrose Agar
pH	:	Power of Hydrogen
ppm	:	Part per million
SOC	:	Soil organic carbon
spp.	:	Species
t	:	Tonne
TOC	:	Total Organic Carbon
Viz.	:	Namely
VLC	:	Very Labile Carbon
Yr.	:	Year

(E) THESIS ABSTRACT

a)	**Title of the thesis**	:	**"ASSESSMENT OF TREE PRODUCTIVITY, PHYSICO-CHEMICAL PROPERTIES AND MICROFLORA OF SOIL UNDER *Hardwickia binata* ROXB."**
b)	**Full name of student**	:	**JAGTAP DEEPAK SURESH**
c)	**Name and address of Major Advisor**	:	**Shri. S. W. Choudhari** Assistant Professor Department of Silviculture and Agroforestry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) - 444104.
d)	**Degree to be awarded**	:	M.Sc. (Forestry)
e)	**Year of award of degree**	:	2023
f)	**Major subject**	:	Silviculture and Agroforestry
g)	**Total number of pages in the thesis**	:	74
h)	**Number of words in the abstract**	:	544
i)	**Signature of the student**	:	
j)	**Signature, name and address of forwarding authority**	:	

Head,
Department of Forestry
PGI, Dr. PDKV, Akola

ABSTRACT

Hardwickia binata, a prominent tree species in arid and semi-arid regions, plays a vital role in the ecological and socio-economic aspects of the ecosystem. The present investigation entitled, “Assessment of tree productivity, physico-chemical properties and microflora of soil under *Hardwickia binata* roxb.”, was conducted during 2022-23 at various locations in the premises of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. This study aimed to assess tree productivity, physicochemical properties and microflora of soil under *H. binata* plantations. The research involved a

comprehensive analysis of tree growth parameters, including volume (height, gbh, basal area) and biomass (above ground and below ground). Concurrently, soil samples were collected and analysed for various physicochemical properties, such as bulk density, soil moisture, pH, electrical conductivity, organic carbon, $CaCO_3$ and Available N, P and K. Also, soil samples were collected and analysed for the enumeration of microbial count viz., fungi, bacteria and actinomycetes. Soil samples were collected at 0-30, 30-60 and 60-90 cm depths of soil under selected four sites of *H. binata* within plantation and without plantation.

The highest plant height (15.79 m), GBH (76.76 cm), volume (44.51 m^3 ha^{-1}) and total biomass (308.53 t ha^{-1}) were recorded under site I of *H. binata*. The pH, EC and OC value decreased while $CaCO_3$, available nitrogen, available phosphorus and available potassium value in soil was increased under all sites of *H. binata* at different soil depth compared to barren sites. The mean maximum OC (0.91%) of site III, calcium carbonate (5.42%) of site II, available N (222.11 kg ha^{-1}) of site III, available P (20.91 kg ha^{-1}) of site I and available K (328.39 kg ha^{-1}) of site I noted under plantation. While, the mean maximum OC (0.67%) of site III, calcium carbonate (7.68%) of site III, available N (171.24 kg ha^{-1}) of site I, available P (12.25 kg ha^{-1}) of site II and available K (285.87 kg ha^{-1}) of site II under barren land. However, soil health in terms of physico-chemical and biological parameters showed improved under all the tree species than the control (adjacent barren site).

The analysis of soil microflora under *H. binata* sites demonstrated a diverse and active microbial community. The mean maximum population of fungi (10.40×10^5cfu g^{-1} soil) of site III, bacteria (2.00×10^7cfu g^{-1} soil) of site I and site III and actinomycetes (4.43×10^6cfu g^{-1} soil) of site III noted within plantation. While, the mean maximum population of fungi (7.57×10^5cfu g^{-1} soil) of site I and site III, bacteria (1.56×10^7cfu g^{-1} soil) of site I and actinomycetes (3.00×10^6cfu g^{-1} soil) of site III noted under barren land. Bacterial and fungal populations were abundant within plantation, contributing to nutrient cycling and soil health. The analysis of soil microflora under *H. binata* plantations demonstrated a diverse and active microbial community.

The results obtained during the course of investigation, it can be concluded that assessment of tree productivity, physicochemical properties and soil microflora under *H. binata* suggests a comprehensive understanding of the ecosystem. The interplay between tree productivity and soil characteristics, including physicochemical properties and microflora, is crucial for ecosystem health. Understanding the intricate relationship between this tree species and the physicochemical properties of soil microflora is essential for effective conservation and management practices in these regions, which can have broader implications for sustainable land use and forest management.

CHAPTER I

INTRODUCTION

1.1 Background information

The variation in potential of tree crops on soil environment with the tree species influences the soil properties. The rate of litter fall, decomposition and mineralization defer according to tree crop (Russell *et al*., 2007). Soil provides the vibrant habitat over the diversity of life forms. For a given site, soil having the characteristics capability features like soil fertility and soil productivity, its productivity is considerably important for soil fertility, supply nutrients and produce higher yields. Its productivity depends on factors among which microbe's role are prominent. The soil fertility, it is the ability of soil to provide plant habitat and result in sustain and consistent tree growth of higher quality. It's having physical support, a rooting medium with plant available water, air for respiration and essential nutrients. Tree plantation is known to bring changes in edaphic, micro-climate, floral and other components of ecosystem recovery process through bio-recycling of mineral elements, micro-climate modification, changes in vegetation composition etc. Objectives of tree planting also vary correspondingly, from multiple use of perpetually 'natural looking forests', development of high yielding and sustainable industrial plantations for wood production, control of land degradation and development of agroforestry systems (Nambiar, 1995).

Among various tree species *Hardwickia binata* is a tree species of known merit of economic importance (fodder, fuel, timber) and improving soil fertility through nitrogen fixation. It is an important tree species for agroforestry land-use in semi-arid region. Since 1990 onwards, it had been intensively planted in agri-silviculture and silvi-pasture systems with the basic aim to supply fuel, fodder and timber and to improve the degraded lands. Considering the importance of *H. binata* based agroforestry system, it is essentially required to assess its impact on soil health in quantifiable terms (Prasad *et al.,* 2017). *H. binata* comes under the endemic biodiversity category and it is multipurpose tree species useful for agroforestry and dry land areas with medicinal, fodder, fuel, fiber, timber and manure utility potential. It is essential to know more about its growth performance in arid condition (Tripathi *et al.,* 2022).

Productivity of any vegetation system mainly depends on biomass production and carbon storage potential in their different components. The biomass and carbon storage potential are affected by nature and age of plant, and other climatic, edaphic, topographic and biotic factors. The biomass stock and its storage rate in vegetation systems play an important role in quantifying the system output and determining the carbon sequestration rate for mitigating of climate change problems. The productivity of forests is based on the height, diameter and total above ground biomass, and influenced by association of different vegetation components, area coverage, age, site factors and growth characteristics (Singh,1994).

It is also source of fiber, fuel, high quality fodder for the cattle and uses as main component in the different agroforestry systems of arid and semi-arid regions. It is propagated mainly by direct sowing of seeds and raising seedlings in the nursery. This tree is a striking deciduous tree and characteristic species of degraded dry deciduous forests. The tree remains leafless during the end of winter season for a very short period. The leaf renewal starts subsequently in April. The specialty of this tree is that the tree is completely with leaves during the hot summer and can be distinctly seen among its associates. The pale yellowish green flowers appear from July to September. The pods develop by November and ripen in April or May. Anjan normally found at an altitudinal gradient of 0-300 m with mean annual temperature of 22-34 ºC and mean annual rainfall of 250-1500 mm. For its better growth, the tree prefers deep porous soil with fissured underlying rock. It tolerates acidic to neutral soils. This tree can thrive well in dry areas and even can withstand in prolonged drought condition. Due to it wider uses and climatic adaptability the present studies attempts were made to investigate the growth performance of tree species in arid climate in rainfed condition and to standardized the best spacing for plantation on farmers' fields, road side and farm boundary in hot arid zone (Tripathi *et al.,* 2022).

Soil physico-chemical properties are basic indicators for estimating the level of soil nutrient contents and characteristics. It was observed that available nutrient balance in soil was influenced by soil pH, moreover phytotoxicity of aluminate was reported in alkaline soil (with pH greater than 9) (Kinyangi, 2007). Soil physicochemical properties such as silt, clay, electrical conductivity water holding capacity, organic matter and total nitrogen contents and microbial population were also affected by soil microorganisms. Soil physico-chemical properties and enzymatic activity together obtain the main indicators of soil quality.

Soil productivity is influenced by physical factors such as texture, structure, and porosity. Texture refers to the relative proportions of sand, silt, and clay, affecting water retention and drainage. Soil structure involves the arrangement of soil particles, influencing aeration and root penetration. Porosity measures the amount of pore space, affecting water movement and nutrient availability. These physical properties collectively impact a soil's ability to support plant growth and productivity. Soil productivity depends on various chemical factors, including nutrient levels (nitrogen, phosphorus, potassium), pH balance, organic matter content, and the presence of essential elements like calcium and magnesium. Proper soil testing can help assess these chemical properties and guide fertility management for optimal crop growth. Soil productivity, from a biological perspective, depends on factors like microbial activity, nutrient content, and the presence of beneficial organisms. Healthy soil ecosystems support plant growth by providing essential nutrients, fostering microbial communities, and maintaining a balanced pH. Practices like crop rotation and organic matter incorporation can enhance biological soil productivity. The productivity of degraded grazing lands in arid and semiarid regions under rainfed conditions is often poor due to dominance of low-yielding annual grasses and lack of proper soil moisture. In this context, introduction of suitable drought-resistant grasses in association with tree and construction of moisture-conservation practices can play a vital role in improving the productivity of degraded grazing lands (Ram *et al.,* 2023).

It is most sensitive pool available relatively in small proportion as it is easily affected by fluctuation in environmental conditions. It also rapidly decomposes and get oxidized easily with any changes in land use practices.

Another SOC pool is the non-labile pool (passive pool) which is more stable and recalcitrant fraction of SOC forming organic-mineral complexes with soil mineral and gets decomposed slowly by microbial activity. It is modified very slowly by action of the microorganisms (Sherrod *et al.,* 2005). Soil fertility is mainly associated with labile pool and the sequestration of atmospheric carbon dioxide is related to the recalcitrant pool. Soil organic carbon (SOC) is one of the most widely use soil quality indicator. In terrestrial ecosystems, it determines the fertility and productivity by improving the physical, chemical and biological properties and also useful in predicting climate change and its effects.

The increasing carbon emission is of major concerns; it has been well addressed in Kyoto protocol (Ravindranath *et al*., 1997). The tree carbon is stored in the foliage, stem and root system and most important, the woody tissue in the main stem of trees. Trees act as CO_2 absorber from the atmosphere and store the same in the form of wood. Thus, absorbing CO_2 from air and locking it in the forest biomass is one of the potential and practical ways of removing large volume of CO_2 from the atmosphere. This process of capturing atmospheric CO_2 and storing it for long term through natural (soils/vegetations) is known as carbon sequestration (Schrag, 2007). As trees grow and their biomass increase, they absorb carbon from the and store it in the plant tissue (Mathews *et al*., 2000) resulting in growth of different parts.

The soil microorganism effect on the physico-chemical properties of soil. The study of physico-chemical properties derives the principles of both physical and chemical nature; they are dependent on or produced by the combined actions of physical and chemical attributes. The concept of rhizosphere was put forward by (Hiltner 1904) to describe the volume of soil around living plant root activity (Hinsinger, 1998; Hinsinger *et al*., 2005). The rhizosphere is first of all a unique hot spot in the soil at the viewpoint of microbial ecology as soil microorganisms are considerably stimulated in the vicinity of the roots, as consequences of the release by roots of a range (Jones *et al*., 2004).

Microorganisms may also alter the soil potential. Thus, the growth of aerobic microorganisms, most of which grow at the expense of decaying plant debris, may lead to reduction in the plant. Alternatively photosynthetic algae can produce oxygen and raise the potential of soil. The soil microbial activity which reflects microbiological processes of soil microorganisms is the potential indicators of soil quality, as plants depends on soil microorganism to mineralize organic nutrients for growth and development. The higher plant diversity increases rhizosphere carbon inputs into the microbial community resulting in both increased microbial activity and carbon storage (Lange, 2015).

1.2 Objectives of study

The present study was undertaken to achieve the objective of productivity and assessment of biomass, physico-chemical properties of soil and study of soil microflora under the plantation of *Hardwickia binata* Roxb.

Therefore, the present study was entitled as **"Assessment of Tree Productivity, Physico-Chemical Properties and Microflora of Soil under *Hardwickia binata* Roxb."** is being conducted with following objectives:

1. To study productivity and accumulation of biomass of *Hardwickia binata*.
2. To assess the physico-chemical properties of soil under *H. binata*.
3. To enumerate the soil microflora under plantations of *H. binata*.

1.3 Importance and need of the study

H. binata is an important fodder and timber tree of dry deciduous forest and can found mainly in various parts of India from Himalayas in north to valley of Cauvery and Bhavani rivers in south. Assessment of its biomass and carbon content is essential, for taking management decisions, and in ecosystem modeling. It is important to maintain health of ecosystem. Understanding the productivity of *H. binata* helps to evaluate the overall health of the ecosystem. Healthy trees contribute to biodiversity, carbon sequestration, and overall ecological balance. Analyzing the chemical properties of the soil, including nutrient content, pH, and organic matter, can help in soil management and ensuring that it provides the necessary nutrients for health. Assessment of microflora diversity can help in to maintain a balanced soil ecosystem. Monitoring these factors are essential for sustainable forest management. It ensures that the population of *H. binata* trees are remains stable and can provide ecosystem services over the long period of time. Healthy trees and well-maintained soils contribute to carbon sequestration, aiding in climate change mitigation efforts. The knowledge gained from soil assessment can also be applied to agricultural practices in the region, as it may have implications for crop cultivation and land use. Understanding the interaction between and different soil samples found in Dr. PDKV, Akola and the microflora is crucial for the conservation of this species and the protection of its habitat. Overall, Assessment of the productivity, physico-chemical properties and microflora of its associated soil is vital for better conservation, management, and understanding these tree species within its ecosystem.

1.5 Scope and limitations

Assessing tree productivity and soil properties can provide insights into the overall health and vitality of the ecosystem where *H. binata* trees are found. Studying the microflora of the soil can reveal the diversity of soil organisms, which is essential for ecosystem biodiversity and nutrient cycling. Healthy trees and well-maintained soil contribute to carbon sequestration, making it relevant for climate change mitigation efforts. Studying the microflora of the soil can reveal the diversity of soil organisms, which is essential for ecosystem biodiversity and nutrient cycling.

The properties assessed may not be directly applicable to other tree species, as each species has its unique requirements and interactions with soil and microflora. Conducting comprehensive assessments can be time consuming and may require long term monitoring to see significant changes. Assessment of properties may be site specific and may not be generalizable to other regions with different environmental conditions.

Factors like climate change, pests, and disease can also influence tree productivity and soil health, making it difficult to isolate the effects of the specific assessments. Implementing changes may require complex and expensive management practices, which could be challenging to execute.

The negligence in site management practices reduced the biomass production and carbon sequestration potential of *H. binata* plantations. This negligence also affects the soil fertility and this declination is recognized as a form of degradation. In farmers' fields, fertility decline occurs if crop uptake is not compensated for with adequate nutrient amendments through the application of fertilizers or return of much needed organic matter from plant debris or most importantly the use of agroforestry technology that could contribute substantial amounts of nutrients to the soil. Combinations of processes occur in the soil, which lowers soil organic matter and subsequently the loss of nutrients. Several practices in farmer's fields including bush burning degrade the soil and deplete the soil of organic matter that may serve as nutrient base for farmers' crop. Evidence of fertility decline include soil organic matter depletion, negative soil nutrient balance, imbalance in fertilizer application, secondary and micronutrient deficiencies and failure to increase fertilizer use to match the increase in crop yield, longer responses to fertilizers and loss of hydraulic properties of soil. The belief in the use of trees to restore fertility loss in crop fields is based on the hypothesis, supported by scientific data that *H. binata* plantations improve the soil beneath them, which have been recognized in many traditional farming systems especially in age long shifting cultivation (Nair, 1993).

1.5 Hypothesis

Increased soil fertility and favorable physico-chemical properties will positively correlate with higher *H. binata* tree productivity. This suggests that better soil conditions result in increased tree productivity. Assessment of physico-chemical properties will reveal that soil improvements, such as increased soil organic matter and nutrient content, are associated with the presence of plantations of *H. binata*. Tropical tree plantations incorporate considerable amounts of nutrients in their biomass over a relatively short period of time (Montagnini and Sancho, 1994). Soil nutrients may be generally abundant early in stand growth as a result of low plant uptake, stimulation of nutrient mineralization and low immobilization in plant biomass, but as plantations grow, decreased nutrient availability can result from immobilization into woody biomass and detritus pools and decreased mineralization (Binkley, 1986; Binkley *et al*., 1997). Soil fertility declines can limit sustained plantation forestry in tropical regions, especially on soils that are inherently nutrient-poor: soil fertility can be decreased through excessive removal of living biomass, particularly if nutrients in tree crowns are lost through harvest or site preparation.

The physico-chemical properties of soil and microflora composition will vary in areas where *H. binata* trees are naturally adopted compared to areas where it is introduced. Over an extended period, continuous assessment will reveal positive trends in tree productivity, soil quality, and microflora diversity, indicating the long-term benefits of *H. binata*, presence. The assessment will indicate that *H. binata* tree plantations contribute to improved nutrient cycling in the ecosystem by affecting soil nutrient dynamics and enhancing microflora activity.

CHAPTER II

REVIEW OF LITERATURE

For the assessment of tree productivity, physico-chemical properties of microflora of soil under *H. binata* tree plantations this study was conducted. The variation in potential of tree crops on soil environment with the tree species influenced soil properties were examined. The study of physico-chemical properties of soil was important for sustainable management of forest and agricultural resources. The goal of current study was to determine the potential of soil microflora under *H. binata* tree plantations for various uses such as restoration of damaged landscapes, the creation of useful agroforestry models, and carbon sequestration above and below the ground level. The effect of *H. binata* tree species on physico-chemical properties of microflora of soil was studied and an effort was made to review the literature related to the influence of vegetation cover on soil properties under following different headings:

1. To study productivity and accumulation of biomass of *Hardwickia binata*.
2. To assess the physico-chemical properties of soil under *H. binata*.
3. To enumerate the soil microflora under plantations of *H. binata*.

2.1 Tree productivity and accumulation of biomass

Gerdemann *et al*. (1963) has estimated the spores of mycorrhizal endogen species which is extruded from the soil by the technique of wet sieving and decanting. The extra material pores of endogen were found in the common cultivated soils in Scotland. There are six different types of spores present in the distinct types of soil. In the preliminary inoculation experiments of four endotrophic mycorrhiza out of the six, the three are from arbuscules and vesicles and one from arbuscules. The result is that the technique of wet sieving and decanting is utilize for the wide variety of investigation.

Bargali and Singh (1991) analyzed on the aspects of productivity and nutrient cycling in and 8-year-old tree plantation of Eucalyptus from the moist plain area which is adjacent to the central Himalaya, India. The comparison between Eucalyptus plantation and *Populus deltoids* plantation takes place, which are of same age. The area of the comparison is a plantation of natural Sal (*Shorea robusta*) and other one is natural forests of the central Himalaya. The result indicates the total biomass of vegetation of the Eucalyptus plantation (126.7 t ha^{-1}) lower than the vegetation of *Populus deltoids* (176 t ha^{-1}) and natural forests (163.4-786.7 t ha^{-1}). The net primary productivity of Eucalyptus plantation (23.4 t ha^{-1} $year^{-1}$) was similar to that of the *Populus deltoides* plantation (25 t ha^{-1} $year^{-1}$) and the natural forest of Sal (22 t ha^{-1} $year^{-1}$). The nutrient of the Eucalyptus plantation is lower than the plantation of *Populus deltoides*.

Ericsson *et al*. (1995) has studied all species having the same basic need for the nutrient. The requirement of the nutrient to the species differs with the time and space. Nutrient use efficiency is higher for the nitrogen which is highest in conifers than the deciduous broadleaved species. The plantation managed for the short rotations are the most nutrient demanding.

Montagnini (2000) worked on the experiment of plantation in tropics where soil fertility is low and plantation of tree species like fast growing has the problem of management. The study done on the two plantations of *Jacaranda spp*. and *Vochysia spp.* The study done for the above ground biomass, nutrient concentration of above ground tree tissues and soil nutrients. In the plantation of *Jacaranda copaia* pure stands tree N, P, and Mg while *Vochysia guatemalensis* had the greatest accumulation of K and Ca. After the five years of plantations, decreases in soil P, K and Ca were apparent in pure plots of the fastest growing species with the largest accumulation of nutrients in above-ground biomass, such as *J. copaia* and *V. guatemalensis*. The results of continued sampling have assessed the long-term effects of plantation treatments on soil chemistry, especially near the end of the rotation (estimated at 12–15 years, depending on the species).

Purwanto *et al*. (2003) worked on the Teak plantations (2 to 7 year-old) under an agroforestry system (Tumpangsari) in East Java, studied for aboveground biomass and net primary productivity by the technique of stratified clip, from October 1996 to September 2000. Result from study indicates total biomass range was 2.76 t for 2-year-old stands to 55.39 t ha^{-1} for 7-year-old stands. In 7 year stands the annual amount of leaf litter fall was 5.58 t ha^{-1}. The Net Primary Productivity increased with age and the mean productivity was 36.05 t ha^{-1} yr^{-1} in 7-year-old stands. Due to the temperature and high humidity the young age productivity of Teak trees in the Madium forest district was moderate. The teak plantation productivity appears to be influenced by management practices contains cultural practices, fertilization and thinning.

Mutanal *et al*. (2007) conducted an experiment to assess the performance of multipurpose tree species (MPTs) suitable for agroforestry system in degraded gravelly soils at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during the year 1990. Ten MPTs viz., *Casuarina equisetifolia*, *Eucalyptus tereticornis*, *Grevillea robusta*, *Tectona grandis*, *Dalbergia sissoo*, *Anogeissus latifolia*, *Albizia lebbek*, *Hardwickia binata*, *Azadirachta indica* and *Acacia nilotica* were planted at 2×2 m spacing (except *C*. *equisetifolia* at 1×1 m) with three replications in randomized block design. At the end of tenth year height was significantly higher in *C*. *equisetifolia* and was followed by *E. tereticornis* as compared to rest of tree species tried. Diameter at breast height was higher in *E*. *tereticornis* as compared to other tree species. Biomass was significantly higher in *C. equisetifolia* (109.18 kg tree^{-1}), followed by *D. sissoo* (12.69 kg tree^{-1}).

Kaul *et al*. (2010) used the dynamic growth model (CO_2 FIX), it was predicted how much carbon may be stored by the Indian forests of *Eucalyptus tereticornis*, *Shorea robusta*, *Tectona grandis*, and *Populus deltoides*. The results showed that *P. deltoides* (8 Mg C ha^{-1} yr^{-1}) fallow by *E. tereticornis* (6 Mg C ha^{-1} yr^{-1}) plants, *T. grandis* forests (2 Mg C ha^{-1} yr^{-1}) and less in *S. robusta* forests (1 Mg C ha^{-1} yr^{-1}) had a net yearly carbon storage potential.

Chavan and Rasal (2011) had measured the above- and below-ground carbon sequestration capabilities of nine Aurangabad city sectors' worth of eucalyptus species. The total standing biomass of Eucalyptus species in 2847 hectares of Aurangabad is 641.35 tonne ha^{-1}, while the total standing biomass of Eucalyptus species in the aboveground and belowground is 509.01 tonne ha^{-1} and 132.34 tonne ha^{-1}, respectively. The total sequestered carbon of Eucalyptus species in an area of 2847 hectares is 320.67 tonne ha^{-1}. The sequestered carbon stock in aboveground and belowground standing biomass of Eucalyptus species is 254.50 tonne ha^{-1} and 66.17 tonne ha^{-1}, respectively. In Aurangabad city, Eucalyptus species take in an average of 1176.85 tonne CO_2.

Suryawanshi *et al*. (2014) investigated aboveground biomass and belowground biomass carbon sequestration potential of selected tree species of North Maharashtra University campus in Jalgaon city was measured. In this study total of 462 numbers of 10 trees species present in selected area of North Maharashtra University Jalgaon. Total biomass and carbon sequestrated in the tree species have been estimated using non-destructive method. The calculated total organic carbon has been compared with allometric model. The result found that *Moringa oleifera* species was found to be dominant sequestrated 15.775 tonnes of carbon and having 14 trees followed by *Azadirachta indica* 12.272 tonnes. The species *Eucalyptus citriodora* has lowest carbon sequestration potential i.e., 1.814 tonnes.

Chambial (2016) conducted research to ascertain the biomass of the multipurpose agroforestry tree species and the potential for carbon sequestration of several multipurpose tree species in Himachal Pradesh. To calculate biomass, every tree that fell on the 0.1 ha patch was counted. Using the formula provided by Pressler (1865), the diameter at breast height (dbh) was measured with a calliper, height with Ravi's multimeter, and form height was computed using Spiegel Relaskop in this study. The investigation's findings showed that compared to other species, *Acero blongum* and *Bauhinia variegata* stored the most carbon, whereas *Morus alba*, *Grewia optiva*, and *Celtis australis* sequestered the least.

Newaj *et al.* (2016) estimated biomass and carbon storage in an established agroforestry experiment with *Albizia procera* and *Dalbergia sissoo* under irrigated conditions and *Emblica officinalis* and *Hardwickia binata* under rain-fed conditions in 2011. *A. procera* collected maximum biomass (120.42 tons ha^{-1} at 11 years), followed by *D. sissoo*, collected 84.75 tons ha^{-1}

biomass at 17 years under irrigated conditions. Also, biomass accumulation in *E. officinalis* was 14.99 tons ha^{-1} in 15 years and *H. binata* accumulated 101.34 tons ha^{-1} biomass in 20 years. As a fast-growing tree, *A. procera* has the highest biomass productivity (10.95 tons ha^{-1} yr^{-1}), followed by *D. sissoo* (4.99 t ha^{-1} yr^{-1}) and *H. binata* (5.10 tons ha^{-1} year^{-1}). *E. officinalis* is the fruit plant with the lowest biomass productivity (1.03 tons ha^{-1} year^{-1}) of all species. *A. procera* had the maximum carbon supply (57.03 tons C ha^{-1}), followed by *D. sissoo* (36.62 tons C ha^{-1}) under irrigated conditions. The carbon stock of *E. officinalis* was 7.12 tons Cha^{-1} at 15 years and 46.13 tons C ha^{-1} of *H. binata* at 20 years under rainfed conditions.

Satheesan *et al.* (2016) assessed the distribution patterns, growth conditions and aboveground biomass in Mullaitivu district during the period of February to May, 2015. Plant height, diameter (dbh), crown height and canopy diameter were measured from selected teak plants in four locations such as Mulliyawalai, Mankulam, Karripatammuripu and Theravil. The measurements were taken with square plot of the size 15×15 m and findings from the Mulliyawalai and Theravil sites had same aged plantation of 22 years, highest average height and dbh value had observed in Theravil site as 19.80±0.28 m and 20.10±0.24 cm, respectively. The highest aboveground biomass of 410.37 tonne ha^{-1} and tree volume of 579.58 m^3 ha^{-1} was found in Mulliyawalai. Among the four locations, the highest average aboveground biomass (1,301.49 tonne ha^{-1}) and tree volume (2,043.77 m^3 ha^{-1}) were observed in Karripatammuripu plantation. From this study Theravil site was selected as the best site for the plantation of teak.

Nirala *et al.* (2018) assessed the total biomass, carbon stock and carbon dioxide (CO_2) content of different age group plantations of teak at five different compartments of Bhabar and Shivalik regions of Kotdwar Forest Division, Uttarakhand. They found that above ground biomass (AGB), below ground biomass (BGB) and total biomass (TB) significantly influenced by different sites and age group of teak plantations. The extent of increase in AGB (687.07 tonne ha^{-1}), BGB (171.77 tonne ha^{-1}) and TB (858.84 tonne ha^{-1}) in S_{26} (Sigaddi-18A) plantation site at the age of 48 was 70.10 % over S_8 (Sigaddi-18B) in AGB (205.40 tonne ha^{-1}), BGB (51.35 tonne ha^{-1}) and TB

(256.75 tonne ha^{-1}) at the age of 33 years. Further, the total carbon (TC) (429.42 tonne ha^{-1}) and CO_2 (1575.97 tonne ha^{-1}) was highest in Sigaddi-18A (S_{26}) plantation site at the age of 48 years. Whereas, the lowest TC (128.37 tonne ha^{-1}) and CO_2 (471.13 tonne ha^{-1}) at the age of 33 years was observed in S_8 (Sigaddi-18).

Tanwar *et al.* (2019) assessed the essential of the biomass and carbon content in *Hardwickia binata,* for taking management decisions and in ecosystem modelling. Seven models, namely, logistic, Gompertz, Chapman, Hill, Allometric, Linear and Monomolecular were tested for this purpose by using diameter at breast height (DBH). Allometric model ($Y = a \times DBH^b$) was found best performing with AIC value of 12.65. This model was then used to develop biomass equations for different tree components using DBH as an independent variable. Developed equations showed high R^2 values (0.894 to 0.989). These equations were then used to assess the biomass and carbon stock of *H. binata* plantations of different age groups. They found that, total biomass of plantations ranged between 63.61 Mg ha^{-1} (14 years) and 139.55 Mg ha^{-1} (36 years) with the corresponding carbon stock of 28.39 Mg ha^{-1} and 63.35 Mg ha^{-1}.

Verma and Jain (2019) assessed carbon stock in different pools of natural vegetation and tree plantations raised in Tropical Forest Research Institute, Jabalpur. In this paper the above ground biomass is quantified by the allometric equation $y=0.007x^2+1.898\times$ -32.69, where x= GBH (cm) previously developed at TFRI by destructive method. The result indicates that the carbon content in tree biomass, ground flora, litter and soil were calculated to be 80.93 tonnes ha^{-1}, 0.42 tonnes ha^{-1}, 1.09 tonnes ha^{-1} and 32.61 tonnes ha^{-1} respectively.

Verma and Jain (2020) conducted a study to quantify the contribution of the plantations and natural forests in Tropical Forest Research Institute (TFRI) Jabalpur campus towards carbon sequestration. Above ground biomass was calculated by non-destructive method. Following allometric regression equation and below ground biomass was calculated following IPCC guidance. The Allometric equation used to calculate above ground biomass was $y = 0.007x^2 + 1.898\times - 32.69$, where, y = above ground biomass in kg and x = average GBH in cm. The carbon stock in plantations and natural forest was calculated to be 75.31 tonne ha^{-1} and 76.34 tonne ha^{-1} respectively during 2015, which enhanced to 79.99 tonne ha^{-1} and 82.17 tonne ha^{-1} in 2016 and 82.37 tonne ha^{-1} and 85.49 tonne ha^{-1} in 2017.

Tripathi *et al.* (2022) experimented about the *Hardwickia binata* under the endemic biodiversity category and it is multipurpose tree species useful for agroforestry and dry land areas with medicinal, fodder, fuel, fiber, timber and manure utility/ potential. It is essential to know more about its growth performance in arid condition. In present studies the attempts have been made to investigate the growth performance of 30 year's old planted *H. binata* tree at different spacing and amelioration of soil. Tree growth data viz., height, diameter at breast height (dbh), clear bole length and crown diameter were measured during the study under rainfed condition of fixed sample trees in rows on a yearly basis in all the treatments and soil sample were collected. The result revealed that *H. binata* tree growth performance was found better at 5×5 m^2 spacing in respect of dbh, clear bole length and volume in rainfed condition. Soil pH was lower at closer spacing and higher at wider spacing and EC and OC were higher at closer spacing and low at wider spacing. This study results may be useful for plantation of *H. binata* trees on farmer's fields, road side and agro-forestry in arid condition. They resulted that the tree height was significantly highest (9.2 m) at narrow spacing (3×5 m^2) followed by spacing of 5×5 m^2 (8.8 m) and 4×5 m^2 (8.5 m). However, the diameter at breast height (dbh) was significantly highest at 5×5 m^2 spacing (23.0 cm) followed by wider spacing 6×5 m^2 (21.4 m), 7×5 m^2 (21.1 m) and 8×5 m^2 (20.2 m).

2.2 Soil fertility under tree plantations

Narain *et al*. (1970) reported that, irrespective of forest covers in Doon valley, bulk density of soil was found to increased and pore space decreased with increase in soil depth. In surface soil (0-30 cm) bulk density was lowest and pore space was highest under brushwood followed by *Eucalyptus* and the Sal Forest, which may be due to the organic carbon content of the soil.

Nandi *et al.* (1981) studied the effect of Eucalyptus species on soil properties in West Bengal and the results showed that there were some changes in soil properties especially pH and nutrient status in plantation areas.

Singh (2000) concluded those significant temporal variations in soil organic carbon, extractable P, NO_3-N and NH_4-N in an aridisol. The pool of available nutrients was generally higher during summer and low during spring season. Winter season increase in the concentration of these nutrients is attributed to the low absorption owing to plants senesce, strongly suggesting that labile carbon and N fraction accumulated during winter. Further studies are suggested to understand the mechanism controlling nutrient availability in different seasons. The concentration of P and NO_3-N were higher under the tree in cropped area than the control which owes to higher status of soil organic carbon and increase in microbial activities. However, concentration of NH_4-N was higher in the control compared to the planted area. Significantly low ratio of NO_3-N to NH_4-N during cropping period could be attributed to the resultant effect of uptake of NO_3-N, atmospheric nitrogen fixation by V. radiata and moisture-controlled nitrification process. In depth studies on the subject are suggested so as to devise package of practices for making fertilizer prescription in agroforestry systems.

Augusto *et al.* (2002) conducted the study on European temperate forest tree species to know its effect on the soil fertility. Result of the study indicated that impact of tree species was maximum in the topsoil. Coniferous tree *Picea abies* showed negative impact on some nutrients (Ca and Mg) and it promoted soil acidification and reduces soil pH. Hence, it is not suitable for very poor soils (areas of acidic atmospheric depositions).

Singh *et al*. (2010) investigated evaluation in the pure stands of tree species and poplar-based agroforestry system on soil organic carbon (OC) and available N, P and K contents. Depth wise soil samples were taken from 13-year-old *Eucalyptus tereticornis* (Eucalyptus), *Azadirachta indica* (Neem), *Melia azedarach* (Dek), *Dalbergia sissoo* (Shisham), *Albizia lebbeck* (Siris), *Leucaena leucocephala* (Subabul) and *Acacia nilotica* (Kikar) spaced at 6x3 m and adjoining open area (control) from PAU Regional Station at

Bathinda. Outcome shows that there was significantly higher amount of Soil OC and available nutrients in the surface soil depths (0-15 cm) than below.

Ogunkunle *et al*. (2011) analyzed the effects of teak single cropping and cocoa-kola intercropping on the soil fertility. The result showed that the decomposition of cocoa and kola leaves improved the soil organic matter content in cocoa/cola site and same in teak site. Thus, there was high soil organic matter content in forest site (9.12%) fallowed by cocoa/kola site (7.34%) and was least in the teak site (3.04%).

Wang *et al*. (2011) conducted the study to determine changes in soil physical-chemical properties, microbial population and enzymatic activities in abandoned farmland over a period of 0,1, 5, 7,10,15, 20, 25, 30, 40 and 50 years in Zhifanggou. The study based on Influence of Different Tree Species on Soil Fertility 6 watershed (8.27 km^2), Shaanxi Province, NW China. Result determined after land abandonment there was a significant improvement in chemical and microbiological properties of soil. It also comes with the establishment of plantation soil organic C, available N and K, total N, soil microbial biomass C, N and P, as well as alkaline phosphatase, saccharase, catalase, and cellulase activity increased. The contrary soil bulk density and pH declined after farmland abandonment. There were no significant changes in total P during the restoration.

Singh *et al*. (2012) study the effects of *Ziziphus mauritiana*, *Moringa olerifera, Carissa congesta* and *Prosopis cineraria* on the physical and chemical properties of soil at different depths (0–15, 15–30, 30–45 and 45–60 cm). In this study soils were analyzed for bulk density, particle density, porosity, water holding capacity, pH, electrical conductivity (EC), per cent organic carbon, available N, P and K, exchangeable cations such as Ca^{2+}, Mg^{2+} and Na^{+} in the laboratory following standard methods described by Jackson (1973). The results obtained from the physical and chemical analyses indicated that among the four different fruit plantations, *Ziziphus mauritiana* recorded substantial improvement and maintenance in soil fertility followed by *Moringa olerifera*. Due to influence of the tree species the increase or decrease in soil properties is more at 0–15 cm and at 15–30 cm than in 30–45 and 45–60 cm. The nutrient return through litter fall followed the order K > N > Ca in *Z*. *mauritiana* and *M*. *olerifera* and N > Ca > K, Ca > N > K in *C*. *congesta* and *P*. *cineraria* respectively.

Basanta *et al.* (2013) experimented on six typical representative pedons viz., Rejental (P1), Parvatapur (P2), Algol (P3), Bilalpur (P4), Zaheerabad (P5) and Krishnapur (P6) of Zaheerabad Mandal in Medak district of Andhra Pradesh for their morphological, physical and physico-chemical properties and their suitability to rice, sugarcane and potato cultivation. The soils are red to dark brown in colour, moderately acidic to neutral (pH-5.9 to 7.0), non-saline, shallow to deep depth. Texture ranged from loamy sand to sandy clay loam in surface soils whereas sandy to clay in subsurface with high sesquioxide percentage. Organic carbon, cation exchange capacity (CEC) and base saturation ranged from 0.04 to 0.57%, 12.0 to 38.0 c mol (p+)/kg and 30.2 to 78.6%, respectively. The dominance of exchangeable ions was in the order viz. Ca2+> Mg2+>Na+ >K+. Soils were low in available nitrogen (N) and phosphorus (P), low to high in available potassium (K). The soils developed with argillic (Bt) horizon, they were classified as Typic Haplustalfs (P4, P5), Lithic Rhodustalfs (P2), Rhodic Kandiustalf (P3), Typic Rhodustalfs (P1, P6). Suitability for three crops P1, P3, P5 were moderately suitable (S2), P2, P4, P6 were marginally suitable (S3).

Bhattacharyya and Jha (2015) assessed the soil bacterial diversity, while enzyme activities such as dehydrogenase, phosphatase and urease were estimated using standard protocols. Degraded forest (DF) and relatively less disturbed forest (RLDF) were the two different land-use systems used, here, to assess the soil bacterial diversity and enzymatic activity. Soil samples were collected randomly at different depths, in four different seasons. A total of 76 bacterial isolates were isolated and characterized based on their morphological and biochemical properties. More bacterial population numbers and enzyme activities were recorded at surface soil that decreased with increase in vertical depths. Maximum bacterial populations as well as activities of different enzymes were recorded during spring season at RLDF while the value was minimum during winter season at DF. Significant positive correlation was observed between the bacterial population number and soil pH at both the surface and subsurface soils (R2=0.993 and 0.954 respectively) in RLDF. The data are significantly different from each other at significance level of $P< 0.05$. The results of the present investigation indicated that difference in soil depth, seasonal variation and land-use systems has a potential influence on the existence of bacterial population numbers and soil enzyme activities.

Oumarou (2016) analyzed the influence of four different tree species (*Acacia albida, Combretum aculeatum*, *Acacia senegalensis* and *Piliostigma reticulatum*) on soil fertility in semi-arid climate Niger. The collection of soil sample was done at various depths (0-10, 10-20, 20-30, 30-40 and 40-50 cm) and two age classes (young and mature). Outcome showed that the OC was more under leguminous trees (A. *albida and* P. *reticulatum*) compared to non-leguminous trees (A. *senegalensis* and C. *aculeatum*). The available N, P and K were less under C. *aculeatum* than other tree species. However, Na, Mg and Ca concentrations were lower under A. *senegalensisth* another tree species. Matured trees are advised to grow under farmer's field to improve crop production.

Krishna *et al.* (2017) experimented on the different agroforestry trials in Agroforestry Research blocks, Professor Jayashankar Telangana State Agricultural University, Hyderabad has showed higher economic gain in marginal lands. Sunflower grown when inter cropped in *Hardwickia binata* after stylo recorded higher seed yield (342 kg ha^{-1}) than grown after fallow in *Hardwickia binata* (248 kg ha^{-1}). The soil productivity and fertility were improved in degraded marginal lands by different agroforestry practices. Pertaining to soil improvement over initial in different agroforestry practices the influence of different land use systems on soil properties and nutrient status revealed that bulk density reduced in surface and sub-surface soil in all tree-based systems as compared to fallow (1.65 and 1.68 mg m^{-3}) and agricultural lands. The water holding capacity and infiltration rate was maximum in agri-horti system, 30% at 0-15 and 15-30 cm depth, respectively. Nutrient status and organic carbon were more in soils with tree plantation. Soil enrichment found in marginal lands in different agroforestry practices such as *Melia azedarach* based agri-silvi system, showed significant effect on OC

(0.59%) and available NPK (150.0, 24.95, 210.0 kg ha^{-1}) followed by 100% RDF (0.55% and 147.0,24.00,216.0 kg ha^{-1}).

Chauhan *et al*. (2018) worked on the soil health under four multipurpose tree plantations (*Acacia catechu*, *Dalbergia sissoo*, *Melia azedarach* and *Terminalia arjuna*) after ten years of growth on riverain soils. The outcome from the worked showed that soil health in terms of physical and chemical parameters improved under all the tree species than the control (tree-less area). An enhanced enzymatic activity besides microbial biomass carbon was observed underneath soil of different species than tree-less area, which shows ameliorative potential of soil through plantations on degraded soils.

Ota *et al*. (2018) conducted the experiment on influence of two prominent species which is exotic to Nigeria and the accumulation of nutrient in the soils. The plantations of species *Gmelina arboria* and *Gliricidia sepium* established in the year 1988. The complete randomized block design is used with 4 treatments and 6 replications for the given tree plantations. The physical and chemical properties of soil have studied. The result from experiment is the calcium, magnesium, carbon exchange capacity, base saturation, exchangeable sodium percentage and sodium adsorption ratio differs significantly ($P<0.05$). The potassium and sodium did not differ significantly. The physical properties like sand, silt, clay, bulk density and gravimetric moisture content except for total porosity did not differ significantly.

Singh *et al.* (2018) experimented on Tropical dry forest (TDF) which covers large areas of tropics and characterized by a mosaic type of plant communities that occur as the co-dominant multi-species sites to predominant mono-species. Previous forest management practices leading to incorporation of certain alien species and recombination or modification of the forest communities. However, we know little about the relative effect of multi-specific, *Shorea robusta*, *Hardwickia binata* and *Tectona grandis* and an alien-specific (*Lantana camara* L.) sites on soil multiple (ecosystem) functions (or soil multifunctionality). They were assessed soil individual functions including status of soil nutrients (N and P), fractions of soil organic carbon

(SOC) and glomalin related soil protein (GRSP), microbial biomass C, CO2 efflux and extracellular hydrolytic (acid and alkaline phosphatase, β-glucosidase, dehydrogenase and fluorescein diacetate) and oxidative (phenol oxidase and peroxidase) enzymes to topsoil and subsoil layers on the seasonal basis (summer, winter, and rainy) in a highland TDF of India. It suggests that under similar soil type and climatic condition higher plant diversity promote soil multifunctionality. However, particularly we found that soil pH, alkaline phosphatase and phenol oxidase activity were higher at the alien-specific sites compared with native mono- and multi-specific sites.

Dhinesh *et al*. (2019) studied that the comparative study of soil nutrient status such as soil chemical properties in different forest types of Dharmapuri forest circle of Tamil Nadu. Totally forty soil samples were collected from three forest types viz., Tropical dry deciduous forest, Tropical dry evergreen forest and Tropical dry thorn forest. The results revealed that nitrogen content was exhibited high (334 kg ha^{-1}) in Tropical dry deciduous forest due to a large extent on the amount and properties of organic matter in the forest floor for Nitrogen rich upper layers as compared to the lower layers. Available phosphorous content was recorded higher (24.99 kg ha^{-1}) in soil of Tropical dry deciduous forest because phosphorus is the ore-based mineral which has no influence by plant communities in that area and this might be the reason for higher phosphorus content forest soils. Similarly, tropical dry deciduous forest exhibited higher potassium content (226.37 kg ha^{-1}) which may be attributed to the fact that most of the dry deciduous forest soils are rich in potassium due to presence of potassium containing minerals.

Ram *et al.* (2023) experimented during 2013–2018 on 5-year-old anjan (Hardwickia binata Roxb.)-based silvo-pasture system at the ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh. The treatment consisted of establishment of 3 grasses in association with *H. binata* with 3 moisture-conservation practices. Establishment of *Chrysopogon fulvus* in association with *H. binata* resulted in significantly higher dry pasture yield (6.40 t ha^{-1}) than *Megathyrsus maximus*, *Panicum maximum* (6.02 t ha^{-1}) and found statistically at par with *Cenchrus ciliaris* (6.39 t ha^{-1}). Among the moisture-conservation practices, construction of staggered trenches recorded significantly higher green top feed (2.04 t ha^{-1}), dry top feed (1.21 t ha^{-1}) and firewood (1.40 t ha^{-1}) of *H. binata* than without moisture-conservation practices (1.64, 0.83 and 0.89 t ha^{-1}) and bund (1.89, 1.04 and 1.31 t ha^{-1}) respectively. Construction of bund across the slope recorded significantly higher moisture content at 0–15 cm (8.71%) and 15–30 cm (9.78%) soil depth as compared to without moisture-conservation practices. However, at 30–60 cm soil depth, moisture content was significantly increased (9.63%) in trenches than the control plots. Available nutrients (N 239.5 and 225.1, P 8.53 and 8.22 and K 221.3 and 212.1 kg ha^{-1}) and organic carbon (0.60% and 0.57%) increased significantly where bund and trenches were constructed than no moisture-conservation practice respectively. In term of monetary returns, *Chrysopogon fulvus* showed the maximum net returns (35,485 ha^{-1}) and benefit: cost ratio (1.53), followed by *Cenchrus ciliaris* (33,853 ha^{-1} and 1.51 respectively) and *Megathyrsus maximus* (32,107 ha^{-1} and 1.49 respectively).

2.3 Enumeration of soil micro-organisms like fungi, bacteria and actinomycetes

Kayang (2006) assessed the number of fungi and bacteria were higher in the surface layer (0-10 cm) than in the deep layer of soil (10-20 cm). Quantitatively the bacterial community was more numerous than the fungal community. The numbers of fungal propagules per gram dry soil were maxima in surface layer (0-10 cm) and minimum in deep layer (10 - 20 cm) depth. In depth wise studies fungal population was always high in surface layer and decreased along with soil depth. Maximum numbers of fungi were recorded in July, thereafter their numbers decreased subsequently in both the depths. Average number of fungi and bacteria was high in summer months and low in winter months in both the soil depths. The total number of bacteria in both the soil depths showed a steady increase up to September and then a sharp decline in October. Qualitatively, similar fungal species were isolated and no marked difference in the species composition was noticed. Altogether 48 and 18 species were isolated from the soil layer of 0-10 cm and 10-20 cm depths respectively.

Durga Devi *et al.* (2007) carried out quantitative estimation of soil borne fungi by serial dilution technique with dilutions of 10^4 and estimated quantitatively soil bacteria was carried out by serial dilution technique with dilutions of 10^6.

Chandra *et al*. (2010) has studied the tree plantation of twelve different plantations established at State Forest Research Institute, Jabalpur (Madhya Pradesh). The soil condition of that region is degraded oxisols. The study conducted on plantations of 19-23 years. Results indicate that the improvement of soil in chemical characteristics by increasing the water holding capacity, porosity and organic matter. The result shows the plantation of *Eucalyptus citrodora*, *Dalbergia sissoo* and *Bambusa arudinacea* are more efficient for the rehabilitation of degraded land of oxisols. The soil microbial activity has enhanced up to 2.9-fold due to the accumulation of humas contain from the plantations. The mycorrhizal density of the soil is also enhanced.

Jagtap (2012) isolated soil borne bacteria by following serial dilution technique and pour plate method and identified bacteria were pseudomonas, rhizobium, and azotobacter, and isolated soil borne fungi by following serial dilution technique and pour plate method.

Das *et al.* (2013) experimented on five different sampling sites viz. Kalia, Miripathar, Bordubi, Holokhbari and Surkey area of Saikhowa range of Dibru-Saikhowa Biosphere Reserve (DSBR) Forest of Assam, India in respect of seasonal and depth wise variations in bacterial and fungal populations. Bacterial and fungal population was highest during spring season in all sites respectively. The highest microbial counts were recorded in the top soil (0-10 cm) layer except during the summer season when the population was greater in the subsurface (10-20 cm) layer. Soil organic C, total N and available P decreased with increasing soil depth. Parameters viz. water holding capacity, soil moisture content, pH, organic C, total N and available P had correlated with the microbial colony forming units (cfu).

Schulz *et al*. (2013) conducted experiment on soil formation processes which are complex network of biological as well as chemical and physical processes. The role of soil microbes is of high interest and development of stable and liable pools of carbon(C), nitrogen (N) and other nutrients. The purpose of the study is the review on the microbiology and major steps in the formation of soil and attention for the formation of biological soil crusts and the establishment of the plant microbe interaction.

Bhattarai *et al*. (2015) analyzed the role of microorganisms on soil depth, organic matter, porosity, oxygen and carbon dioxide concentration, soil PH, etc. present in the different layers of soil. The Microorganisms decompose organic matter, detoxifying the toxic substance, fixing the nitrogen, transformation of nitrogen, phosphorous, potassium and other secondary & micro nutrients are the major biochemical activities performed by microbes in soil. Low population of microorganism is found in the compact soil, soil with low organic matter percentage and on deeper strata of soil. The purpose for influence soil microbial population and its role in soil productivity which strengthen the microorganism role in soil productivity and factor that influence growth of microorganism.

Kanagaraj *et al.,* (2017) assessed the microbial populations in the Western Ghats. The soil samples were collected from tropical thorn and moist deciduous forest at the depth of 15 cm. The bacterial, fungal and actinomycetes population was assessed using serial dilution and plating technique. Among microbes, the fungal population was observed to be highest in thorn forest (60.07 $\times 10^3$cfu $g^{-1}$of soil) and moist deciduous forest (112.60 $\times 10^3$cfu g^{-1} of soil). The comparative study between these two forest types, showed the results of lowest bacterial (27.60 $\times$ 10^5cfu g^{-1}), actinomycetes (35.13 $\times$ 10^4cfu g^{-1}) and fungi (60.07 x10^3cfu g^{-1}) population in tropical thorn forest.

Kumar *et al.* (2017) assessed soil biological properties under different land uses in Barog-Dhillon watershed in Solan district of Himachal Pradesh was carried out with a view to ascertain the biological properties of soils under different land uses viz. agriculture land, forest land, grassland and scrub land under project area and non-project area of Barog-Dhillon watershed. On the basis of detailed survey and random sampling, representative soil samples from two depths i.e., 0-15cm and 15-30cm were collected. The Bacterial count (310.56 and 155.56cfu g^{-1}), fungal count (3.57

and 1.78cfu g^{-1}), and actinomycetes count (15.81 and 8.43cfu g^{-1}) recorded higher in surface and subsurface soils under forest land and lowest under scrub land soils, respectively. Whereas, in case of conditions, bacterial count (271.62 and 136.01cfu g g^{-1}), fungal count (3.73 and 1.86cfu g^{-1}) and actinomycetes count (12.52 and 6.73cfu g^{-1}) recorded higher in surface and subsurface soils under watershed project area compared to non-project area of watershed. It was concluded that biological properties assessed for different land uses were found higher in case of watershed project area as compared to non- watershed project area.

Ganesan *et al*. (2017) estimated the actinomycetes with antimicrobial metabolites present in layers of soil of different tree plantations. The collection of soil samples from Nilgiris district of western Ghats of Tamilnadu. Actinomycetes have isolated using serial dilution and plating techniques on actinomycetes isolation agar. The result of the study is isolation of 106 actinomycetes strains and cross streaked against various human pathogens.

Costa *et al*. (2018) assessed the method and techniques for the structural and functional diversity of soil microorganisms. It also provides the methods and procedures to isolate and characterize plant growth promoting bacteria and to stain roots of legumes and detect arbuscular mycorrhiza. The chapter finalizes with some considerations regarding sampling and extraction methods of nematodes and presents optimized procedures to stain and detect the microorganisms.

Soman *et al.* (2018) experimented that the diversity of microbes in Western Ghats using laboratory culture methods and metagenomics method. Metagenomic approaches helped to overcome the practical difficulties in the study of microbial diversity using the traditional culturing methods. The soil samples were collected from the peripheral areas of Thattekad bird sanctuary situated in Western Ghats. Soil samples from 3 different sites of the peripheral areas of Thattekad Bird sanctuary from 3 different depths were taken and analyzed. Isolation of bacteria using nutrient agar showed a total number of 42 different bacterial strains which were identified using colony, morphology, biochemical tests and molecular techniques. In culturable bacteria, the most abundant species was Bacillus cereus. They were resulted total count of West of Knacheri temple surface 3.5×10^7cfu g^{-1} soil , 15 cm depth 2.7×10^6cfu g^{-1} soil and for depth of 30 cm depth 1.6×10^5cfu g^{-1} soil, for Kochu Knacheri Surface 5.0×10^7cfu g^{-1} soil,15 cm depth 4.6×10^6cfu g^{-1} soil and 30 cm depth 3.3×10^5cfu g^{-1} soil and the Pinavoorkudi surface 8.7×10^7cfu g^{-1} soil, 15 cm depth 8.0×10^6cfu g^{-1} soil and 30 cm depth 2.5×10^5cfu g^{-1} soil.

Asiya *et al.* (2019) enumerated that the microbial communities in soil samples from rice, banana and arecanut from the wet lands of Wayanad district Kerala. The total viable bacterial count in the paddy field was $120 x 10^6$cfu, $121 x 10^6$cfu and $147 x 10^6$cfu in Nenmeni, Kaniyambatta and Pozhuthana Gramapanchayat and that of fungi was $30 x 10^3$cfu, $32 x 10^3$cfu and $37 x 10^3$cfu. Likewise, the total viable count of bacteria in arecanut at Nenmeni, Kaniyambatta and Pozhuthana Gramapanchayat were $66 x 10^6$cfu, $80 x 10^6$cfu, $118 x 10^6$cfu and that of fungi was $14 x 10^3$cfu, $18 x 10^3$cfu, and $30 x 10^3$cfu. The total viable count of bacteria in banana field at Nenmeni, and Pozhuthana was $51 x 10^6$cfu and that of Kaniyambatta Gramapanchayath was $56 x 10^6$cfu. The viable fungal colony at Nenmeni and Kaniyambatta was $18 x 10^3$cfu and that of Pozhuthana Gramapanchayath was $24 x 10^6$cfu.

Akande and Adekayode (2019) examined on the identification of microbial population under different land use types in Akure, Nigeria. The land use types were oil palm, teak plantation, unclear forest, and cassava and sugar plantations. The soil samples were collected at depth of 0–15 cm, 15–30 cm and 30–75 cm on each land use area and were taken to the laboratory for microbial analysis. Microbial analysis was carried out using the dilution spread plates techniques of identification of microbial population. The result showed that, there are 40 different species of bacteria and 10 fungal strains isolated from all the land use types. Some of the isolated bacterial species were from phylumactinobacter, bacteriodietes, firmicutes, proteobacter and that of fungi were representatives of phylum Ascomycota and Zycomycota. Microbial population varied significantly ($p < 0.05$) across the land use types, the number of soil bacteria in the cassava land was significantly higher (p <

0.05) with 6.80×10^4cfu g^{-1} compared to other land use types and lowest bacteria population was observed in teak plantation with 6.57×10^4cfu g^{-1}. Significantly higher number of soil fungi was present in the sugarcane with 5.64×10^4cfu g^{-1} compared to other land use type. Maximum number of microbes was recorded from surface soil (0–15 cm) as compared to other depths. The highest microbial population of 6.83×10^4cfu g^{-1} was recorded at the surface soil layer of the cassava land (0–15 cm), whereas the lowest 6.53×10^4cfu g^{-1} was observed at subsoil layer of the teak land (30–75 cm). The fungi population was significantly high at the surface layer of cassava (30–75 cm) with 5.72×10^4cfu g^{-1} and lowest value was recorded at subsoil layer of uncleared forest (30–75 cm) with 5.43×10^4cfu g^{-1}.

Singh and Tripathi (2020) studies microbes are ubiquitous in the soil and abundantly available even in a small amount of soil and are represented by group of bacteria, fungi and actinomycetes. Studies are more abundant on bacterial and fungal population while actinomycetes are less studied. Soil samples were collected from two forests during June 2015 to May 2016 every three months interval-based changes in temperature and precipitation. Using serial dilution Method, different agar media was prepared separately for assessing bacteria, fungi and actinomycetes, for example, nutrient agar with nystatin and actidione for bacteria (using dilution 10^5 to 10^7), potato dextrose agar (PTA) with rose bengal, antibiotic (i.e. penicillin and chloramphenicol) for fungi (10^3 to 10^5) and starch case in agar (SCA) mixed with nystatin were used for isolation of actinomycetes (10^4 to 10^6). They resulted that the seasonal variations in microbial counts were more pronounced in the TF site as compared to the STF site as result of alternating wet and dry conditions in the TF due to fluctuation in temperature. Diversity of fungi (F) was maximum in S1 (21×10^3) season and minimum in S3(17×10^3) season in STF. Similarly, actinomycetes (A) population count was maximum in S1 (44×10^6) and minimum in S4 (59×10^5) in STF. In TF site, maximum A population (84 × 10^5) was recorded in S2 and minimum in S3 (48×10^5). In contrast, soil bacterial (B) count was maximum in S3 (98×10^6) and minimum in S4 (72×10^6) in STF site. Whereas, maximum (128×10^6) B count was recorded in S1 season and minimum (65×10^6) in S4 in TF site.

Hota *et al*. (2022) the study focused on the shifting course of the Brahmaputra Rive, the fluvial landforms of the Brahmaputra Valley are under the changes in landform and land use. The soil management under such conditions is crucial to have information about soil physicochemical, soil microbial population and biological properties of the various land uses. The region of study has five major lands such as paddy fields, banana systems, and arecanut cultivations, rubber plantations and sal forests in the varying slope gradients and soil depths (0–25 cm and 25–50 cm) in the lower Brahmaputra Valley. The results of the available K, B, Fe, Mn, Zn, and Cu, and soil moisture content across two different soil depths. Paddy cultivated systems recorded the highest (1.23%) soil organic carbon (SOC). All soil microbial populations (bacteria, fungi, and actinomycetes) studied varied significantly in different land uses across varying soil depths. Perennial land uses under arecanut, rubber, and forest cultivations showed significantly higher microbial populations than paddy and banana systems.

Mirza and Patil (2022) resulted that the microorganisms help in the fertility and endurance of soil. Additionally supporting the growth of several biological systems, soil and soil microorganisms fill in as the best mode for plant growth. Soil microbes are essential for recycling old plant material and decaying organic matter. In the upkeep of the Environment microbial diversity plays a dominant role. The study was focused on the seasonal variations in the microbial count, which are increased or decreased (Impact on counts) in the Gautala reserve forest. In the present study, soil samples from Gautala Reserve Forest were collected from 15 different sites during the rainy, winter, and summer seasons. The present study was attempted to cover the microbial diversity of the whole Gautala forest through covering maximum sampling spots. The average total microbial count (TMC) in the rainy season was 36.73 and 35.46 respectively and the final count was 36.4×10^6cfu. The average TMC in the winter season for plate 1 and plate 2 was 32.4 and 31.93 $\times10^6$cfu respectively and the final count was 32.46×10^5cfu. The average TMC in the summer season for plate 1 and plate 2 was 37.13 and 36.4×10^5cfu and the final count was 37.6×10^4cfu.

Mandal *et al.* (2023) reported that the population of aerobic heterotopic, starch hydrolyzing, phosphate solubilizing, lipid solubilizing, nitrate reducing, spore forming, Gram-negative, and nitrifying bacteria varied from 9.43 to 12.55×10^6cfu, 2.88 to 6.11×10^3cfu, 6.07 to 9.23×10^3cfu, 2.21 to 5.91×10^2cfu, 3.23 to 9.7×10^3cfu, 6.81 to 12.30×10^5cfu, 2.22 to 8.6×10^3cfu, 2.7 to 8.63×10^3cfu g^{-1} of dry soil respectively. The organic carbon content ranged from 0.39% to 0.68% in the soil sample collected. The available nitrogen, potassium, phosphate, and pH levels in the soil sample ranged from 42.55 to 144.68 mg/kg, 1661.61 to 3749.28 mg/kg, 153.37 to 349.36 mg/kg, and 5.4 to 8.

CHAPTER III

MATERIAL AND METHODS

The present study entitled **"Assessment of tree productivity, physico-chemical properties and micro-flora of soil under *Hardwickia binata* Roxb."** was carried out at various locations in the premises of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during the year 2022-23 to find out the assessment of *Hardwikia binata* Roxb. tree species on tree productivity, accumulation of biomass, carbon status of soil, soil fertility and enumerate soil microflora. The details of the study, techniques used and methodology adopted during the course of investigation is given in this chapter under the following headings.

3.1 Study site

The field study was conducted at various locations in the premises of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during season 2022-23. Akola is situated in the subtropical region at 22.42° North latitude and 77.07° East longitude and at an altitude of 307.42 m above MSL. The study site conditions are more or less uniform under different plantations selected for the study.

3.2 Climate

The climate of Akola is semi-arid and characterized three distinct seasons viz., hot and dry summer from Match to May, warm and rainy monsoon from June to October and mild cold winter from November to February. The normal mean monthly maximum temperature is 44.3 °C during the hottest May. While the normal mean monthly minimum temperature is 8.4 °C in the coldest December. The region receives annual rainfall averages about 711.1 mm. Most of the rainfall occurs in the monsoon season between June and September, but there is some rainfall observed occasionally in January and February. The mean daily evaporation reaches as high as 6.1 mm in the month of June and as low as 3.4 mm in the month of December. The mean wind velocity varies from 4.7 km hr^{-1} during June.

3.3 Silent features of plantations.

For the said study, the plantations of *Hardwickia binata* species at different locations were selected in the premises of Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, were identified and selected to find out the influence of plantation on various soil properties.

3.3.1 Site I

Location	: Dairy Farm, Department of Animal Husbandry and Dairy Science (20°41’19’’ N; 77°01’44’’E)
Age Range of Plantation	: 30-35 years
Area of Plantation	: 1.00 ha.

3.3.2 Site II

Location	: NBPGR Farm, NBPGR regional station (20°42’10’’N; 77°02’00’’E)
Age Range of Plantation	: 25-30 years
Area of Plantation	: 0.50 ha.

3.3.3 Site III

Location	: Experimental Field, Agro-Ecology and Environmental Centre (20°42’32’’N; 77°02’59’’E)
Age Range of Plantation	: 35-40 years
Area of Plantation	: 1.00 ha.

3.3.4 Site IV

Location	: Experimental Field, All India Coordinated Research Project for Dryland Agriculture (20°43’06’’N; 77°02’52’’E)
Age Range of Plantation	: 25-30 years
Area of Plantation	: 0.40 ha.

Plate 1: General view of site I (Dairy Farm; 20°41’19’’ N; 77°01’44’’E)

Plate 2: General view of site II (NBPGR Farm; 20°42’10’’N; 77°02’00’’E)

Plate 3: General view of site III (AECC Field; 20°42’32’’N; 77°02’59’’E)

Plate 4: General view of site IV (Dry Land Farm; 20°43’06’’N; 77°02’52’’E)

3.4 Concise description of *Hardwickia binata* Roxb.

Hardwickia binata (Family – Fabaceae): The Anjan tree is medium or large deciduous, valuable fodder tree species of semi-arid region of India. It is a monotypic genus of flowering plant which grows up to 25 – 30m (82-98 ft.) high. It is native Indian tree in the subfamily Caesalpiniaceae of the legumes. It can be used to check ground water level as well as to increase ground water level. It thrives in a dry climate characterized by a long drought, scanty to moderate rainfall, and intense heat during the hot season. The tree is moderate in size with large drooping branches. The bark of tree is grayish-brown, rough with deep cracks and darkens with age. In months of April; the leaves are shed from the tree and in early May; new leaves are emerged from the tree. The tree grows best on soil types like sandstone, conglomerate, quartzite, granite and schist and overlying soil of sandy loam or very characteristic quartz reddish gravelly sand. The tree species can tolerate acidic soils to neutral soils.

3.5 Estimation of tree productivity and accumulation of biomass

3.5.1 Sampling technique

Selection of sample plots to study standing tree growth parameters: - Three quadrates of size 10x10 m was laid out in each plantation. All the trees within quadrate were enumerated for following biophysical measurements of productivity and biomass of *Hardwickia binata*. Sampling was done according to standard procedure.

3.5.2 Biophysical parameters for determination of productivity and biomass: -

i. Tree height
ii. Tree GBH
iii. Basal area
iv. Tree Volume
v. Total biomass
vi. Above ground biomass
vii. Below ground biomass

3.5.3 Estimation of tree productivity

The tree productivity indicates increase of tree biomass per unit area and it was calculated by non-harvest method.

3.5.3.1 Tree Height (m)

The tree height was measured by Ravi's altimeter. Altimeter was generally altitude measuring instrument had been devised to determine height of tree using trigonometric principles (Chaturvedi and Khanna, 1981).

3.5.3.2 Tree GBH (cm)

The girth at breast height (GBH) 1.37m from the ground level was measure with the help of measuring tape.

3.5.3.3 Basal area (m^2/ha.)

The cross-sectional areas of tress falling in the recording was determined by the formula as: -

Basal area = $g^2/4\pi$ (Chaturvedi and Khanna, 1981)

Where 'g' is the girth at breast height (m) and 'π' is 3.142857.

3.5.3.4 Form Factor

The tree form factor(m) was calculated, to find out the tree volume using the formula given by Presslers' (1865).

$$F=2h^1/3h$$

Where 'F' is the Form Factor, 'h^1' is height at which diameter is half of DBH and 'h' is the total Height.

3.5.3.5 Tree Volume (m^3/ha.)

Volume was calculated by using the following formula given by Pressler's (1865).

Volume (m^3) = Basal Area (m^2) × Height (m) × Form Factor

3.5.3.6 Estimation of total biomass (Tonnes/ha)

Estimation of biomass is an essential aspect for studying carbon stocks and global balance (Kettering's *et al*. 2001). Total biomass is the sum of above ground biomass and below ground biomass. (Sheikh *et al*. 2011).

Total standing biomass (t/ha) = above ground biomass (t/ha) + Below ground biomass (t/ha)

3.5.3.7 Aboveground biomass of standing tree using allometric equation (Tonnes/ha)

Above ground biomass is the most important visible and dominant carbon pool in vegetation systems (Ravindranath and Ostwald, 2008). It includes all living biomass above the soil. It was quantified by non-destructive method using following allometric equation against GBH:

$$y = 0.007\,x^2 + 1.898 \times - 32.69$$

Where,

y = Above ground biomass (kg)

x = Girth at breast height (cm)

This equation has been developed at TFRI Jabalpur by destructive method (Jain *et al.* 2015).

3.5.3.8 Estimation of below ground biomass (Tonnes/ha)

The below ground biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter (Chavan and Rasal, 2011). Biomass estimation equations for tree roots are relatively uncommon in the literature. The below ground biomass of trees was been calculated by multiplying above ground biomass with default value of 0.25 (Root: Shoot ratio of trees as per guidelines of IPCC, 2006).

Below ground biomass (t/ha) = Above ground biomass(t/ha) × Root:Shoot ratio

= Above ground biomass (t/ha) × 0.25

3.6 Estimation of soil fertility

3.6.1 Soil sampling technique

Soil sampling was carried out at all the four sites of *Hardwickia binata.* Three quadrates were laid out in each plantation. The pit was dug at the center of each quadrate with dimensions of 1×1×1m. The soil sample was collected from the three depths of soil 0 – 30 cm, 30 – 60 cm and 60 – 90 cm.

One or single site was consisting nine soil sample. Another three samples from uncultivated land which is adjacent to selected plantation was taken for comparison with the soil samples of selected tree plantation. Soil samples was taken and tested in the laboratory of Department of Soil Science and Agriculture Chemistry, Dr. P.D.K.V., Akola.

Total number of soil samples: 48

3.6.2 Soil parameters: -

a) Physical parameters: -

i. Bulk density

ii. Soil moisture

b) Chemical parameters: -

iii. pH

iv. Electric Conductivity

v. Organic Carbon

vi. $CaCO_3$

vii. Available N

viii. Available P

ix. Available K

3.6.3 Details of the methodology adopted to analysis the following physico-chemical.

Soil physical parameters

3.6.3.1 Bulk density (BD)

Bulk density (Mg m^{-3}) of soil was estimated using clod clotting method given by Blake and Hartge (1986).

3.6.3.2 Soil moisture (SM)

Soil moisture (%) was estimated by using the gravimetric method.

Soil chemical properties

3.6.3.3 Soil pH

pH of soil was measured with 1:2.5 soil water suspension using glass electrode pH meter (Jackson 1973).

3.6.3.4 Electrical conductivity (EC)

The electrical conductivity (dS m^{-1}) was measured with 1:2.5 soil water suspension using conductivity meter (Jackson 1973).

3.6.3.5 Organic carbon (OC)

The organic carbon content (%) was estimated using wet oxidation method given by Walkley and Black (1934).

3.6.3.6 Calcium carbonate ($CaCO_3$)

The $CaCO_3$ (%) was calculated by using rapid titration method given by Piper (1966).

3.6.3.7 Available N

Available N (kg ha^{-1}) was estimated by alkaline-permanganate method given by Subbiah and Asija (1956).

3.6.3.8 Available P

Available P (kg ha^{-1}) was estimated by Olsen's method given by Olsen's *et al.* (1954).

3.6.3.9 Available K

Available potassium (kg ha^{-1}) content was estimated by extraction with neutral normal ammonium acetate and determined on flame photometer (Jackson, 1973).

3.7 Microbial status of soil under tree plantations

The media like Nutrient Agar, Potato Dextrose Agar and Munairs and Kenknight medium were prepared in the plant pathology laboratory, Dr. PDKV, Akola for the estimation of population of microorganism. The various glassware, equipment and miscellaneous material were used for microbial study.

3.7.1 Collection of soil samples

Soil samples were collected from the experimental sites at 00-30 cm, 30-60 cm and 60-90 cm. The soil samples were collected and tested in the laboratory for population of bacteria, fungi and actinomycetes.

3.7.2 The materials used

3.7.2.1 Glassware

The glassware used during the research work were petri plates, test tubes, conical flasks, measuring cylinder, glass rods, slides, cover slips, beaker and pipettes.

3.7.2.2 Equipment

The laboratory equipment autoclave, laminar air flow, incubator, refrigerator, hot air oven, colony counter, etc. were used.

3.7.3 Preparation of media

Nutrient Agar (NA), Potato dextrose agar (PDA) and Munairs and Kenknight medium were prepared as per their composition, sterilized it and used for isolation of bacteria, fungi and actinomycetes.

NA medium was used for isolation of bacteria. The media was prepared by using following ingredients.

Peptone	- 5 g
Beef extract	- 1 g
Yeast extract	- 2 g
Sodium chloride	- 5 g
Agar	- 20 g
Distilled water	- 1000 ml

Peptone, Beef extract, yeast extract and sodium chloride were dissolved in 1L distilled water and agar in remaining water filtered through muslin cloth, distributed in flasks and tubes. The flasks and tubes were plugged with cotton and media was sterilized in autoclave at 15 lbs. for 15 minutes.

PDA media was used for isolation of fungal colonies. The media was prepared by using following ingredients:

Peeled Potato - 200 g

Dextrose - 20 g

Agar - 20 g

Distilled water - 1000ml

Peeled potatoes were sliced into pieces and boiled in 500 ml distilled water till properly cooked. The extract was strained through muslin cloth and measured. In the remaining water, after dissolving dextrose and agar, potato extract was added and the volume was made to 1L. The medium was distributed in flasks and tubes. The flasks and tubes were plugged with cotton and medium was sterilized in autoclave at 15 lbs for 15 minutes.

Munairs and Kenknight media was used for isolation of actinomycetes colonies. The media was prepared by using following ingredients:

Dextrose - 1 g

Monopotassium dihydrogen phosphate - 0.10

Sodium nitrate - 0.10 g

Potassium chloride - 0.10 g

Magnesium sulphate - 0.10 g

Agar - 15.00 g

Distilled water - 1000 ml

Monopotassium dihydrogen phosphate, Sodium nitrate, Potassium chloride, Magnesium sulphate, Dextrose was dissolved in 1L distilled water and agar in remaining water Filtered through muslin cloth, distributed in flasks and tubes. The flasks and tubes were plugged with cotton and medium was sterilized in autoclave at 15 lbs for 15 minutes.

Disinfection / sterilization of laboratory materials

Petri plates, pipettes, beakers and test tubes were washed with detergent powder under running tap water and sterilized in hot air oven at 180°C for 1 hour before use. Distilled water, NA, PDA and Munairs and

Plate 5: Preparation of pit and collection of soil samples.

Plate 6: Soil profile 0-30, 30-60 and 60-90 cm inside and outside the Hardwickia plantations.

Kenknight media were sterilized in an autoclave at 15 lbs for 15 min. The sterilized media was used for experimentation.

3.7.4 Microbial observations: -

i. Number of colonies of fungi

ii. Number of colonies of bacteria

iii. Number of colonies of actinomycetes

3.7.4.1 Enumeration of fungi from rhizosphere

For the enumeration of fungal population from rhizosphere of *Hardwickia binata* plantations, serial dilution plate method (Latha and Gopal 2010) and media of Potato Dextrose Agar (PDA) was used.

On the basis of cultural characteristics; fungal colony was count and the population of fungi present in the one gram of soil sample was

$$\text{Number of colonies g}^{-1}\text{ of soil sample} = \frac{\text{Number of colonies}}{\text{Amount of aliquots suspension plated}} \times \text{Dilution Factor}$$

calculated by using formula: -

3.7.4.2 Enumeration of bacteria from rhizosphere

For estimation of bacterial population from rhizosphere of *Hardwickia binata* plantations, serial dilution plate method (Vincent, 1970) and media of Nutrient Agar (NA) was used.

On the basis of cultural characteristics; bacterial colony was counted and the population of bacteria present in the one gram of soil sample was counted by using formula, (Varalakshmi *et al.* 2010): -

$$\text{Number of colonies g}^{-1}\text{ of soil sample} = \frac{\text{Number of colonies}}{\text{Amount of aliquots suspension plated}} \times \text{Dilution Factor}$$

3.7.4.3 Enumeration of actinomycetes from rhizosphere

For the enumeration of actinomycetes population from rhizosphere of *Hardwickia binata* plantations, serial dilution plate method (Vincent, 1970) and the Munairs and Kenknight medium was used.

On the basis of cultural characteristics; a colony of actinomycetes was count and the population of actinomycetes present in one gram of soil sample was calculated by using formula: -

$$\text{Number of colonies } g^{-1} \text{ of soil sample} = \frac{\text{Number of colonies}}{\text{Amount of aliquots suspension plated}} \times \text{Dilution Factor}$$

CHAPTER IV

RESULTS AND DISCUSSION

The results emerging from the present investigation undertaken to elucidate the **"Assessment of Tree Productivity, Physico-Chemical Properties and Microflora of Soil under *Hardwickia binata* Roxb."** was carried out at various locations in the premises of Dr. Panjabarao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during 2022-23 are presented in this chapter.

4.1 Tree parameter

4.1.1 Tree height and girth at breast height (GBH)

4.1.2 Basal area of trees

4.1.3 Volume of trees

4.2 Assessment of biomass of *H. binata* plantations

4.2.1 Assessment of aboveground biomass of *H. binata* plantations

4.2.2 Assessment of belowground biomass of *H. binata* plantations

4.2.3 Assessment of total biomass of *H. binata* plantations

4.3 Soil Physico – chemical and biological properties

4.3.1 Assessment of bulk density and soil moisture of soil under *H. binata* plantations and without plantation

4.3.2 Assessment of pH and electrical conductivity of soil under *H. binata* plantations and without plantation

4.3.3 Assessment of organic carbon and calcium carbonate of soil under *H. binata* plantations and without plantation

4.3.4 Assessment of available N, P and K status of soil under *H. binata* plantations and without plantation

4.4 Assessment of soil microbial population

4.4.1 Assessment of fungal population of soil under *H. binata* plantation and without plantation

4.4.2 Assessment of bacterial population of soil under *H. binata* plantation and without plantation

4.4.3 Assessment of actinomycetes population of soil under *H. binata* plantation and without plantation

4.5 Assessment of biomass, soil parameters and microbial population of soil under *H. binata* plantations.

In this study the age of the trees in the selected sites and their growth habit were similar to each other. It will show the pattern and picture of tree growth of the *H. binata* at their respective sites. In the present study we tried to find out the *H. binata* in biomass, influence on soil fertility and its microbial status.

4.1 Tree parameters

4.1.1 Tree height and girth at breast height (GBH)

The tree growth observations were recorded as a basic reference to understand of the condition of tree plantations and presented in Table-1. The present study looks into growth pattern of four different sites of *H. binata*. The site III of *H. binata* has maximum mean height (15.79 m), followed by site I has mean height (14.37 m), followed by site II of *H. binata* (13.64 m) and the least in site IV (12.44 m).

Table 1. Mean height and GBH *H. binata* tree plantations.

Tree Site	Mean Height (m)	Mean GBH (cm)	Age range of the plantation (Years)
Site I	14.37	70.69	30-35
Site II	13.64	67.45	25-30
Site III	15.79	76.76	35-40
Site IV	12.44	64.34	25-30

The result also shows that, the maximum mean GBH of site III (76.76 cm), followed by mean GBH of site I (70.69 cm), then mean GBH of site II (67.45 cm) and the least mean GBH were observed in site IV (64.34 cm). Tree height and GBH are the growth variables that are strongly influenced by the site condition and different growth behavior of trees. The volume and subsequently, biomass was reported to be related with girth and height (FSI, 1996; Jha, 1999 and Kiyono *et al.*, 2010).

4.1.2 Basal area of trees

Tree basal area was estimated using girth at breast height (GBH) of tree. The estimated data is placed in Table-2.

Table 2. Mean basal area of *H. binata* tree plantations.

Site	Basal area (m^2 $tree^{-1}$)	Basal area (m^2 ha^{-1})
Site I	0.0398	3.98
Site II	0.0362	3.62
Site III	0.0469	4.69
Site IV	0.0329	3.30

It is observed that as the age increases, basal area also increases. The highest (4.69 m^2 ha^{-1}) basal area was observed in site III at the age of 35-40 years, followed by site I (3.98 m^2 ha^{-1}) at the age 30-35 years, then the basal area (3.62 m^2 ha^{-1}) was observed in site II at the age of 25-30 years and the least basal area was (3.30 m^2 ha^{-1}) at the age of 25-30 years. Das (2016) also estimated the basal area of same tree plantation of *H. binate* and found that (2.83 m^2 ha^{-1}).

4.1.3 Volume of trees

The volume of trees was recorded as a basic reference to understand the condition of tree plantations. Accordingly, the growth parameters of tree, such as basal area, tree total height and form factor were used to find out tree volume. The estimated data is placed in Table-3. The maximum (44.50 m^3 ha^{-1}) volume was observed in site III at the age of 35-40 years, followed by volume (34.33 m^3 ha^{-1}) was observed in site I, followed by volume (29.66 m^3 ha^{-1}) was observed in site II, whereas, in site IV (24.59 m^3 ha^{-1}) volume at the age of 25-30 years, showed minimum value. The present study is comparable to the findings of Satheesan *et al.* (2016) and Chauhan *et al.* (2019).

Table 3. Volume of *H. binata* tree plantations

Site	Volume (m^3 $tree^{-1}$)	Volume (m^3 ha^{-1})
Site I	0.3434	34.34
Site II	0.2966	29.66
Site III	0.4451	44.51
Site IV	0.2459	24.59

4.2 Assessment of biomass of *H. binata* plantations

Biomass production in any system reflects the potential production of their vegetation components in a set of environment, number and types of constituent species, age and their management (Swamy and Puri, 2006). The tables revealed that all the components of biomass viz., above, below and total biomass was significantly influenced due to plantations of *H. binata* at various plantations.

4.2.1 Assessment of aboveground biomass of *H. binata* plantations

The assessment of aboveground biomass was done in the plantations of *H. binata*. The resulted data presented in the Table-4 revealed that, biomass in *H. binata* plantation site varied to each other. From the data depicted in the Table-4 of aboveground biomass of trees were recorded as a basic reference to understand the condition of sites. Accordingly, the resulted data the above ground biomass of *H. binata* plantation sites.

Table 4. Aboveground biomass of *H. binata* plantations

Site	AGB (tonne $tree^{-1}$)	AGB (tonne ha^{-1})
Site I	0.1365	218.36
Site II	0.1272	203.49
Site III	0.1543	246.83
Site IV	0.1184	189.45

The maximum (246.83 tonne ha^{-1}) was observed in site III at the age of 35-40 years, followed by, site I (218.36 tonne ha^{-1}) at the age of 30-35 years, followed by site II (203.49 tonne ha^{-1}), whereas, in site IV the above ground biomass (189.45 tonne ha^{-1}) recorded the minimum value. The similar results were depicted for 20-year-old *H. binata* (79.29 tonne ha^{-1}), reported by Newaj *et al.* (2016) at Central Agroforestry Research Institute, Jhansi.

4.2.2 Assessment of belowground biomass of *H. binata* plantations

The assessment of belowground biomass was done in the plantations of *H. binata*. The resulted data presented in the Table-5 revealed that, biomass in *H. binata* tree plantations varied to each other. From the data depicted in the Table-5 of belowground biomass of trees were recorded as a basic reference to understand the condition of sites. Accordingly, the resulted data the belowground biomass, maximum (61.70 tonne ha^{-1}) was observed in site III at the age of 35-40 years, followed by site I (54.59 tonne ha^{-1}) at the age of 30-35 years, followed by (50.87 tonne ha^{-1}) was observed in site II, whereas, in site IV the below ground biomass (47.36 tonne ha^{-1}) showed minimum value. Newaj *et al.* (2016) also suggested that equations from similar regions should be applied where possible in order to maximize accuracy in estimating belowground biomass of agroforestry tree species.

Table 5. Belowground biomass of *H. binata* plantations

Site	BGB (tonne $tree^{-1}$)	BGB (tonne ha^{-1})
Site I	0.0341	54.59
Site II	0.0318	50.87
Site III	0.0386	61.70
Site IV	0.0296	47.36

4.2.3 Assessment of total biomass of *H. binata* plantations

Accordingly, the resulted data of total ground biomass presented in the Table-6 depicted in fig.1. The maximum (308.53 tonne ha^{-1}) was observed in site III at the age of 35-40 years, followed by site I (272.95 tonne ha^{-1}) at the age of 30-35 years, followed by (254.36 tonne ha^{-1}) was observed in site II, whereas, in site IV (236.81 tonne ha^{-1}) showed minimum value of total biomass. Newaj *et al.* obtained (101.34 tonne ha^{-1}) total biomass in 20-

year-old *H. binata* plantation at Central Agroforestry Research Institute, Jhansi (Uttar Pradesh).

Table 6. Total biomass of *H. binata* plantations

Site	Total biomass (tonne tree^{-1})	Total biomass (tonne ha^{-1})
Site I	0.1706	272.95
Site II	0.1590	254.36
Site III	0.1928	308.53
Site IV	0.1480	236.81

4.3 Soil Physico – chemical and biological properties

4.3.1 Assessment of bulk density and soil moisture of soil under *H. binata* plantations and without plantation.

The assessment of bulk density and soil moisture were observed for the soil samples collected at three depths (00-30 cm, 30-60 cm and 60-90 cm) and analyzed. The data generated is placed in Table-7. The higher mean bulk density (1.29 Mg m^{-3}) was recorded in site II, then in site I and IV (1.27 Mg m^{-3}) respectively, whereas, in site III (1.26 Mg m^{-3}) recorded the minimum value among the three different depths of soil.

Among the given depths of soil, the highest observed soil bulk density is from site I and site II under depth 60-90 cm (1.32 Mg m^{-3}) respectively, followed by, site IV under depth 60-90 cm (1.30 Mg m^{-3}). The lowest value of was recorded in site I 00-30 cm depth of soil (1.23 Mg m^{-3}). The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean bulk density (1.34 Mg m^{-3}) was recorded in site III, then in site IV (1.33 Mg m^{-3}), followed by site II (1.32 Mg m^{-3}), whereas, in site II (1.31 Mg m^{-3}) recorded the minimum value among the three different depths of soil. The results are supported by Sharma *et al.* (1995), who reported that the lower values of bulk density are indicative of top soil rich in organic matter. Stockfish *et al.* (1999) observed that bulk density increased with depth due to compaction.

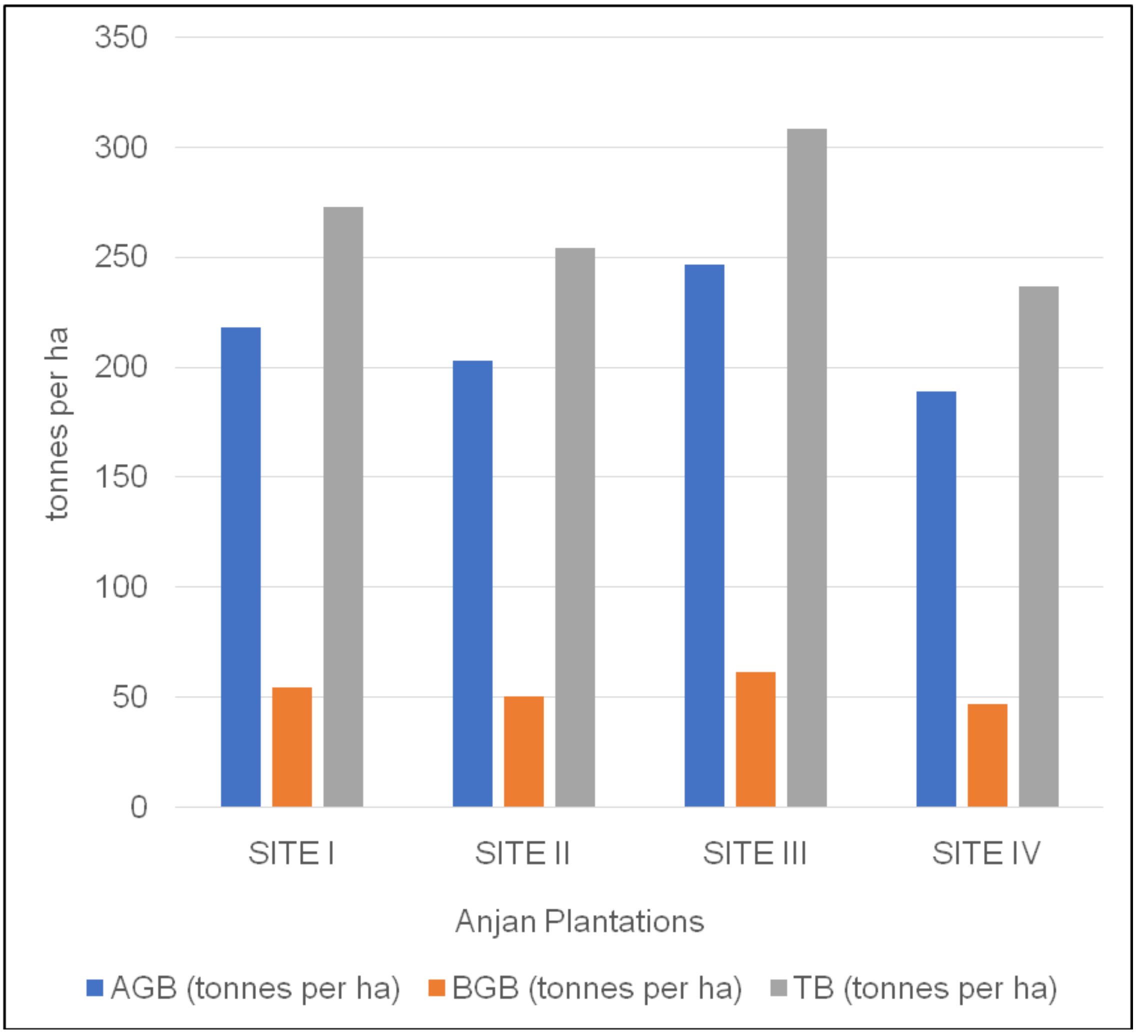


Fig. 1. Assessment of total biomass of *H. binata* plantations

Table 7. Bulk density and soil moisture under *H. binata* tree plantations and without plantation.

Site	Bulk Density (Mg m^{-3})				Soil Moisture (%)			
	00-30 cm Soil Depth	**30-60 cm Soil Depth**	**60-90 cm Soil Depth**	**Mean**	**00-30 cm Soil Depth**	**30-60 cm Soil Depth**	**60-90 cm Soil Depth**	**Mean**
Site I	1.23	1.25	1.32	1.27	7.82	8.80	9.20	8.61
Site II	1.26	1.29	1.32	1.29	7.81	8.44	9.12	8.46
Site III	1.24	1.25	1.28	1.26	6.85	7.24	8.00	7.36
Site IV	1.25	1.26	1.30	1.27	6.40	5.16	5.44	5.67
Mean	**1.25**	**1.26**	**1.31**	**--**	**7.22**	**7.41**	**7.94**	**--**
S.D.	0.0129	0.0189	0.0191	--	0.7103	1.6416	1.7544	--
C.V. (%)	1.0369	1.4994	1.4673	--	9.8385	22.154	22.096	--
ABS I	1.29	1.31	1.34	1.31	5.85	4.38	5.15	5.13
ABS II	1.30	1.32	1.34	1.32	4.74	5.34	5.86	5.31
ABS III	1.31	1.34	1.37	1.34	3.92	4.12	4.89	4.31
ABS IV	1.30	1.33	1.36	1.33	3.98	4.14	5.08	4.40
Mean	**1.13**	**1.19**	**1.22**	**--**	**5.92**	**7.17**	**7.68**	**--**
S.D.	0.0082	0.0129	0.015	--	0.8994	0.5756	0.4245	--
C.V. (%)	0.72	1.0815	1.2294	--	15.19	8.0323	5.5236	--

The higher mean soil moisture (8.61%) was recorded in site I, then in site II (8.46 %), followed by site III (7.36%), whereas, in site IV (5.67%) recorded the minimum value among the three different depths. The highest observed soil moisture was from site I under depth 60-90 cm (9.20%), followed by, site II under depth 60-90 cm (9.12%), whereas, lowest value was recorded in site IV at 00-30 cm depth of soil (6.40%). The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean soil moisture was recorded in site II (5.31%), then in site I (5.13 %), followed by site IV (4.40%), whereas, in site III (4.31%) recorded the minimum value among the three different depths of soil.

4.3.2 Assessment of pH and electrical conductivity of soil under *H. binata* plantations and without plantation.

The assessment of soil pH and EC of *H. binata* plantations were observed for soil samples collected at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The data generated is placed in Table-8. The higher mean pH (7.82) was recorded in site III, then in site II (7.77), followed by (7.71) was observed in site I, whereas, in site IV the pH (7.69) recorded the minimum value among the three different depths of soil.

Table 8. Assessment of pH and electrical conductivity of soil under *H. binata* plantations and without plantation

Site	pH				EC (dS m^{-1})			
	00-30 cm Soil Depth	**30-60 cm Soil Depth**	**60-90 cm Soil Depth**	**Mean**	**00-30 cm Soil Depth**	**30-60 cm Soil Depth**	**60-90 cm Soil Depth**	**Mean**
Site I	7.65	7.68	7.79	7.71	0.18	0.20	0.25	0.21
Site II	7.72	7.78	7.82	7.77	0.21	0.23	0.27	0.24
Site III	7.78	7.82	7.88	7.82	0.22	0.25	0.27	0.25
Site IV	7.64	7.68	7.75	7.69	0.22	0.25	0.29	0.26
Mean	**7.70**	**7.74**	**7.81**	**--**	**0.21**	**0.23**	**0.27**	**--**
S.D.	0.0665	0.699	0.054	--	0.0215	0.244	0.0177	--
C.V. (%)	0.864	0.9037	0.6921	--	10.328	10.42	6.5312	--
ABS I	7.82	7.86	7.93	7.87	0.27	0.30	0.33	0.30
ABS II	7.81	7.85	7.91	7.86	0.29	0.32	0.35	0.32
ABS III	7.86	7.91	7.96	7.91	0.26	0.29	0.33	0.29
ABS IV	7.79	7.82	7.88	7.83	0.28	0.30	0.36	0.31
Mean	**7.82**	**7.86**	**7.92**	**--**	**0.28**	**0.30**	**0.34**	**--**
S.D.	0.0294	0.0374	0.0337	--	0.0129	0.0126	0.015	--
C.V. (%)	0.3765	0.476	0.4251	--	4.6945	4.1597	4.3796	--

Among the given depths of soil, the highest observed soil pH is from site III under depth 60-90 cm (7.88), followed by, site II and site III under depth 60-90 cm and 30-60 cm (7.82) respectively. The lowest value of pH was recorded in site IV 00-30 cm depth of soil (7.64). This decrease in pH may be due to litter fall, which on decomposition is known to produce weak acids (Vijay Shankar Babu, 2007).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean pH (7.91) was recorded in site III, then in site I (7.87), followed by site II (7.86), whereas, in site IV (7.83) recorded the minimum value among the three different depths of soil.

The higher mean EC (0.26 dS m^{-1}) was recorded in site IV, then in site III (0.25 dS m^{-1}), followed by site II (0.24 dS m^{-1}), whereas, in site I (0.21 dS m^{-1}) recorded the minimum value among the three different depths ranges from 0-30 cm, 30-60 cm and 60-90 cm. Among the given depths of soil, the highest observed soil EC was from site IV under depth 60-90 cm (0.29 dS m^{-1}), followed by, site II and site III under depth 60-90 were (0.27 dS m^{-1}) respectively. The lowest value of EC was recorded in site I 00-30 cm depth of soil (0.18 dS m^{-1}).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean EC (0.32 dS m^{-1}) was recorded in site II, then in site IV (0.31 dS m^{-1}), followed by site I (0.30 dS m^{-1}), whereas, in site III (0.29 dS m^{-1}) recorded the minimum value among the three different depths of soil. EC in soil under different depths varies from 0.21–0.24 dS m^{-1}, suggesting the low amount of soluble salt. The variation in high litter fall addition leads to higher values of electric conductivity under the tree plantations.

4.3.3 Assessment of organic carbon and calcium carbonate of soil under *H. binata* plantations and without plantation.

Assessment of organic carbon and calcium carbonate of soil were observed for soil samples collected at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The data generated is placed in Table-9. The higher mean organic carbon was recorded in site III (0.91%), then in site I (0.90%), followed by site II (0.89%), whereas, in site IV (0.88%) recorded the minimum value among the three different depths.

Table 9. Organic carbon and calcium carbonate of soil under *H. binata* plantations and without plantation.

Site	OC (%)				CaCO3 (%)			
	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean
Site I	0.94	0.92	0.84	0.90	4.86	5.54	5.83	5.41
Site II	0.93	0.90	0.83	0.89	4.84	5.53	5.89	5.42
Site III	0.95	0.93	0.85	0.91	4.87	4.95	5.42	5.08
Site IV	0.92	0.90	0.82	0.88	4.81	4.91	5.36	5.03
Mean	**0.935**	**0.9125**	**0.835**	**--**	**4.845**	**5.2325**	**5.625**	**--**
S.D.	0.0129	0.015	0.0129	--	0.0265	0.3497	0.2736	--
C.V. (%)	1.3807	1.6438	1.5461	--	0.5461	6.6833	4.8632	--
ABS I	0.67	0.64	0.57	0.63	6.52	7.47	8.34	7.44
ABSII	0.69	0.65	0.59	0.64	6.74	7.69	8.49	7.64
ABSIII	0.71	0.68	0.63	0.67	6.98	7.63	8.42	7.68
ABS IV	0.65	0.63	0.56	0.61	6.42	7.36	8.23	7.34
Mean	**0.799**	**0.8019**	**0.7349**	**--**	**4.678**	**5.7587**	**6.0674**	**--**
S.D.	0.0258	0.0216	0.031	--	0.2489	0.1504	0.1117	--
C.V. (%)	3.2317	2.6938	4.2123	--	5.3214	2.612	1.8402	--

Among the given depths of soil, the highest observed soil organic carbon was from site III under depth 00-30 cm (0.95%), followed by, site I under depth 00-30 cm (0.94%). The lowest value was recorded in site IV 60-90 cm depth of soil (0.82%).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean OC (0.67%) was recorded in site III, then in site II (0.64%), followed by site I (0.63%), whereas, in site IV (0.61%) recorded the minimum value among the three different depths of soil. The build-up of organic carbon on surface layers of soils may be attributed to the regular accumulation of litterfall in tree species on throughout the age of trees. The subsequent incorporation and decomposition of litterfall in the soil with time might have helped in raising the organic matter status of soil. Increase in organic carbon status under tree species with addition and decomposition of litter fall been reported by Kumar *et al.* (1998).

The higher mean calcium carbonate was recorded in site II (5.42%), then in site I (5.41%), followed by site III (5.08%), whereas, in site IV (5.03%) recorded the minimum value among the three different depths. Among the given depths of soil, the highest observed calcium carbonate was from site II under depth 60-90 cm (5.89%), followed by, site I under depth 60-90 cm (5.83%). The lowest value was recorded in site IV 00-30 cm depth of soil (4.81%). The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. The higher mean calcium carbonate was recorded in site III (7.68%), then in site II (7.64%), followed by site I (7.44%), whereas, in site IV (7.34%) recorded the minimum value among the three different depths of soil.

4.3.4 Assessment of available N, P and K status of soil under *H. binata* plantations and without plantation.

Assessment of nitrogen, phosphorous and potassium of soil were observed for the soil samples collected at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. From the data presented in Table-10 depicted in fig.-2., the higher mean nitrogen was recorded in site III (222.11 Kg ha^{-1}), then in site II (221.25 Kg ha^{-1}), followed by site I (220.60 Kg ha^{-1}), whereas, in site IV (210.76 Kg ha^{-1}) recorded the minimum value. Among the given depths of soil, the highest observed nitrogen was from site III under depth 00-30 cm (229.88 Kg ha^{-1}), followed by, site I under depth 00-30 cm (228.40 Kg ha^{-1}). The lowest value was recorded in site IV 60-90 cm depth of soil (198.10 Kg ha^{-1}). The available N content in the soil showed a general diminishing trend as the depth of the soil increased. Good amount of litter fall addition in the soil lead to higher accumulation of soil N. These are in accordance with the findings of Yadava (2001). In another similar study conducted by Singh *et al.* (2009) at highly degraded site, the nitrogen accumulation due to plantation of MPTs increased and was found 250.88 kg ha^{-1}. Similar findings have been reported by Mohsin and Ram (2002), Yadava (2001) and Singh and Sharma (2007).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. From the data presented in Table-10 depicted in fig.-2., the higher mean nitrogen was recorded in site I (171.24 Kg ha^{-1}), then in site II (171.07 Kg ha^{-1}), followed by site III (170.54 Kg ha^{-1}), whereas, in site IV (168.87 Kg ha^{-1}) recorded the minimum value.

From the data presented in Table-10 depicted in fig.-2., it is observed that, the higher mean phosphorous site I (20.91 Kg ha^{-1}), then in site II (20.02 Kg ha^{-1}), followed by site III (19.51 Kg ha^{-1}), whereas, in site IV (19.39 Kg ha^{-1}) recorded the minimum value. Among the given depths of soil, the highest observed phosphorous was from site I under depth 00-30 cm (21.21 Kg ha^{-1}), followed by site II under depth 00-30 cm (26.53 Kg ha^{-1}). The lowest value was recorded in site IV 60-90 cm depth of soil (11.77 Kg ha^{-1}). The available P improved remarkedly under tree canopies in comparison to barren site which reinforces the earlier findings, Aggarwal *et al*. (1993) reported that there was an increase of 43 % in available P under the *Prosopis cineraria* over the soils in adjacent open fields. Similar improvements in available P under tree canopies have also been observed by Bhola (1995) & Singh *et al.* (2020).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. From the data presented in Table-10 depicted in fig.-2., the higher mean phosphorous was recorded in site II (12.25 Kg ha^{-1}), then in site I (12.18 Kg ha^{-1}), followed by site III (12.02 Kg ha^{-1}), whereas, in site IV (10.65 Kg ha^{-1}) recorded the minimum value.

From the data presented in Table-10 depicted in fig.-2., the higher mean potassium site I (328.39 Kg ha^{-1}), then in site III (326.79 Kg ha^{-1}), followed by site II (325.49 Kg ha^{-1}), whereas, in site IV (319.13 Kg ha^{-1}) recorded the minimum value. Among the given depths of soil, the highest observed potassium was from site II under depth 00-30 cm (332.35 Kg ha^{-1}), followed by site III under depth 00-30 cm (331.92 Kg ha^{-1}), lowest value recorded in site IV 60-90 cm depth of soil (313.24 Kg ha^{-1}).

The soil samples collected from the adjacent barren site at three depths (00-30 cm and 30-60 cm and 60-90 cm) and analyzed. From the data presented in Table-10 depicted in fig.-2., The higher mean phosphorous was recorded in site II (12.25 Kg ha^{-1}), then in site I (12.18 Kg ha^{-1}), followed by site III (12.02 Kg ha^{-1}), whereas, in site IV (10.65 Kg ha^{-1}) recorded the minimum value.

The higher potassium content under plantations might be due to the litterfall and presence of good number of grasses on site. These results were in agreement with the findings of Swamy *et al.* (2006) and also with the studies conducted by Singh and Sharma (2007). They noticed that higher organic carbon (OC) and available nitrogen, phosphorus and potassium content were observed in the soil under plantations than from a site without trees. Higher build-up of available nutrients (N, P and K) on surface layers under tree species is attributed to accumulation and decomposition of litterfall on the soil surface as well as its incorporation in the soil surface layers. It leads to mineralization of organic N and P from the litter and its release into the soil. Higher availability of K at surface layers under trees is attributed to liberation of K by decomposition process of litterfall as well as solubilization of insoluble forms of K present in soil due to organic products. The differences in available nutrient content under different species might be due to variation in nutrient concentration of litter, total litter production and varying rates of mineralization in these species. Yadav *et al.* (2008), Das and Chaturvedi (2008) reported improvement in soil chemical properties under different tree species.

Table 10. Available N, P and K of soil under *H. binata* tree plantation and without plantation

Site	Available N (Kg ha^{-1})				Available P (Kg ha^{-1})				Available K (Kg ha^{-1})			
	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean
Site I	228.40	220.37	213.04	220.60	28.21	20.68	13.83	20.91	331.30	327.50	326.37	328.39
Site II	226.92	221.97	214.85	221.25	26.53	20.60	12.94	20.02	332.35	325.10	319.03	325.49
Site III	229.88	222.23	214.21	222.11	21.80	21.81	14.93	19.51	331.92	327.99	320.47	326.79
Site IV	220.46	213.71	198.10	210.76	25.51	20.90	11.77	19.39	324.05	320.09	313.24	319.13
Mean	**226.42**	**219.57**	**210.05**	**--**	**25.51**	**21.00**	**13.37**	**--**	**329.90**	**325.17**	**319.78**	**--**
S.D.	4.1498	3.9923	8.0013	--	2.7138	0.5563	1.3391	--	3.9265	3.6136	5.3925	--
C.V.(%)	1.8328	1.8182	3.8092	--	10.637	2.6495	10.017	--	1.1902	1.1113	1.6863	--
ABS I	178.51	173.85	161.36	171.24	14.18	12.75	9.61	12.18	288.3	281.60	279.5	283.13
ABS II	177.87	171.82	163.52	171.07	15.26	12.00	9.48	12.25	291.54	284.61	280.57	285.57
ABS III	178.45	170.84	162.32	170.54	13.97	12.60	9.50	12.02	279.56	276.36	273.54	276.49
ABS IV	177.55	169.45	159.62	168.87	12.80	10.40	8.75	10.65	287.42	280.60	272.35	280.12
Mean	**168.22**	**162.69**	**155.35**	**--**	**17.92**	**14.18**	**10.50**	**--**	**254.68**	**250.34**	**246.54**	**--**
S.D.	0.464	1.8496	1.6471	--	1.0083	1.075	0.3942	--	5.0821	3.4112	4.1452	--
C.V.(%)	0.2758	1.1368	1.0602	--	5.6265	7.5829	3.7527	--	1.9955	1.3626	1.6814	--

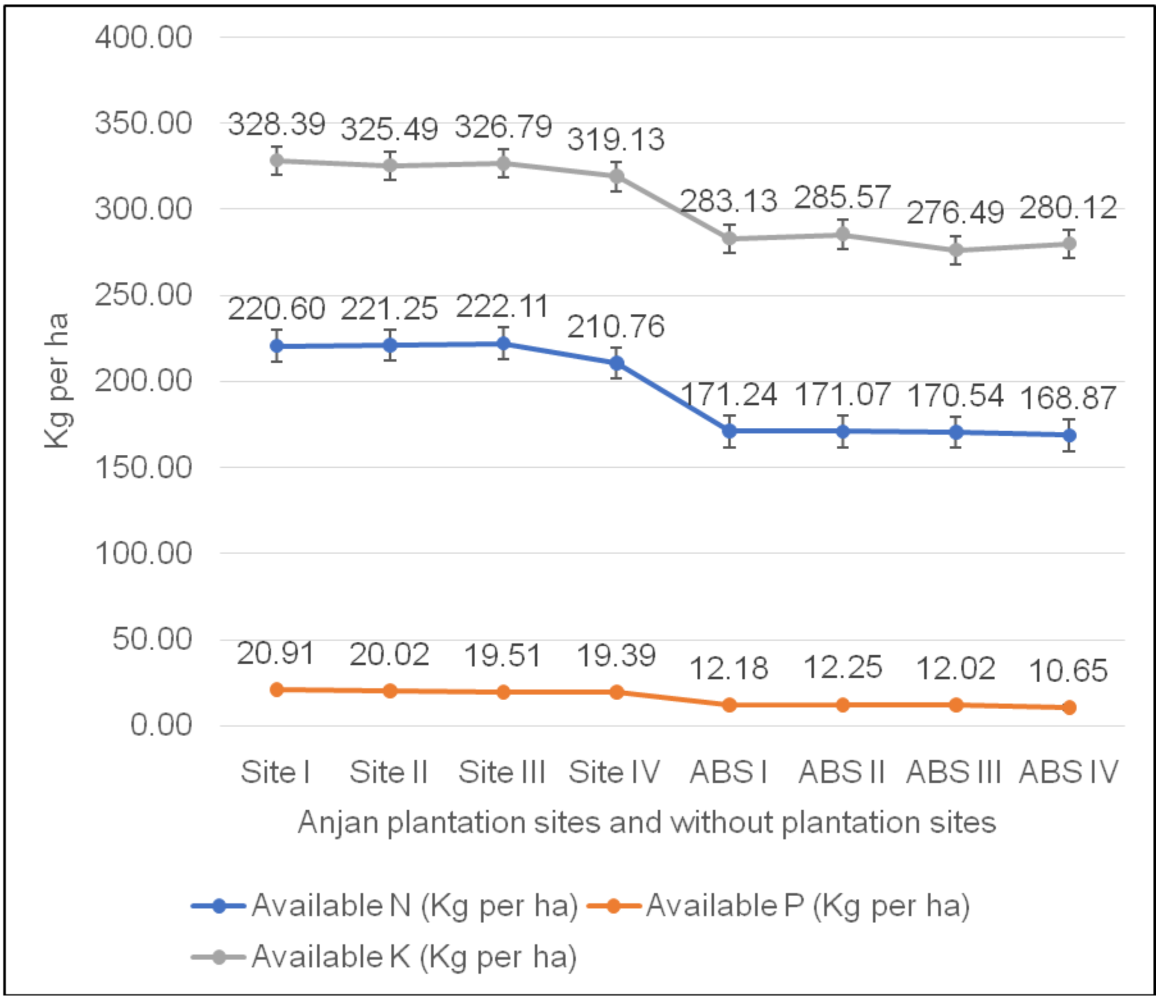


Fig. 2. Assessment of available Nitrogen (N), Phosphorous (P) and Potassium (K) status of soil under *H. binata* plantations and without plantation

4.4 Assessments of soil microbial population

4.4.1 Enumeration of fungal population count of soil under *H. binata* plantation and without plantation

During experimentation, we were recorded the observations on population of soil fungi under *H. binata* plantation and nearby barren site. For the enumeration of fungal population from rhizosphere of *H. binata* plantations, serial dilution plate method (Latha and Gopal 2010) and media of Potato Dextrose Agar (PDA) was used. The fungal population was estimated after 5 days of incubation on PDA medium by using colony counter. The results presented in Table 11, depicted in fig.3. It was revealed from data, observed that highest fungal population recorded in site III i.e. (10.40×10^5cfu g^{-1} soil), followed by site II (10.30×10^5 cfu g^{-1} soil), site I (10.27×10^5cfu g^{-1} soil) and site IV (10.13×10^5cfu g^{-1} soil).

If we compared it with adjacent barren site without plantation, at site ABS I and ABS III recorded only (7.57×10^5cfu g^{-1} soil), ABS II (7.47×10^5cfu g^{-1} soil) and ABS IV recorded (7.23×10^5cfu g^{-1} soil). The soil under *H. binata* Plantation recorded high fungal population as compared to soil without plantation.

For 0-30 cm depth of soil, all plantation sites contain (11.35×10^5cfu g^{-1} soil) fungal population at all ABS contain (8.41×10^5cfu g^{-1} soil), whereas 30-60 cm depth at all site under plantation soil contains (10.23×10^5cfu g^{-1} soil) and at all ABS contain (7.36×10^5cfu g^{-1} soil) fungal population, whereas at 60-90 cm depth all site under plantation soil contains (9.25×10^5cfu g^{-1} soil) and all ABS contain (6.75×10^5cfu g^{-1} soil) fungal population.

From the above observation the highest fungal population observed in upper layer 0-30 cm of soil. Fungal count is reduced in deep soil layer i.e., 30-60 cm and 60-90 cm soil under *H. binata* plantation. Similarly, *H. binata* plantations suppose the growth of fungi if we compared the observations with soil of ABS. Similar results were reported by Chandra *et al.* (2010) that the microbial population comprised of actinomycetes, bacteria and fungi was significantly higher in soil under trees than unplanted soils adjacent to the area, total microbial counts excluding mycorrhiza ranged from ($31x10^6$ to $89.8x10^6$cfu g^{-1} soil) with a mean of about ($47.27x10^6$cfu g^{-1} soil), which were composed of (14.36%) actinomycetes, (51.02%) bacteria and (34.5%) fungi. Also, Kanagaraj *et al.* (2017) resulted the fungal population was enumerated from (32 x 10^3 to $90x10^3$cfu g^{-1} soil) in tropical thorn forest. Similar improvements in fungal population under tree plantation soil have also been observed by Kayang (2006), Das *et al.,* (2013), Bhattarai *et al.,* (2015) and Mandal *et al.* (2023).

4.4.2 Enumeration of bacterial population count of soil under *H. binata* plantation and without plantation

During experimentation, we were recorded the observations on population of soil bacteria under *H. binata* plantation and nearby barren site. For estimation of bacterial population from rhizosphere of *H. binata* plantations, serial dilution plate method (Vincent, 1970) and media of Nutrient Agar (NA) was used. The bacterial population was estimated after 5 days of incubation on NA medium by using colony counter. The results presented in Table 11, depicted in fig.3. It was revealed from data, observed that highest bacterial population recorded in site I and site III i. e. (2.00×10^7cfu g^{-1} soil), followed by site II (1.99×10^7 cfu g^{-1} soil), site IV (1.98×10^7cfu g^{-1} soil).

If we compared it with adjacent barren site without plantation, at ABS III recorded only (1.56×10^7cfu g^{-1} soil), ABS I and ABS II (1.53×10^7cfu g^{-1} soil) and ABS IV recorded (1.50×10^7cfu g^{-1} soil). The soil under *H. binata* Plantation recorded high bacterial population as compared to soil without plantation. For 0-30 cm depth of soil, all plantation sites contain (2.25×10^7cfu g^{-1} soil) bacterial population at all ABS contain (1.72×10^7cfu g^{-1} soil), whereas 30-60 cm depth at all site under plantation soil contains (2.02×10^7cfu g^{-1} soil) and at all ABS contain (1.48×10^7cfu g^{-1} soil) bacterial population, whereas at 60-90 cm depth all site under plantation soil contains (1.72×10^7cfu g^{-1} soil) and all ABS contain (1.32×10^7cfu g^{-1} soil) bacterial population.

From the above observation the highest bacterial population observed in upper layer 0-30 cm of soil. Bacterial count is reduced in deep soil layer i.e., 30-60 cm and 60-90 cm soil under *H. binata* plantation.

Similarly, *H. binata* plantations suppose the growth of fungi if we compared the observations with soil of ABS. The similar results were depicted by the Kanagaraj *et al.* (2017) in tropical thorn forest, the total viable bacteria count ranged from (13 x 10^3cfu g^{-1} to 45 x 10^5cfu g^{-1} of soil). And also reported by Chandra *et al.* (2010). Similar improvements in bacterial population under tree plantation soil have also been observed by Kumar *et al.,* (2017), Soman *et al.,* (2018) and Asiya *et al.* (2019).

4.4.3 Enumeration of actinomycetes population count of soil under *H. binata* plantation and without plantation

During experimentation, we were recorded the observations on population of soil actinomycetes under *H. binata* plantation and nearby barren site. For the enumeration of actinomycetes population from rhizosphere of *H. binata* plantations, serial dilution plate method (Vincent, 1970) and the Munairs and Kenknight medium was used. The actinomycetes population was estimated after 5 days of incubation on Munairs and Kenknight medium by using colony counter. The results presented in Table 11, depicted in fig.3. It was revealed from data, observed that highest actinomycetes population recorded in site III i. e. (4.43×10^6cfu g^{-1} soil), followed by site II (4.40×10^6 cfu g^{-1} soil), site I (4.33 ×10^6cfu g^{-1} soil) and in site IV (4.20 ×10^6cfu g^{-1} soil).

If we compared it with adjacent barren site without plantation, at ABS III recorded only (3.00×10^6cfu g^{-1} soil), ABS I (2.90×10^6cfu g^{-1} soil), ABS II recorded (2.80×10^7cfu g^{-1} soil) and in ABS IV (2.57×10^6cfu g^{-1} soil). The soil under *H. binata* Plantation recorded high actinomycetes population as compared to soil without plantation.

For 0-30 cm depth of soil, all plantation sites contain (5.33 x 10^6cfu g^{-1} soil) actinomycetes population at all ABS contain (3.92 x 10^6cfu g^{-1} soil), whereas 30-60 cm depth at all site under plantation soil contains (4.45 x 10^6cfu g^{-1} soil) and at all ABS contain (3.45 x 10^6cfu g^{-1} soil) actinomycetes population, whereas at 60-90 cm depth all site under plantation soil contains (3.25×10^6cfu g^{-1} soil) and all ABS contain (2.67×10^6cfu g^{-1} soil) actinomycetes population.

Table 11. Microbial count of soil under *H. binata* plantations and without plantations.

Site	Fungi (10^5cfu g^{-1} soil)				Bacteria (10^7cfu g^{-1} soil)				Actinomycetes (10^6cfu g^{-1} soil)			
	00-30 cm Soil Depth	30-60 cm Soil Depth	60-90 cm Soil Depth	Mean	00-30 cm Soil Depth	30-60 cm	60-90 cm soil depth	Mean	00-30 cm soil depth	30-60 cm soil depth	60-90 cm soil depth	Mean
Site I	11.40	10.20	9.20	10.27	2.24	2.02	1.73	2.00	5.20	4.50	3.30	4.33
Site II	11.30	10.20	9.40	10.30	2.25	2.01	1.71	1.99	5.30	4.70	3.20	4.40
Site III	11.50	10.40	9.30	10.40	2.26	2.02	1.72	2.00	5.50	4.40	3.40	4.43
Site IV	11.20	10.10	9.10	10.13	2.24	2.01	1.70	1.98	5.30	4.20	3.10	4.20
Mean	**11.35**	**10.23**	**9.25**	**--**	**2.25**	**2.02**	**1.72**	**--**	**5.33**	**4.45**	**3.25**	**--**
S.D.	0.1291	0.1258	0.1291	--	0.0096	0.0058	0.0129	--	0.1258	0.2082	0.1291	--
C.V. (%)	1.1374	1.2306	1.3957	--	0.426	0.2865	0.7528	--	2.363	4.6779	3.9723	--
ABS I	8.70	7.30	6.70	7.57	1.81	1.48	1.29	1.53	3.60	2.80	2.30	2.90
ABS II	8.60	7.20	6.60	7.47	1.82	1.49	1.28	1.53	3.50	2.70	2.20	2.80
ABS III	8.80	7.10	6.80	7.57	1.84	1.51	1.33	1.56	3.70	2.90	2.40	3.00
ABS IV	8.40	6.90	6.40	7.23	1.78	1.46	1.25	1.50	3.20	2.40	2.10	2.57
Mean	**8.41**	**7.36**	**6.75**	**--**	**1.72**	**1.48**	**1.32**	**--**	**3.92**	**3.45**	**2.67**	**--**
S.D.	0.1708	0.1708	0.1708	--	0.025	0.0208	0.033	--	0.216	0.216	0.1291	--
C.V. (%)	2.0306	2.3198	2.5293	--	1.4533	1.4042	2.5081	--	5.5116	6.2639	4.8383	--

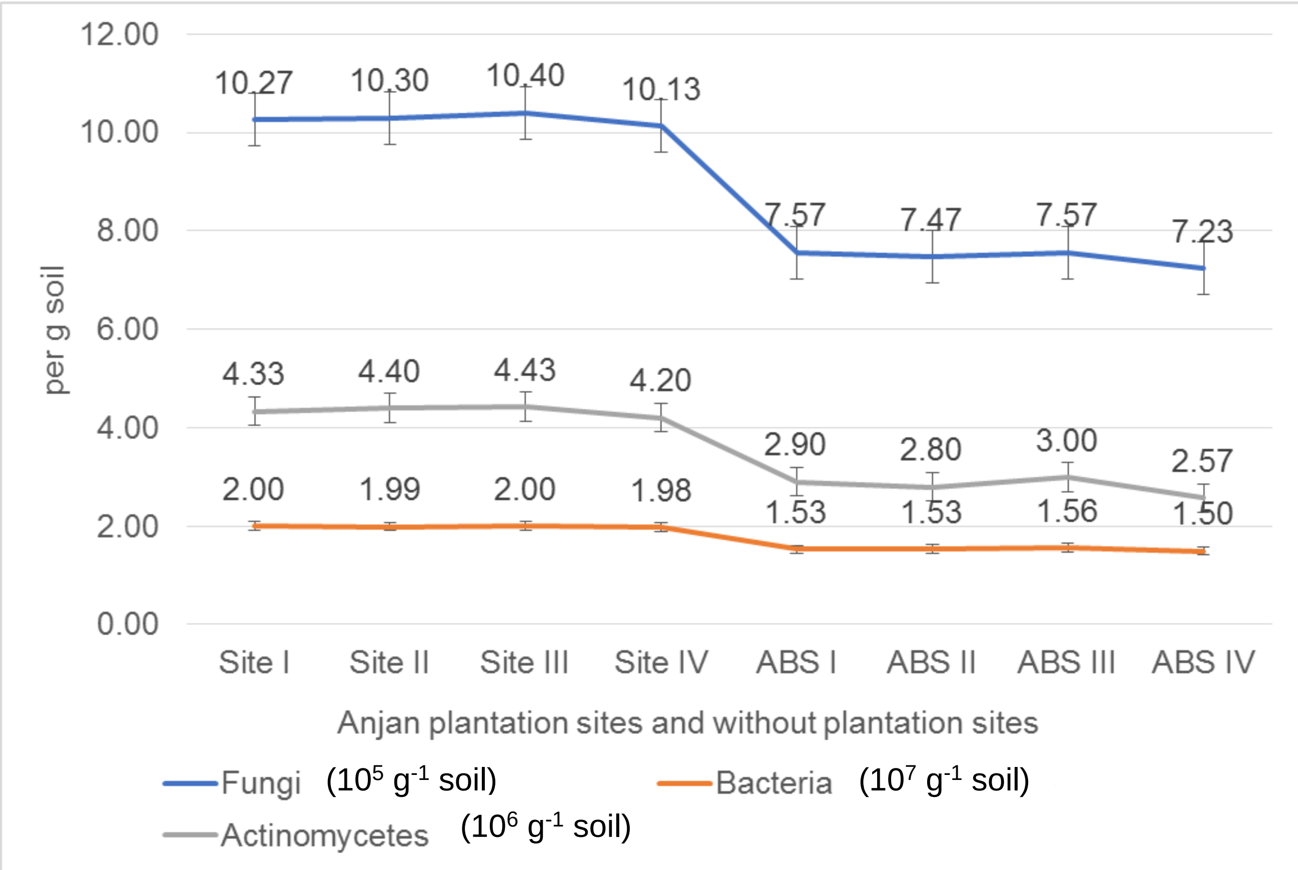
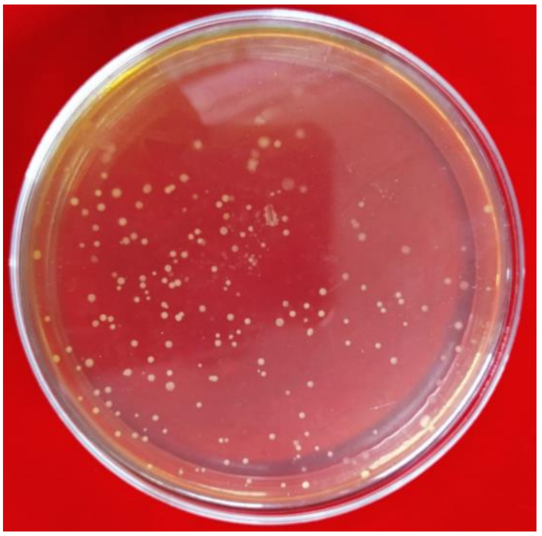
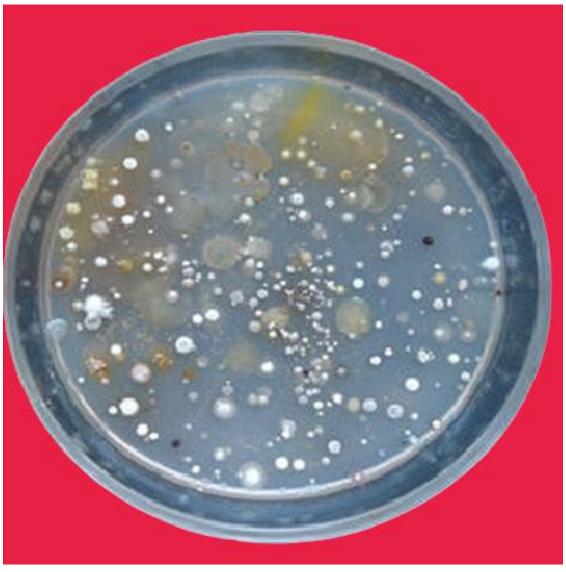


Fig. 3. Assessment of microbial population count of soil under *H. binata* plantation and without plantation

A) Fungal colonies



B) Bacterial colonies



C) Actinomycetes colonies

Plate 7: Soil microbial population under *H. binata* plantation and without plantations

From the above observation the highest actinomycetes population observed in upper layer 0-30 cm of soil. Actinomycetes count is reduced in deep soil layer i.e., 30-60 cm and 60-90 cm soil under *H. binata* plantation. Similarly, *H. binata* plantations suppose the growth of fungi if we compared the observations with soil of ABS. The similar results were depicted by the Kanagaraj *et al.* (2017) in tropical thorn forest, actinomycetes population ranged from (22 x 10^4 to 53 x 10^4cfu g^{-1} soil). However, this indicated that in tropical thorn forest soil, fungal population was predominantly thrived followed by actinomycetes and bacteria. Kumar *et al.,* (2017) assessed soil samples from two depths i.e., 0-15cm and 15-30cm. For given samples the actinomycetes count (15.81 and 8.43cfu g^{-1} soil) recorded higher in surface and subsurface soils under forest land and lowest under scrub land soils. Similar improvements in actinomycetes population under tree plantation soil have also been observed by Akande and Adekayode (2019), Singh and Tripathi (2020) and Mirza and Patil (2022).

4.5 Assessment of biomass, soil parameters and microbial population of soil under *H. binata* plantations.

The result given in Table-12 revealed that all the soil parameters are influenced due to total biomass produced by *H. binata* plantation sites. The highest plant height (15.79 m), GBH (76.76 cm), volume (44.51 m^3 ha^{-1}) and total biomass (308.53 t ha^{-1}) were recorded under site I of *H. binata*. The pH, EC and OC value decreased while calcium carbonate, available nitrogen, available phosphorus and available potassium value in soil was increased under all sites of *H. binata* at different soil depth compared to barren sites. The mean maximum OC (0.91%) of site III, calcium carbonate (5.42%) of site II, available N (222.11 kg ha^{-1}) of site III, available P (20.91 kg ha^{-1}) of site I and available K (328.39 kg ha^{-1}) of site I noted within plantation. While, the mean maximum OC (0.67%) of site III, calcium carbonate (7.68%) of site III, available N (171.24 kg ha^{-1}) of site I, available P (12.25 kg ha^{-1}) of site II and available K (285.87 kg ha^{-1}) of site II noted without plantation. However, soil health in terms of physico-chemical and biological parameters showed improvement under all the tree species than the control (adjacent barren site).

Tabel 12. Comparative analysis for assessment of biomass, soil parameters and microbial population of soil under *H. binata* plantations.

Site	Age	Volume	Biomass	BD	SM	pH	EC	OC	$CaCO_3$	N	P	K	Fungi	Bacteria	Actinomycetes
Unit	Yr.	t/ha	t/ha	Mg/m^3	%	--	dSm^{-1}	%	%	kg/ha	kg/ha	kg/ha	10^5cfu g^{-1} soil	10^7cfu g^{-1} soil	10^6cfu g^{-1} soil
Site I	30-35	34.33	272.95	1.27	8.61	7.71	0.21	0.90	5.41	220.60	20.91	328.39	10.27	2.00	4.33
Site II	25-30	29.66	254.36	1.29	8.46	7.77	0.24	0.89	5.42	221.25	20.02	325.49	10.30	1.99	4.40
Site III	35-40	44.50	308.53	1.26	7.36	7.82	0.25	0.91	5.08	222.11	19.51	326.79	10.40	2.00	4.43
Site IV	25-30	24.59	236.81	1.27	5.67	7.69	0.26	0.88	5.03	210.76	19.39	319.13	10.13	1.98	4.20
ABS I	--	--	--	1.31	5.13	7.82	0.30	0.63	7.44	171.24	12.18	283.13	7.57	1.53	2.90
ABS II	--	--	--	1.32	5.31	7.86	0.32	0.64	7.64	171.07	12.25	285.57	7.47	1.53	2.80
ABS III	--	--	--	1.34	4.31	7.91	0.29	0.67	7.68	170.54	12.02	276.49	7.57	1.56	3.00
ABS IV	--	--	--	1.33	4.40	7.83	0.31	0.61	7.34	168.87	10.65	280.12	7.23	1.50	2.57

The analysis of soil microflora under *H. binata* sites demonstrated a diverse and active microbial community. The mean maximum population of fungi (10.40×10^5cfu g^{-1} soil) of site III, bacteria (2.00×10^7cfu g^{-1} soil) of site I and site III and actinomycetes (4.43×10^6cfu g^{-1} soil) of site III noted within plantation. While, the mean maximum population of fungi (7.57×10^5cfu g^{-1} soil) of site I and site III, bacteria (1.56×10^7cfu g^{-1} soil) of site I and actinomycetes (3.00×10^6cfu g^{-1} soil) of site III noted without plantation. Bacterial and fungal populations were abundant within plantation, contributing to nutrient cycling and soil health. The analysis of soil microflora under *H. binata* plantations demonstrated a diverse and active microbial community. This comparative analysis highlights the significance of *H. binata* in promoting tree productivity and maintaining soil fertility in the ecosystem. Understanding the intricate relationship between this tree species and the physicochemical properties of soil microflora is essential for effective conservation and management practices in these regions, which can have broader implications for sustainable land use and forest management.

CHAPTER V

SUMMARY AND CONCLUSION

The summary and conclusion of results emerging from the present investigation undertaken to elucidate the **"Assessment of Tree Productivity, Physico-Chemical Properties and Microflora of Soil under *Hardwikia binata* Roxb."** was carried out at various locations in the premises of Dr. Panjabarao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during 2022-23 are presented in this chapter.

The investigation is being conducted with the following objectives:

1. To study productivity and accumulation of biomass of *Hardwickia binata*.
2. To assess the physico-chemical properties of soil under *H. binata*.
3. To enumerate the soil microflora under plantations of *H. binata*.

For study of tree productivity, biomass and microflora; three quadrates of size 10x10m was laid out in each plantation. All the trees within quadrate were enumerated for following biophysical measurements of productivity and biomass of *Hardwickia binata*. Sampling was done according to standard procedure. In each sample plot one pit was dug out within each sample plot for collection of soil samples at three different depth (0-30 cm, 30-60 cm and 60-90 cm).

The observations were recorded on phytosociology viz., basal area, volume, aboveground, belowground and total biomass. Soil samples were analyzed for soil determination of its physico-chemical and biological properties viz., pH, electrical conductivity, bulk density, soil moisture, $CaCO_3$, OC, available N, available P and available K and microbial status of soil for the estimation of colonies of fungi, bacteria and actinomycetes.

A brief summary of the results emerging out from present investigation are presented as below:

5.1 Tree growth parameters

5.1.1 Mean height and girth at breast height (GBH)

The highest (15.79 m) mean height was found in site III plantation followed by site I (14.37 m) plantation, site II plantation (13.64 m) and site IV plantation (12.44 m). Also, the mean diameter was found to be in site III plantation (76.76 cm), site I plantation (70.69 cm), site II plantation (67.45 cm) and in site IV plantation (64.34 cm).

5.1.2 Basal area

The basal area (m^2 ha^{-1}) recorded in site III, site I, site II and site IV were (4.69 m^2 ha^{-1}), (3.98 m^2 ha^{-1}), (3.62 m^2 ha^{-1}) and (3.30 m^2 ha^{-1}) respectively.

5.1.3 Volume of trees

The maximum (44.50 m^3 ha^{-1}) volume was recorded in site III, followed by site I (34.34 m^3 ha^{-1}), while in site II and site IV it was recorded (29.66 m^3 ha^{-1}) and (24.60 m^{-3} ha^{-1}) respectively.

5.1.4 Total standing tree biomass

The minimum (236.81 tonne ha^{-1}) total standing tree biomass was found in*,* site IV, whereas, (254.36 tonne ha^{-1}), (272.95 tonne ha^{-1}) and (308.53 tonne ha^{-1}) in site II, site I and site III respectively.

5.2 Soil parameters

5.2.1 Bulk density (BD) and soil moisture (SM)

The mean bulk density maximum mean in site II (1.29 Mg m^{-3}), whereas, (1.27 Mg m^{-3}) in site I and site IV respectively and minimum (1.26 Mg m^{-3} Mg m^{-3}) in site III. For the adjacent barren site mean bulk density, maximum in (1.34 Mg m^{-3}) site III, followed by (1.33 Mg m^{-3}), (1.32 Mg m^{-3}) and (1.31 Mg m^{-3}) in site IV, site II and site I respectively.

The mean soil moisture, maximum (8.61%) in site I, whereas, (8.46%), (7.36%) and (5.67%) in site II, site III and site IV respectively and for adjacent barren site mean soil moisture, maximum (5.31%) in site II, whereas (5.13%), (4.40%) and (4.31%) in site II, site IV and site III respectively.

5.2.2 Soil pH and electrical conductivity (EC)

The maximum (7.82) mean pH was observed in site III and minimum in site IV (7.69) and for the adjacent barren site the maximum pH was (7.91) in site III and minimum in site IV (7.83).

The maximum mean EC (0.26 dS m^{-1}) in site IV and minimum in site I (0.21 dS m^{-1}). For the adjacent barren site maximum EC (0.32 dS m^{-1}) in site II and minimum in site III (0.29 dS m^{-1}).

5.2.3 Soil organic carbon (OC) and calcium carbonate ($CaCO_3$)

The mean organic carbon under site III (0.91%), was found significantly higher than site I (0.90%), site II (0.89%), and site IV (0.88%) plantation respectively. For adjacent barren site higher in site III (0.67%), followed by site II (0.64%), site I (0.63%) and site IV (0.61%) respectively.

The mean calcium carbonate under site IV (5.03%) minimum than site III (5.08%), site I (5.41%) and site II (5.42%) plantation respectively. For adjacent barren land site IV (7.34%) minimum than site I (7.44%), site (7.64%) and site III (7.68%) respectively.

5.2.4 Available N, P and K

Available N, P and K are found to be decreased with increasing soil depth. The highest (222.11 and 328.39 kg ha^{-1}) available N and K found in soil under site III and site I respectively. Whereas highest (20.91 kg ha^{-1}) available P was found in soil under site I plantation. For the adjacent barren site highest (171.24 and 285.57 kg ha^{-1}) available N and K in soil under site I and site II respectively. Whereas highest (12.25 kg ha^{-1}) available P was found in the site II plantation.

5.3 Microbial population

Microbial population viz., fungi, bacteria and actinomycetes was found decreased with the increasing soil depth. The highest mean fungi population (10.40×10^5cfu g^{-1} soil) and actinomycetes population (4.43×10^6cfu g^{-1} soil) found in soil under site III plantations. The highest mean bacterial population (2.00×10^7cfu g^{-1} soil) found in soil under site I and site II plantations respectively. For the adjacent barren site plantations, the highest mean fungi population (7.57×10^5cfu g^{-1} soil) found in soil under site I and site III plantations respectively, whereas, highest mean actinomycetes (3.00×10^6cfu g^{-1} soil) and bacterial (1.56×10^7cfu g^{-1} soil) population found in soil under site III plantation.

Conclusions

Based on the results obtained during the course of investigation, it can be concluded that assessment of tree productivity, physicochemical properties, and soil microflora under *Hardwickia binata* plantations suggests a comprehensive understanding of the ecosystem. The interplay between tree productivity and soil characteristics, including physicochemical properties and microbial population, is crucial for ecosystem health. Further research and sustainable management practices can be explored based on these findings to promote biodiversity and environmental resilience.

To draw a conclusion on the physicochemical properties of soil under *H. binata*, it is essential to analyses the specific findings from the assessment. Consider factors like bulk density, soil moisture, pH, electrical conductivity, organic carbon, calcium carbonate, available N, available P, available K and microbial status viz., fungi, bacteria and actinomycetes. Assessing these properties can provide insights into the soil fertility, potential for plant growth, and overall ecosystem health under *H. binata*.

The impact of *H. binata* plantation on soil microbial population appears to be multifaceted. While the presence of this plants may contribute to specific changes in the soil microbiome, a conclusive assessment would require detailed studies considering factors such as soil composition, environmental conditions, and plant-microbe interactions. Additional research is recommended to fully understand the various effects of *H. binata* plantations on soil microflora.

CHAPTER VI

LITERATURE CITED

Aggarwal, R. K., P. Kumar and P. Raina, 1993. Nutrient availability from sandy soils underneath *Prosopis cineraria* compared to adjacent open site in an arid environment. *The Indian Forester*, 119 (1-6): 321-325.

Akande, G. M., F. O. Adekayode and F. O. Adekayode, 2019. Identification of soil microbial population under different land use. *Trop. Plant Res*, *6*(1), 90-100.

Asiya, P., M. Menon, G. Gopi and V. Das, 2019. Impact of Cropping Systems on Soil Microbial Load: Evidence from Wetland Ecosystems of Wayanad District, Kerala. *Mapana Journal of Sciences*, *18*(4), 1.

Augusto, L., J. Ranger, D. Binkley and A. Rothe, 2002. Impact of several common tree species of European temperate forests on soil fertility. *Ann. For*. *Sci*., 59: 233–253.

Bargali, S. S. and S. P. Singh, 1991. Aspects of productivity and nutrient cycling in an 8-year-old *Eucalyptus* plantation in a moist plain area adjacent to central Himalaya, India. *Canadian Journal of Forest Res*., 21 (9): 1365-1372.

Basanta, S. T., K. Nandini Devi, K. Y. Bijen, K. S. L. Bishworjit, Nongdren and S. A. Herojit, 2013. Characterization, and evaluation for crop suitability in lateritic soils. *African Journal of Agricultural Research*, *8*(37), 4628-4636.

Bhattarai, A., B. Bhattarai and S. Pandey, 2015. Variation of soil microbial population in different soil horizons. *Journal Microbiol Exp, 2*(2), 00044.

Bhattacharyya, P. N. and D. K. Jha, 2015. Variations in bacterial population numbers and enzyme activities in different land-use systems of Brahmaputra valley, Assam. *IJAR*, *1*(12), 762-766.

Bhola, N., 1995. Studies on relative growth performance and soil enrichment potential of some nitrogen fixing trees, M.Sc. Thesis, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, India, 1995, 14.

Binkley, D., 1986. Forest Nutrition and Management. Wiley, New York.

Binkley, D., A. M. O'Connell and K. V. Sankaran, 1997. Stand development and productivity. In: Nambiar, E. K. S., A. G. Brown (Eds.), Management of soil, nutrients and water in tropical plantation forests. ACIAR/ CSIRO/ CIFOR, ACIAR, Canberra, Australia, pp. 419±442.

Blake, G. R. and K. H. Hartge, 1986. Bulk density. In: Methods of soil analysis, part-I, Klute, A. (Ed.). *American Society of Agronomy Inc.* and *Soil Science.*

Chambial, A., 2016. Carbon sequestration potential of different multipurpose tree species. *Journal of Agriculture and Veterinary Science,* 9 (5): 11-14.

Chandra, K.K., K. Niraj, V. Avinash and A. K. Saxena, 2010. Influence of tree plantations on physico-chemical properties and microflora of soil. Indian *Journal of Agroforestry*, 12(1), pp.84-90.

Chaturvedi, A. N. and L. S. Khanna, 1981. *Forest Mensuration.* International book distributors, Dehra Dun, 183–202.

Chauhan, S. K., S. Singh, S. Sharma, B. B. Vashist, R. Sharma and H. S. Saralch, 2018. Soil health (physical, chemical and biological) status under short rotation tree plantations on riverain soils. *Journal of Pharmacognosy and Phytochemistry,*7 (5): 1599-1605.

Chauhan, S. K., S. Singh, S. Sharma, R. Sharma and H. S. Saralch, 2019. Tree biomass and carbon sequestration in four short rotation tree plantations. *Range Mgmt. and Agroforestry*, 40 (1): 77-82.

Chavan, B. L. and G. B. Rasal, 2011. Potentiality of carbon sequestration in six-year ages young plant from university campus of Aurangabad. *Global Journal of Researches in Engineering,* 11 (7): 15-20.

Chavan, B. L. and G. B. Rasal, 2011. Sequestered carbon potential and status of *Eucalyptus* tree. *International Journal of Applied Engineering and Technology,* 1 (1): 41-47.

Chavan, B. L. and G. B. Rasal, 2011. Sequestered carbon stalk in young *Annona reticulata* plant in Aurangabad. *Proceeding of International conference on Climate change and social issues, Sri Lanka.* 69-73.

Costa, J., R. S. Oliveira, I. Ma Y. Tiago, C. Galhano, H. Freitas and P. Castro, 2018. Soil microorganisms. In Advances in plant ecophysiology techniques (pp. 457-482). Springer, Cham.

Das, D. K. and O. P. Chaturvedi, 2008. Root phytomass recovery and rooting characteristics of five agroforestry tree species in eastern India. *Journal of Tropical Forest*, 20: 156-166.

Das, K., R. Nath and P. Azad, 2013. Soil microbial diversity of Dibru-Saikhowa biosphere reserve forest of Assam, India. *Global Journal of Science Frontier Research Biological Science*, *13*(3), 7-13.

Das, M., 2016. Appraisal of carbon sequestration potential of *H. binata* Roxb. based silvopastoral system. M.Sc. Thesis, Akola Agricultural University, Akola, (Maharashtra).

Devi, K. D., M. M. Kannan, C. T. Abraham and S. Beena, 2007. Persistence of herbicides and its impact on soil micro flora in rice-rice system. *Journal of Crop and Weed,* 3(1), 3-8.

Dhinesh, K. S., S. Radhakrishnan, A. Balasurbramanian and K. Sivakumar, 2019. Comparative study of soil nutrient status in three forest types of Dhrampuri Forest circle, Tamil Nadu, South India. *International Journal of Current Microbiology and Applied Sciences*, *8*(2), 1613-1621.

Ericsson, T., 1995. Growth and shoot: root ratio of seedlings in relation to nutrient availability. In Nutrient uptake and cycling in forest ecosystems (pp. 205-214). Springer, Dordrecht.

Forest Survey of India, 1996. Volume equations for forests of India, Nepal and Bhutan. Published by Director, Forest Survey of India Dehra Dun-248195 and printed at Saraswati Press Dehra Dun - 248001, 249.

Ganesan, P., A. D. Reegan, R. H. A. David, M. R. Gandhi, M. G. Paulraj, N. A. Al-Dhabi and S. Ignacimuthu, 2017. Antimicrobial activity of some actinomycetes from Western Ghats of Tamil Nadu, India. *Alexandria journal of medicine*, 53(2), 101-110.

Gerdemann, J.W. and T.H. Nicolson, 1963. Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. *Transactions of the British Mycological society*, 46(2), pp.235-244.

Hota, S., V. Mishra, K. K. Mourya, K. Giri, D. Kumar, P. K. Jha and S. K. Ray, 2022. Land use, landform, and soil management as determinants of soil physicochemical properties and microbial abundance of Lower Brahmaputra Valley, India. Sustainability, 14(4), 2241.

Hiltner, L., 1904. About recent experiences and problems in the field of soil bacteriology with special consideration of foundation and fallow land. Works of the German Agricultural Society, 98, pp.59-78.

Hinsinger, P., 1998. How do plant roots acquire mineral nutrients? Chemical processes involved in the rhizosphere. *Advances in agronomy*, 64, pp.225-265.

Hinsinger, P., G. R. Gobran, P. J. Gregory and W. W. Wenzel, 2005. Rhizosphere geometry and heterogeneity arising from root-mediated physical and chemical processes. *New phytologist*, 168(2), 293-303.

IPCC, 2006. Guidelines for National Greenhouse Gas Inventories, Edited by Eggelston, S., L. Buendia, K. Miwa, T. Ngara, K. Tanabe. Published by the Institute for Global Environmental Strategies (IGES) for the IPCC ISBN 4-88788-032-4.

IPCC, 2006. IPCC guidelines for national greenhouse gas Inventories, prepared by the national greenhouse gas inventories programme, Eggleston, H. S., L. Buendia, K. Miwa, T. Ngara and K. Tanabe (eds). *IGES*, Japan.

Jackson, M. L., 1973. Soil chemical analysis, Prentice Hall India Ltd, New Delhi.

Jagtap, G. P., 2012. Effect of agrochemicals on micro flora in soybean rhizospheric soil sciences *Journal Microbiol*, 1(2), 55-62.

Jain, A., G. Chandra, A. K. Bhowmik and U. Prakasham, 2015. Economic evaluation of intangible benefits of tree plantations: A case study. In: *Statistics in Forestry: Methods and Applications*, India, Bonfring Intel-lectual integrity. 130-134.

Jha, K. K., 1999. Teak (*Tectona grandis)* “Farming – A Textbook”, International Book Distributors Company, Uttara Pradesh, India.

Jones, D.L., A. Hodge and Y. Kuzyakov, 2004. Plant and mycorrhizal regulation of rhizodeposition. *New phytologist*, *163*(3), pp.459-480.

Kanagaraj, N., 2017. Assessment of Soil Microbial Population in Thorn Forest and Moist Deciduous Forest, Western Ghats, Tamil Nadu. *International Journal of Microbiology Research, ISSN*, 0975-5276.

Kaul, M., G. M. J. Mohrend, V. K. Dadhwal, 2010. Carbon storage and sequestration potential of selected tree species in India*. Mitig. Adapt. Strateg. Glob. Change.,* 15: 489–510.

Kayang, H., 2013. Soil microbial population numbers in sacred grove forest of Meghalaya, Northeast India.

Ketterings, Q. M., R. Coe, M. Noordwijk, Y. Ambagau and C. A. Palm, 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above- ground tree biomass in mixed secondary forests. *Forest Ecology and Management,* 146: 199-209.

Kinyangi, J., 2007. Soil health and soil quality: A review.

Kiyono, Y., N. Furuya, T. Sum, C. Umemiya, E. Itoh, M. Araki and M. Matsumoto, 2010. Japan Agri. Res. Quarterly, 44: 81–92. ISSN 0021-3551.

Krishna, A., M. A. Khan and B. Joseph, 2017. Stabilizing crop productivity returns and soil improvement by agroforestry practices under marginal lands in semi-arid tropics of Telangana State, India. *Asian Journal of Soil Science*, *12*(2), 290-295.

Kumar, D., G. P. Upadhyay and B. K. Anil Dutt, 2017. Assessment of soil biological properties under different land uses in Barog-Dhillon watershed in Solan district of Himachal Pradesh. *International Journal of Chemical Studies*, *5*(4), 221-224.

Kumar, R., A. Kumar and R. S. Dhillon, 1998. Morphological and physico-chemical characteristics of soil under different plantations in arid ecosystem. *Indian J. For*., 21: 248-52.

Lange, M., N. Eisenhauer, C. A. Sierra, H. Bessler, C. Engels, R.I. Griffiths, P.G. Mellado-Vázquez, A.A. Malik, J. Roy, S. Scheu, and S. Steinbeiss, 2015. Plant diversity increases soil microbial activity and soil carbon storage. Nat Commun 6: 6707.

Latha, P.C. and H. Gopal, 2010. Effect of herbicides on soil microorganisms. Indian Journal of Weed Science, 42(3 and 4), pp.217-222.

Mandal, A., S. Bag, B. Sarkar, M. Seal, A. Mondal, and S. Chatterjee, 2023. Soil bacterial diversity in the tropical dry deciduous forest of Ajodhya hills, Purulia, West Bengal. *Acta Ecologica Sinica*.

Mathews, E., R. Payne, M. Rohweder and S. Murray, 2000. Forest ecosystem: Carbon storage sequestration, Carbon sequestration in soil. *Global Climate Change Digest,* 12 (2): 19-99.

Mirza, A. N. and S. S. Patil, 2022. Mapping of Microbial Diversity of Gautala Reserve Forest in Aurangabad (District)(MS), India.

Mohsin, F. and B. Ram, 2002. Sixty-month study on litter production, changes in soil chemical properties and productivity under poplar (*Populus deltoides*) intercropped with wheat. *Indian Journal of Agroforestry,* 4: 81-87.

Montagnini, F., 2000. Accumulation in above-ground biomass and soil storage of mineral nutrients in pure and mixed plantations in a humid tropical lowland. Forest Ecology and Management, 134(1-3), 257-270.

Montagnini, F. and F. Sancho, 1994. Above-ground biomass and nutrients in young plantations of four indigenous tree species: implications for site nutrient conservation. *J. Sustainable For*., 1: 115-139.

Mutanal, S. M., S. J. Patil and G. Shahapurmath, 2007. Investigation on the productivity of multipurpose tree species in degraded waste lands. *Karnataka Journal of Agricultural Sciences,* 20 (4).

Nair, P. K. R. 1993. An introduction to Agroforestry: Effect on crop yields. *Kluwer Academic Publishers*, London UK.

Nambiar, E. K. S. 1995. Relationships between water, nutrients and productivity in Australian forests: Application to wood production and quality. *Plantand Soil,* 168-169: 427-435.

Nandi, R. and K. V. Raman, 1981. Characterization of humic and fulvic acids extracted from different Indian soils. *J. Indian Soc. Soil Sci.,* 29 (2): 179-183.

Narain, P., R. Singh and K. Singh, 1970. Influence of forest covers on physicochemical and site characteristics in Doon valley. *Indian For*., 116: 901-915.

Newaj, R., S. B. Chavan, B. Alam and S. K. Dhyani, 2016. Biomass and carbon storage in trees grown under different agroforestry systems in semi-arid region of central India.*The Indian Forester*, 142 (7): 642-648.

Nirala, D., V. P. Khanduri and M. S. Sankanur, 2018. Biomass and carbon stock assessment in different age group plantations of Teak (*Tectona grandis* Linn. F.) in Bhabar and Shivalik Regions of Uttarakhand. *International Journal of Bio-resource and Stress Management*, 9 (3): 379-382.

Ogunkunle, C. O. and O. O. Awotoye, 2011. Soil fertility status under different tree cropping system in a southwestern zone of Nigeria. *Not. Sci. Biol.,* 3 (2): 123-128.

Olsen, S. R., C. V. Cole, F. S. Watanable and L. A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United State Department of Agriculture.* Cir. No. 939.

Ota, H. O., D. Aja, C. C. Okolo, C. O. Oranu and J. N. Nwite, 2018. Influence of tree plantation *Gmelina Arborea* and *Gliricidia sepium* on soil physico-chemical properties in Abakaliki, Southeast, Nigeria. Acta Chem Malay, 2, 23-8.

Oumarou, M. B. D., 2016. Soil fertility under four tree species in the semi-arid climate of Niger. United *Nations University Land Restoration Training Programme*.

Piper, C. S., 1966. Soil and plant analysis, Hans Publishers, Bombay.

Prasad, R., A. Bhattacharyya and Q. D. Nguyen, 2017. Nanotechnology in sustainable agriculture: recent developments, challenges, and perspectives. *Frontiers in microbiology*, *8*, 1014.

Pressler, M., 1865. Das Gesetzder. Stamlildung. *Leipzig*,153p.

Purwanto, R. H., H. Simon and S. Ohata, 2003. Estimation of net primary productivity of young teak plantations under the intensive *Tumpangsari* system in Madiun, East Java. *TROPICS.,* 13 (1).

Ram, S., M. Das and A. Ahmed, 2023. Performance of anjan tree (Hardwickia binata)-based silvopasture systems under moisture-conservation practices in semi-arid conditions. *Indian Journal of Agronomy*, *68*(1), 83-88.

Ravindranath, N. and M. Ostwald, 2008. Carbon inventory methods: Handbook for greenhouse gas inventory, carbon mitigation and roundwood production projects. advances in global change research. *Springer Science and Business Media,* 306.

Ravindranath, N. H., B. S. Somashekhar and M. Gadhil, 1997. Carbon flow in Indian forests, submitted to the Ministry of Environment and Forest.

Russell, A.E., J. W. Raich, O. J. Valverde-Barrantes and R. F. Fisher, 2007. Tree species effects on soil properties in experimental plantations in tropical moist forest. Soil Science Society of America Journal, 71(4), pp.1389-1397.

Satheesan, T., S. Sivchandran and D. K. N. G. Phuspakumara, 2016. Distribution, Growth and Aboveground Biomass of Teak (*Tectona grandis* L.) Plantation in Mullaitivu District of Sri Lanka. *International Journal of Scientific and Research Publications*, 6 (3): 72-76.

Schrag, D. P., 2007. Preparing to capture carbon. *Science,* 315: 812–13.

Schulz, S., R. Brankatschk, A. Dumig, I. Kogel-Knabner, M. Schloter and J. Zeyer, 2013. The role of microorganisms at different stages of ecosystem development for soil formation. Biogeosciences, 10(6), 3983-3996.

Sharma, P. K., T. S. Verma and R. M. Bhagat, 1995. Soil structure improvement with the addition of *Lantana camara* biomass in rice, wheat cropping. *Soil Use and Management*, 11: 199-203.

Sheikh, M. A., M. Kumar, R. W. Bussman and N. P. Todaria, 2011. *Carbon balance and management*, 6: 15.

Sherrod, L. A., G. A. Peterson, D. G. Westfall and L. R. Ahuja, 2005. Soil organic carbon pools after 12 years in no till dryland agroecosystems. *Soil Sci. Soc. Am. J.* 67: 1533-43.

Singh, A., K. S. Pant and P. Prakash, 2020. Effect of multipurpose tree species on soil Physico-chemical properties and available nutrients in subtropical region of Himachal Pradesh. *Journal of Pharmacognosy and Phytochemistry*, 9 (3): 935-938.

Singh, A. K., A. Rai, R. Banyal, P. S. Chauhan and N. Singh, 2018. Plant community regulates soil multifunctionality in a tropical dry forest. *Ecological Indicators*, *95*, 953-963.

Singh, B. and K. N. Sharma, 2007. Tree growth and nutrient status of soil in a poplar (*Populus deltoides* Bartr.) based agroforestry system in Punjab, India. *Agroforestry Systems,* 70: 113-124.

Singh, B., R. Gill and P. S. Gill, 2010. Soil fertility under various tree species and poplar-based agroforestry system. *J. Res. Punjab agric. Univ.,* 47 (3 & 4): 160-64.

Singh, G., G. N. Gupta and V. Kuppusamy, 2000. Seasonal variations in organic carbon and nutrient availability in arid zone agroforestry systems. *Tropical Ecology*, *41*(1), 17-23.

Singh, I. S., I. P. Awasthi, B. D. Sharma, T. A. More and S. R. Meena, 2010. Soil fertility changes under fruit trees in Thar desert ecosystem.

Central Institute for Arid Horticulture, Bikaner. *Technical Bulletin,* 37: 2.

Singh, I. S., O. P. Awasthi, R. S. Singh, T. A. More and S. R. Meena, 2012. Changes in soil properties under trees species. *Indian J. Agri. Sci*., 82 (2): 146-151.

Singh, K., V. C. Pandey, B. Singh and R. R. Singh, 2012. Ecological restoration of degraded sodic land through afforestation and cropping. *Ecological*., 43: 70-80.

Singh, N. S. and S. K. Tripathi, 2020. Temporal Changes in Soil Microbial Diversity of Tropical and Sub-Tropical Forests of Mizoram, Northeast India. *Environment and Ecology*, *38*(1), 31-37.

Singh, R., R. S. Pal and S. Banerjee, 2009. Growth performance of multipurpose tree species in degraded land under agroforestry practices. *Journal of Tropical Forestry,* 25: 1-2.

Singh, V., 1994. Morphology and pattern of root distribution in *Prosopis cineraria, Dalbergia sissoo* and *Albizia lebbeck* in an arid region of North-Western India. *Tropical Ecology,* 35: 133-140.

Soman, R., A. Thomas, N. M. Sarma, V. Jagadeesh and M. Sankarshanan, 2018. Bacterial diversity in soil from peripheral areas of Thattekad bird sanctuary. *Indian J. Sci. Res*, *18*(2), 80-87.

Stockfisch, N., T. Forstreuter and W. Ehlers, 1999. Ploughing effects on soil organic matter after twenty years of conservation tillage in Lower Saxony, Germany. *Soil Till Research,* 52:91-101.

Subbiah, B. V. and G. L. Asija, 1956. A rapid procedure for estimation of the available nitrogen in soils. *Current Sci*., 25: 259-260.

Suryawanshi, M. N., A. R. Patel, T. S. Kale and P. R. Patil, 2014. Carbon sequestration potential of tree species in the environment of North Maharashtra University Campus, Jalgaon, India. *Bioscience Discovery,* 5 (2): 175-179.

Swamy, S. L., A. Mishra and S. Puri, 2006. Comparison of growth, biomass and nutrient distribution in five promising clones of *Populus deltoides* under an agri-silviculture system. *Bioresource Tech*., 97: 57-68.

Tanwar, S. P, S., A. Verma, P. Kumar, N. M. Alam and R. K. Bhatt, 2019. Biomass and carbon projection models in *Hardwickia binata* Roxb. vis a vis estimation of its carbon sequestration potential under arid environment. *Archives of Agronomy and Soil Science*, 66 (14): 1925-1935.

Tripathi, D., R. Meena, M. Khan, S. Attar, Y. K. Sharma and S. R. Dhaka, 2022. Effect of spacing on growth performance and soil dynamics in Hardwickia binata Roxb. under arid ecosystem.

Varalakshmi, T., K. M. Sekhar, M. M. Rafi and P. B. B. N. Charyulu, 2010. Population studies of actinomycetes isolated from the rhizosphere of Foxtail millet. Population studies, 4(3)

Verma, S. and A. Jain, 2019. Crbon stock in different pools in natural forest and plantations raised in TFRI, Jabalpur campus, India. *Eco. Env. and Cons*., 25 (1).

Verma, S. and A. Jain, 2020. Contribution of small pockets of forests towards carbon sequestration - Tropical Forest Research Institute, Jabalpur, A case study. *The Indian Forester,* 146 (1): 25-31.

Vijay, S. B. M., C. M. Reddy, A. Subramanyam and D. Balaguravaiah, 2007. Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. *Journal of the Indian Society of Soil Science,* 55: 161–166.

Vincent, J.M., 1970. A manual for the practical study of the root-nodule bacteria. A manual for the practical study of the root-nodule bacteria.

Walkley, A. J. and I. A. Black, 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science,* 37: 29-38.

Wang, B., G. B. Liu, S. Xue and B. Zhu, 2011. Changes in soil physico-chemical and microbiological properties during natural succession on abandoned farmland in the Loess Plateau. *Environ. Earth. Sci.,* 62: 915-925.

Yadav, R. S., B. L. Yadav and B. R. Chhipa, 2008. Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. *Agroforestry Systems*, 73: 1-12.

Yadava, A. K., 2001. Cultivation of lemon grass (*Cymbopogon flexosus*, 'CKP-25') under poplar-based agroforestry-based system. *The Indian Forester*, 127: 213-223.

VITA

1. Name of student : **JAGTAP DEEPAK SURESH**
2. Date of birth : 19/10/1998
3. Name of college : Post graduate Institute,
   Dr. PDKV, Akola
4. Residential address : At Ajispur Post Nandrakoli
   Tq Dist - Buldhana
   Pin. - 443001
   Email – jagtapdeepak1998@gmail.com
   Mobile No.- 9284499701
5. Academic Qualification :

Sr. No.	Name of degree awarded	Year in which obtained	Division/ Class	Name of awarding university	Subjects
1	B.Sc. (Forestry)	2021	First with distinction	Dr. P.D.K.V. Akola	Forestry and Allied subjects

6. Research paper published: Nil

7. Field of interest : Research & Development

Signature of Student

Place: Akola

Date: / /2023

JAGTAP DEEPAK SURESH