

**“PRODUCTION POTENTIAL OF PADDY UNDER BUND  
PLANTATIONS IN AGRI-SILVICULTURE MODULE UNDER  
AGROFORESTRY SYSTEM IN KENDRAPADA, ODISHA”**

**M. Sc. (FORESTRY) THESIS**

**By**

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**COLLEGE OF AGRICULTURE**

**INDIRA GANDHI KRISHI VISHWAVIDYALAYA**

**RAIPUR (C. G.)**

**AUGUST, 2021**

**“PRODUCTION POTENTIAL OF PADDY UNDER BUND  
PLANTATIONS IN AGRI-SILVICULTURE MODULE UNDER  
AGROFORESTRY SYSTEM IN KENDRAPADA, ODISHA”**

**Thesis**

**Submitted to the**

**Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)**

**By**

**ALOK TRIPATHY**

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## CERTIFICATE - I

This is to certify that the thesis entitled "*Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada Odisha*" submitted in partial fulfilment of the requirements for the degree of "**Master of Science in Forestry**" in the **Department of Forestry** of the Indira Gandhi Agricultural University, Raipur (C.G.), is a record of the bonafide research work carried out by **Mr. Alok Tripathy** under my guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: 03.08.2021



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## CERTIFICATE – II

This is to certify that the thesis entitled “*Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada Odisha*” submitted by **Mr. ALOK TRIPATHY** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Forestry** in the **Department of Forestry** has been approved by the external evaluator and Student’s Advisory Committee after oral examination, under the chairmanship of head of the Department/Dean.

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Director of the Instructions

  
  
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## LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL FORM
%	Percent
=	Equal to
°C	Degree Celsius
&	And
Cm	Centimetre
DAT	Days after transplanting
<i>et al.</i>	And co-worker/ and others
Etc.	So on
Fig.	Figure
g	Gram
Ha	Hectare
<i>i.e.</i>	That is
Kg	Kilogram
Mm	Millimeter
M	Meter
Q	Quintal
<i>viz.,</i>	Namely
/	Per
N	Nitrogen
P	Phosphorus
K	Potassium

## THESIS ABSTRACT

- a) Title of the thesis : Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada, Odisha
- b) Full Name of the Students : ALOK TRIPATHY
- c) Major Subject : Forestry
- d) Name and Address of the Major Advisor : Dr. R.K Prajapati, Professor, Department of Forestry, IGKV, Raipur (C.G.) 492012
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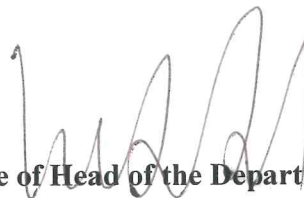


Signature of Major Advisor



Signature of the Student

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Signature of Head of the Department


## ABSTRACT

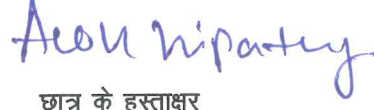
Agroforestry is a land use system where woody perennials are cultivated on the same land management units along with annual/biennial agricultural crops and livestock components. To study the yield of Paddy under the bund plantation of *Acacia auriculiformis* & *Eucalyptus tereticornis*, B-C ratio in the agri-silviculture system as well as in the sole crop and growth increments of the tree components in the bund plantation an experiment was conducted in two different fields in Kendrapada District (Odisha) during the year 2020-21 in Kharif season (Oct-Dec). Observations were recorded for several

growth and yield parameters such as Height measurement of paddy plants in 30-day interval till the harvest of crop 150 DAP, No. of Tillers /Plant at harvest, Panicle length of Paddy at harvest, Number of grains per panicle at harvest, Seed weight of 100 grains at harvest, Grain yield (q/ha), Straw yield (q/ha), Biological Yield, Harvest index (%), Height of trees present in the field bunds, Diameter at Breast Height (D.B.H.), Girth at Breast Height (G.B.H.) for both the tree and crop components in a 30 days interval. The same observation also recorded under sole cropped field of the paddy varieties Pooja and Kalachampa. The observed data was then statically analyzed using T-test. After analyzing and computing the data of this experiment results showed that If we consider only growth parameters and economic yield of paddy, bund plantation of trees has an adverse effect on paddy up to 5 % of low yield. But when we calculated the B-C ratio, B-C ratio of the sole crop was significantly lower than the B:C ratio of crop under bund plantation of *A.auriculiformis* and *E.teretocornis*. In experimental site – 1, the B-C ratio of sole crop was 2.04 whereas the B-C ratio of crop with the bund plantation of *A.auriculiformis* was 3.00. In experimental site - 2, the B-C ratio of sole crop was 2.22 whereas the B-C ratio of crop with the bund plantation of *E.teretocornis* was 2.55. This is due to wood component income after harvest of mature tree crop farmers get money in 12 year. The calculation of amount obtained in 12 year equally divided by yearly basis. BC ratio we may conclude the results that there is more economic benefit when we plant trees on field bund along with the crops despite of a little reduction of the yield of rice compared to the sole crop. Thus agroforestry system is economically beneficial in the long run as compared to a sole crop. After this experiment we can suggest the farmers in Kendrapada to go with bund plantation of trees rather than sole cropping of Paddy. As bund plantation of trees improve the soil fertility with litter decomposition and addition of nitrogen through nitrogen fixing trees. The bund plantation of agroforestry trees are beneficial for to enhance the income as well sustainable agriculture maintain soil fertility both this comes under eco-friendly agriculture system.

## शोध सारांश

- (अ) शोध का शीर्षक: केंद्रपाड़ा, ओडिशा में कृषि वानिकी प्रणाली के तहत कृषि-सिल्विकल्चर मॉड्यूल में बांध वृक्षारोपण के तहत धान की उत्पादन क्षमता का अध्ययन
- (ब) विद्यार्थी का पूरा नाम : आलोक त्रिपाठी
- (स) प्रमुख विषय : वानिकी
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मुख्य सलाहकार के हस्ताक्षर

  
छात्र के हस्ताक्षर

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विभाग प्रमुख के हस्ताक्षर

## सारांश

एग्रोफोरेस्ट्री एक भूमि उपयोग प्रणाली है जहां वार्षिक/द्विवार्षिक कृषि फसलों और पशुधन घटकों के साथ एक ही भूमि प्रबंधन इकाइयों पर लकड़ी के बारहमासी की खेती की जाती है। बबूल औरिकुलफॉर्मिस और यूकेलिप्टस टेरैटिकोर्निस के मेड़ रोपण के तहत धान की उपज का अध्ययन करने के लिए, कृषि-सिल्विकल्चर प्रणाली में बीसी अनुपात के साथ-साथ एकमात्र फसल और बंड रोपण में पेड़ के घटकों की वृद्धि वृद्धि में एक प्रयोग दो अलग-अलग में आयोजित किया गया था। खरीफ मौसम (अक्टूबर-दिसंबर) में वर्ष 2020-21 के दौरान केंद्रपाड़ा जिले (ओडिशा) में खेतों में। फसल की कटाई तक 30 दिनों के अंतराल में धान के पौधों की ऊंचाई माप 150 डीएपी, फसल कटाई के समय टिलर/पौधे की संख्या, फसल के समय धान की लंबाई, अनाज की संख्या प्रति फूल फसल के समय, फसल के समय 100 दानों का बीज भार, अनाज की उपज (क्यू/हेक्टेयर), पुआल की उपज (क्यू/हेक्टेयर), जैविक उपज, हार्वेस्ट इंडेक्स (%), खेत की मेड़ में मौजूद पेड़ों की ऊंचाई, स्तन की ऊंचाई पर व्यास (DBH), गिरथ एट ब्रेस्ट हाइट (GBH) पेड़ और फसल दोनों घटकों के लिए 30 दिनों के अंतराल में। यही अवलोकन धान की किस्मों पूजा और कालाचंपा के एकमात्र फसल वाले खेत के तहत भी दर्ज किया गया

है। तब देखे गए डेटा का टी-टेस्ट का उपयोग करके सांख्यिकीय रूप से विश्लेषण किया गया था। इस प्रयोग के आंकड़ों के विश्लेषण और गणना के बाद पता चला कि यदि हम केवल धान के विकास मापदंडों और आर्थिक उपज पर विचार करते हैं, तो पेड़ों के बंद रोपण से धान पर 5% तक कम उपज पर प्रतिकूल प्रभाव पड़ता है। लेकिन जब हमने बी-सी अनुपात की गणना की, तो एकमात्र फसल का बीसी अनुपात ए.ऑरिकुलीफॉर्मिस और ई.टेरेटोकोर्निस के बांध रोपण के तहत फसल के बी:सी अनुपात से काफी कम था। प्रायोगिक स्थल-1 में एकमात्र फसल का बी-सी अनुपात 2.04 था जबकि ए.ऑरिकुलीफॉर्मिस के बांध रोपण के साथ फसल का बी-सी अनुपात 3.00 था। प्रायोगिक स्थल-2 में एकमात्र फसल का बी-सी अनुपात 2.22 था जबकि ई.टेरेटोकोर्निस के बांध रोपण के साथ फसल का बी-सी अनुपात 2.55 था। यह लकड़ी के घटक आय के कारण परिपक्व पेड़ की फसल की कटाई के बाद किसानों को 12 साल में पैसा मिलता है। 12 वर्ष में प्राप्त राशि की गणना को समान रूप से वार्षिक आधार से विभाजित किया जाता है। बीसी अनुपात हम यह निष्कर्ष निकाल सकते हैं कि एकमात्र फसल की तुलना में चावल की उपज में थोड़ी कमी के बावजूद फसलों के साथ-साथ खेतों में पेड़ लगाने से अधिक आर्थिक लाभ होता है। इस प्रकार कृषि वानिकी प्रणाली एकमात्र फसल की तुलना में लंबे समय में आर्थिक रूप से फायदेमंद है। इस प्रयोग के बाद हम केंद्रपाड़ा के किसानों को सुझाव दे सकते हैं कि वे धान की एकमात्र फसल की बजाय बंधी वृक्षारोपण करें। वृक्षों के बंद रोपण से मिट्टी की उर्वरता में सुधार होता है, कूड़े के सड़ने से और नाइट्रोजन स्थिर करने वाले पेड़ों के माध्यम से नाइट्रोजन की वृद्धि होती है। कृषि वानिकी वृक्षों का बांध वृक्षारोपण आय बढ़ाने के साथ-साथ स्थायी कृषि मिट्टी की उर्वरता बनाए रखने के लिए फायदेमंद है, यह दोनों पर्यावरण के अनुकूल कृषि प्रणाली के अंतर्गत आता है।

# CHAPTER-I

## INTRODUCTION

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Agroforestry is the branch of forestry where woody perennial trees are deliberately grown with the annual crops simultaneously and sequentially on the same land management unit over a period of time. The management practices followed in the agroforestry system are in accordance with the needs of the local people and location-specific. In this context trees plantation in the Paddy field bunds serve as the best example of an eco-friendly agroforestry approach and hence a critical study can be fruitful to estimate the performance of various tree species in the rice field bunds.

The agroforestry system of land use is rapidly gaining importance in recent years for meeting the dual objectives of achieving food security and environmental sustainability. It not only improves the farm production and income but also conserves the natural resources and ensures their optimum utilization. This land-use pattern has been instrumental in reducing the CO<sub>2</sub> emissions from the agro-ecosystem, stabilizes the atmospheric CO<sub>2</sub> concentration, and hence minimizes the impact of climate change. Agroforestry is the judicious integration of woody perennials with crops and/or animals on the same unit of land for meeting the multiple need of the community like food, fodder, firewood, timber, and other ancillary benefits. It facilitates nutrient recycling, improves soil fertility, arrests soil erosion and land degradation, conserves soil and water, improves the village environment, conserves biodiversity, and serves as a major carbon sink. Realizing the importance of this type of land use, emphasis is being given to promote agroforestry in agricultural field bunds and permanent fellow lands for stabilizing food production and extending the environmental services.

However, even before the evolution of agroforestry as a concept and technology, farmers are maintaining a variety of tree species in the field bunds and boundary plantations of their crop fields along with their agricultural crops since time immemorial. It has evolved along with the development of human civilization and continues to play a vital role in maintaining the sustainability of rural livelihoods. The indigenous agroforestry systems such as scattered trees on farmlands and on-field bunds, home gardens, and fodder trees for green fencing are practiced by farming

communities. These traditional agroforestry systems are deeply linked with agroforestry systems specific to agro-climatic zone, agro-ecological situations, and the social setup of the community. Therefore, diverse tree species are grown and maintained traditionally by the community of different regions of the country for deriving their multiple needs. In Odisha diverse traditional agroforestry systems exist in different areas characterized with high species diversity including multipurpose tree species, shrubs, and herbs. While, in the drought-prone western parts *Acacia nilotica* and *Butea monosperma* based farm forestry are the dominant one, in the central inland districts *Madhuca latifolia* and *Schleichera oleosa* based agroforestry are more prevalent. However, in the coastal areas tree species like Palm (*Borassus flabellifer*), *Casuarina equisetifolia*, *Pongamia pinnata*, *Acacia mangium*, *Samanea saman*, *Terminalia spp.*, *Dendrocalamus strictus* and *Cocos nucifera*, etc. are maintained by the farmers along with their agricultural crops as field bund plantations as a part of farm forestry or in their backyard as a home garden. Agro-forestry in the coastal areas has the potential to improve the livelihoods of vulnerable rural communities by supplementing their household income and reducing their exposure to climate risks. The traditionally palm-based (coconut and palm) agroforestry are still preserved in the coastal areas of Puri district of Odisha for food during lean season, firewood, and building materials.

The Paddy (*Oryza sativa*) which is commonly known as Asian rice is one of the chief grains of India. It contributes to more than 40 percent of total food grain production in India. The total field production of rice during 2019-20 is estimated at a record 117.47 million tonne. Rice is grown in almost all the states of India primarily during the Kharif season (July-October). The most rice-producing states in India are Chhattisgarh, West Bengal, Uttar Pradesh, Odisha, Tamil Nadu, Andhra Pradesh, Telangana, Punjab, and Bihar.

Paddy covers about 69% of the cultivated area in India. It is one of the major crops, covering about 63% of the total area under food grains. It is the staple food of Odisha therefore; the state economy is directly linked with improvements in the quantity and quality of rice in the state. In Odisha, Rice is now grown on an area of 4.4 million hectares. It accounts for 91% of the area under cereals and contributes about 94% of total cereal production in Odisha.

The Kalachampa variety of paddy is one of the popular varieties of Odisha developed by the Director of Agriculture & Food production, Department of Agriculture, Govt. of Odisha. It is a semi-dwarf variety with having a height of 105 - 110 cm. It takes 150-170 days to mature under normal cultivation practices. It is tolerant to all the major diseases and pests common in the field conditions in coastal Odisha and moderately tolerant to biotic and abiotic stresses. The seed rate of this variety is 30kg/ha for transplanting and the average yield in normal conditions is 7000 kg/ha. It is very popular among the farmers in Odisha due to its high yielding properties and its resistance to various diseases and biotic stress conditions. It is also very suitable for cultivation in areas that have wild rice infestation because it's easy to identify at the vegetative stage with basal leaf sheath pigmentation.

The Pooja variety of paddy is another very popular variety of Coastal Odisha which is the late duration (150 days) and short height (90-95cm) variety. It was released and notified (1999/1999) for cultivation in Primarily shallow & low land areas of Odisha, Assam, Madhya Pradesh, and West Bengal Pooja variety has medium slender grains and it gives an average yield of 5.0 tonne ha<sup>-1</sup>. It possesses field tolerance to all major diseases & pests. It can tolerate water stagnation (up to 25 cm) and is even suitable for late transplanting with aged seedlings.

*Eucalyptus tereticornis* species is native to Eastern Australia and Southern New Guinea. This species has a very wide distribution, occurring over the widest range of latitudes, occurring from southern Papua New Guinea at latitude 15°S, to South Eastern Victoria at latitude 38°S. In India, it's one of the most popular plantation trees for its quick growth and quality pulp and plywood industries and paper mills.

Eucalyptus is a very popular tree to be grown with crops. It has some very attractive properties such as Fast growth, straightness, self-pruning, and wide utilities of wood in Furniture as well as Plywood and Paper & Pulp industries. Eucalyptus wood is being used for furniture, doors, windows, fuel, pulpwood, and even as a source of rayon and essential oil. Eucalyptus can be grown as a boundary plantation tree as well as for block plantation. But preference should be given to boundary plantation. Eucalyptus is one of the most popular species to be planted along the edges of a plantation area or bunds of agricultural fields. Eucalyptus appears to be very well

incorporated and well accepted in agroforestry especially in Indian Climatic Conditions (Tejwani, 1994)

Eucalyptus species have some very distinct Silvicultural properties that make them very popular among farmers for a choice of the tree component in agroforestry species. Some of the characteristics are straightness of bole, narrow crown, self-pruning ability, high growth rates, adaptability to a wide range of soils and climates, very good coppicing ability, tendency not to spread like a weed, and wide utility of wood. Eucalyptus clones are very popular among the farmers for raising as block plantations. Eucalyptus has more than 600 varieties, among 175 which are closely related to two varieties, *Eucalyptus camaldulensis* Dehnh and *E. tereticornis* Smith. These are very popular among Indian farmers. These species are drought-tolerant varieties while also capable of withstanding waterlogging conditions, very hot summer temperatures, and suitable for a wide range of sites (Lal *et al.*, 1997)

Acacia (*Acacia auriculiformis*) is one of the most important tree species of eastern India. It is native to Australia, Indonesia, and Papua New Guinea. This plant is raised as an ornamental plant, as a shade tree and it is also raised on plantations for fuelwood. Its wood is good for making paper, furniture, and tools. Akashmoni (*Acacia auriculiformis*) is a fast-growing, nitrogen-fixing tree that has shown adaptability to a wide range of environmental conditions and also has multiple uses (Pinyopusarek, 1990).

In the present scenario, attempts are being made to introduce improved agroforestry practices using indigenous, multipurpose, and nitrogen-fixing tree species which could be planted in the field bunds to cater positive feedback to the adjoining annual crops. However, there has been a growing realization of the benefits of tree crop integration systems in the coastal areas and since the 1980s there is widespread interest in the planting a new species of acacias that is native to Australia, *Acacia mangium*, popularly known as Australian teak in the farm boundaries as bund plantations, home garden, and permanent fallows. Farmers are also planting and maintaining tree species like *Acacia auriculiformis*, *Acacia nilotica*, *Casuarina equisetifolia*, *Gmelina arborea*, etc. along with their agricultural crops as a part of commercial agro-forestry.

Agroforestry models adopted by farmers across Odisha are very profitable economically. In most areas, *Acacia auriculiformis* and *Acacia mangium* are planted

on agricultural fields and field boundaries are harvested around 10 to 12 years. The average economic return of *Acacia auriculiformis* and *Acacia mangium* based agroforestry systems is generally high compared to that of sole agriculture crops.

In spite of the multiple benefits of agroforestry practices, the majority of farmers have been hesitant to adopt these systems on a large scale. It is mostly because of certain apprehensions about the tree component such as very long rotation, reduction in gross area, and complicated legal procedures involved in tree felling, transportation, and negative market fluctuations. From a farmer's perspective, It is beneficial that the new trees to be integrated into agroforestry, especially along with paddy cultivation will be planted on field bunds rather than on the paddy floors to avoid losing areas for rice cultivation as well as for easy to use machines and various vehicles during the individual cultivation practices.

Thus **“Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada, Odisha”** in the Kendrapada district of Odisha can be an interesting work to assess the following objectives:

1. To study the yield of paddy under Agri-silviculture under *Acacia auriculiformis* and *Eucalyptus tereticornis* and as sole crop.
2. Comparative study of B-C ratio of paddy under Agri-silviculture system *Acacia auriculiformis* and *Eucalyptus tereticornis* based bund plantation.
3. Growth increments in DBH and height of the tree component *Acacia auriculiformis* and *Eucalyptus tereticornis* will be observed before and after harvesting the crop.

## CHAPTER-II

### REVIEW OF LITERATURE

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The research review, analysis of the research work carried out by various workers on this line has been cited in this chapter on **“Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada, Odisha”**. The following major elements of the literature are discussed in depth.

2.1 To study the yield of paddy under Agri-silviculture under *Acacia auriculiformis* and *Eucalyptus tereticornis* and as sole crop.

2.2 Comparative study of BC ratio of paddy under Agri-silviculture system *Acacia auriculiformis* and *Eucalyptus tereticornis* based bund plantation.

2.3 Growth increment in DBH and height of the tree component *Acacia auriculiformis* and *Eucalyptus tereticornis* will be observed before and after harvesting of the crop.

#### **1. To study the yield of paddy under Agri-silviculture under *Acacia auriculiformis* and *Eucalyptus tereticornis* and as sole crop.**

Ahmed (1989) observed a very interesting fact that in the first two year after plantation of *Eucalyptus tereticornis* the effect of trees on crop production, in terms of yield and economic benefits, was almost negligible contrary to popular beliefs among farmers. However in the 3rd and 4th year loss was 8.2 % and 13.6%.

Bahar (2006) reported that *Ulmus laevigata* and *Populus deltoids* affect some growth characteristics in wheat. He found out that under mature boundary plantation of *these tree species*, shoot height and ear length of the intercropped wheat was less than the control, primarily due to the shading effect of trees.

A very similar study was done by Nazir *et al.*, (1993) where the influence of *Dalbergia sissoo* on wheat crop was studied. He found that plant height of wheat was lower under tree canopy of *Dalbergia sissoo*, compared to the control conditions, with increasing the duration of shading.

Couto and Gomes (1995) reported that *Eucalyptus grandis* has a complementary relationship with beans (*Phaseolus vulgaris*) when intercropped. The inter cropping showed higher production & yield than sole cropping. A very similar study also showed that germination of wheat and cowpea was significantly higher in the agroforestry system where the crops are planted with Eucalyptus trees than sole cropping. However the reverse was true for maize (Blaise *et al.*, 1997)

A study showed that in the poplar (*Populus radiate*) based agroforestry system, the grain yield of paddy and wheat increased significantly with increase in distance from 2m to 10 m distance from the poplar trees (wheat:2.85 tonne ha<sup>-1</sup> to 3.63 tonne ha<sup>-1</sup> and paddy:3.22 tonne ha<sup>-1</sup> to 5.66 tonne ha<sup>-1</sup>). However, in the sole cropping conditions wheat and paddy grain yield was significantly higher *i.e.*, 4.47 tonne ha<sup>-1</sup> and 6.96 tonne ha<sup>-1</sup>, respectively. There was a significant decrease of 33.75 and 36.15 per cent in paddy and 26.68 and 25.69 per cent in wheat under 5<sup>th</sup> and 6<sup>th</sup> year old poplar bund plantation than the sole crop. (Chauhan *et al.*, 2012)

Chauhan *et al.*, (2013) for yield, researchers looked at an agri-horticultural model that included poplar (*Populus deltoids*) as a timber tree, fruit trees, and agronomic crops like turmeric (*Curcuma longa*) and moong (*Vigna radiata*). Agronomic crops initially performed best in partial shade in terms of yield and yield contributing parameters, but this improved as the poplar canopy grew older. Changes in these parameters have an inverse relationship with canopy age and vice versa, with the fifth-year-old canopy seeing the most yield decline, followed by the previous years and power. While crop yields decreased as poplar got older, the economic benefits of intercropping were two to three times greater than conventional crop rotation.

Dhillon *et al.* (1984) studied the effect of *Dalbergia sissoo* and *Acacia nilotica* trees on yields of paddy & wheat crop when planted in an agroforestry system. He reported a significant reduction in the yields of both the crops under shade of *Dalbergia sissoo* and *Acacia nilotica*. It was also seen that the yield of paddy crop had greater reduction (11-20%) than the wheat crop.

Hasan *et al.* 2006 observed that the leaf biomass of *Acacia auriculiformis* and other trees improved the soil quality in the paddy field dramatically, and the leaf biomass has the ability to be used as an alternative to chemical fertilizers, which pollute the soil and the atmosphere and as a result increases yield of crop.

Islam *et al.*, (2013) carried out an experiment in Bangladesh Agricultural University, Mymensingh during December 2005 to look at the growth and yield of medicinal plants and spices in a sissoo-based agro-forestry method. The results showed that in a Guava-based agro-forestry method, the output of the experimental plant *Aloe vera*, Asparagus, Misridana, Turmeric, Ginger, Onion, and Chilli was more important. When compared to the open condition, all of the test plants performed better in the Guava and Sissoo dependent agro-forestry method.

Moore (1992) studied that trees had the ability to harvest timber, diversifying farmers' incomes, lowering the cost of producing wood, and rising wood product exports. Despite the fact that all of the multipurpose plantings would be dispersed and growth rates would be poor in certain areas, farmers should have a competitive advantage in wood production because trees also have significant land care and agricultural productivity benefits.

Agricultural Research Station, Mundagod, Karnataka, conducted a field experiment to determine the best management practice for bund planted trees to mitigate negative tree crop interaction in an *Acacia auriculiformis* dependent agro-forestry environment. Due to tree management techniques placed on *Acacia auriculiformis*, the seed production of black gram increased dramatically. Treatments that received trenching had significantly higher seed yields than treatments that received 50% branch pruning. Seed yield was significantly higher at 12 to 14 m distance from tree row, which was comparable to 10 to 12 m distance from tree row. The seed yield of black gram was slightly lower when the control and 0 to 2m distances from the tree row were combined (Patil and Channabasappa, 2008).

Another study was done on the impact of *Dalbergia sissoo*, *Azadirachta indica*, *Acacia nilotica*, and *Prosopis cineraria* when planted as the tree component in the agroforestry system, on irrigated wheat crop yield. The crop yield data were obtained for each tree species at various distances (1, 3, 5, and 7 m) and in four directions (east, west, north, and south) from the tree bases, as well as a monitor (sole crop). The results reveal that wheat yields were not significantly different between *A. indica* and *P. cineraria*, but wheat yields were reduced in the other two species (*Dalbergia sissoo* and *Acacia nilotica*). The most important and noticeable effect was caused by *A. nilotica*, which resulted in a wheat yield reduction of approximately 40% to 60%. The yield was

decreased by 4 to 30% by *D. sissoo*, but only up to a distance of 3 meters (Puri and Banagrwa, 2013).

Several studies have been conducted to determine the value of perennial plants for water use in Sri Lanka's humid tropics, and it has been proposed that the growth of fruit and coconut trees can be very profitable, while other trees improve the climate of the country's irrigated humid tropics. (Renault *et al.*, 2001).

Sharma *et al.* (2001) reported that there was no significant decrease in the yield of wheat when grown with a 3-year-old boundary plantation of poplar. However, a significant decline of yield by 15.5 percent was recorded up to the distance of three meters from the tree base when wheat is cultivated with 4-year-old *Populus deltoides* planted as bund plantations.

The Division of Social Forestry, Forest Research Institute India is studying the impact of single row bund *Acacia nilotica* var. *juquemontii* plantation on the growth and yield of associated wheat crops under irrigated conditions in Haryana, India. The bund plantation influence all crop parameters such as crop height, number of shoots, ear length, number of grains, and grain yield in the vicinity of trees up to 4 m away from the base of the trees. It is found that as the distance from the tree base increases, wheat crop growth and yield improves. When comparing crops near the center of the tree line to crops near the outer boundary, the effect on the wheat crops was found to be more pronounced (Sharma, 1992).

Singh *et al.* (2014) observed that Rice growth slowed as it approached the base of the *Acacia auriculiformis* tree. Furthermore, the optimal values of all rice growth parameters were found to be highest in shade conditions.

Singh and Kohli (1992) studied the effect of *Eucalyptus tereticornis* shelterbelt plantation, on Chickpea, lentil, wheat, cauliflower, berseem, and toria crop yield. The yield is found reduced by more than half in a 12m wide strip to the south of 1-year-old *Eucalyptus tereticornis* shelterbelts in three separate locations. It is concluded that the poor production of crops in the sheltered region is primarily due to the Eucalyptus' allelopathic influence.

The Faculty of Agriculture and Eastern University, Sri Lanka ran a study from September 2014 to March 2015 on bamboo crops primarily to assess the growth and

production of turmeric (*Curcuma longa*) under four different shade stages. A randomized design was used to test treatments consisting of open field conditions *i.e.* 0% shade level (T1), 50% shade (T2), 70% shade (T3), and 80% shade (T4). The results very interestingly showed that at 50 percent shade (T2) characteristics like leaf area, biomass, and yield were significantly higher than at T3 and T1. Higher levels of radiation would have destroyed photosynthetic pigments, resulting in a decline in growth, according to Srikrishnah and Sutharsan (2015).

Verma *et al.* (2014) studied the crop yields of paddy and wheat under the *Eucalyptus tereticornis* based agri-silvicultural system. They concluded that under the *Eucalyptus tereticornis* canopy paddy grain yield was 14.7-19.7% less (1.99 tonne ha<sup>-1</sup>). However, in the same agri-silvicultural conditions, the wheat grain yield (1.49 tonne ha<sup>-1</sup>) was 26.4-34.6% lower than that of sole cultivation. And it was conducted that paddy can tolerate reduced light under the tree canopy to some extent and does not show a too severe a decrease in grain yield. On contrary, wheat being a strong light demander might experience relatively greater suppression in the number of tillers per meter row length, grain yield, reduced crop height, dry matter accumulation, the weight of 100 grains, and grain yield when planted under *Eucalyptus tereticornis* based agri-silvicultural system compared to sole crop.

## **2. Comparative study of B-C ratio of paddy under Agri-silviculture system *Acacia auriculiformis* and *Eucalyptus tereticornis* based bund plantation.**

Raniet *al.*, (2016) studied that perennial tree-based land-use systems are economically more viable and more profitable than monoculture crops. The study was done in Punjab, India. The highest B: C ratio among all the observations was recorded in pure *E. tereticornis* plantations (3.30) after the duration of 5 years. Simultaneously the second-highest B-C ratio (2.02) was recorded in *P. Deltoids* + *T. aestivum* crop-based land-use system followed by solo *T. grandis* plantations (2.06), *T. Aestivum* + *O. sativa* (1.89), *T. Aestivum* + *P. Glaucum* + fruit crop (1.72), *B. napus* + fruit crop (1.56) and *B. napus* + *O. sativa* (1.27) after studying all the different observations. *E. tereticornis* and *P. deltoids*-based land-use systems are concluded to be economically viable and more profitable than other land-use systems in this study area of Punjab.

Saxena (1991) studied that crop losses and their economic consequences as eucalyptus are grown in paddy field bunds. He observed that the crop remained weak

in a 2 to 10-meter wide strip adjacent to the tree line. Farmers' earnings from tree sales were greatly decreased as a result of these defeats. Without these losses, the typical B-C Ratio at a 15% discount rate would have been 9.2, but when crop losses were factored in, it was just around 2. Since the lower profit margin was not thought to be high enough to offset the cost of development and fluctuating output rates, none of the farmers replanted Eucalyptus after the auction.

Singh *et al.*, (2018) investigate the impact of Agroforestry practices on livelihood improvement of the farmers of Lohardaga District Jharkhand. The study showed that in Ghamhar based agri-silviculture system found B: C ratio 2.96 and average annual net returns were to the tune of Rs.28,875/- at current prices whereas in mango based agri-horticulture system found B-C ratio 2.00 and average annual net returns were to the tune of Rs.23,050/- at current prices. In Shisham based silvi-pastoral system B-C ratio 2.44 and average annual net returns were to the tune of Rs.6,655/- at current prices. Whereas Teak-based home garden system B-C ratio 3.04 and average annual net returns were to the tune of Rs.27,520/- at current prices.

Wannawong (1991) investigate Benefit-Cost analysis of selected agro-forestry systems in northeastern Thailand. The agroforestry system studies consisted of a combination of Eucalyptus, Leucaena or Acacia intercropped with cassava or mung bean. Fresh cassava provided the highest return of the monocultures studies with an NPV of 2,807 baht/rai and a B-C ratio of 2.7. Mung bean, marketed as seed, provided the second-highest return having an NPV of 604 baht/rai, only 22% of that of cassava. Of the agroforestry systems, studies, Eucalyptus intercropped with cassava provided the highest NPV, 3,968 baht/rai, and a B-C ratio, 2.5. The 1161 baht/rai increase in net benefits over the highest monocrop (cassava 2,807 baht/rai) indicated that farmers should prefer agroforestry.

### **3. Growth increment in DBH and height of the tree component *Acacia auriculiformis* and *Eucalyptus tereticornis* will be observed before and after harvesting of the crop.**

Couto *et al.* (1994) reported that at the time of stand establishment, intercropping 1 to 4 rows of maize between the 3.0 2.0 m spaced eucalyptus rows had little effect on the eucalyptus survival rate at 6 months. Increasing the number of rows of maize between the rows of eucalyptus from one to four during the first six months of intercropping decreased the height and diameter of the trees.

Couto and Gomes (1995) observed that when *Phaseolus vulgaris* is intercropped with *Eucalyptus grandis* in an agroforestry scheme, tree growth and survival are unaffected, and no disease or pests are found in either the forest or agricultural plants.

Chaudhry *et al.*, (2003) reported that As compared to the intercropped stand, the pure stand had the largest diameter increment at breast height (DBH) and the DBH growth peak occurred in the third year of planting, while the highest value for the pure stand was also in the same stand.

Chauhan *et al.*, (2009) reported that the poplar growth peaked in the second year and then slowed down as the tree grew older. The average height of poplar trees rose from 6.64m in the first year to 21.80m in the fifth year, with DBH ranging from 5.83 to 21.38cm. Except for DBH for the 4<sup>th</sup> and 5<sup>th</sup> years. Chauhan *et al.* (2012) found a longitudinal pattern in tree height and diameter growth, with increases statistically important in each year over the previous one

Chaturvedi (1992) reported that Poplars grow faster in agricultural crops than in pure stands, and agriculture should be continued before the poplar harvest rotation is completed. In their research, Singh *et al.*, (1988) found that under agroforestry conditions, poplar trees grew faster than under forest conditions

Dhanda and Verma (2001) found that tree height growth increased with age, from more than 5.5m per year over the first two years to 4-5m per year at 3-5 years of age, and finally to 3.1-3.4m per year at 6 to 9 years of age. Poplar development peaked in the second year, after which it gradually increased with age but at a slower pace. During the second year of planting, the average monthly height and diameter at breast height growth were 0.67m and 0.58cm, respectively, and 0.31m and 0.25cm, respectively, during the fifth year of planting (Kumar *et al.*, 2005)

Dhillon *et al.*, (2012) reported that the highest mean basal girth was found in kinnow-planted poplar (75.88 cm), followed by peach-planted poplar (69.78 cm), and the lowest basal girth was found in control poplar (53.90 cm). Poplar trees inter-planted with guava (18.87 cm) had the largest diameter at breast height, followed by poplar inter-planting with kinnow (17.67 cm), which was on average when raised with peach (17.27 cm), and control trees had the smallest DBH (15.16 cm).

Heque and Osman (1993) at Kaptai, Bangladesh, height, and DBH of trees were measured. They found that while the height and diameter of two pure Teak plantations did not differ greatly, the diameter of a mixed plantation was significantly greater. The average teak height was found to be 18.30 meters in a mixed plantation and 16.17 meters and 18.91 meters in two pure stands, respectively. The average DBH was found to be 35.59 centimeters in a mixed plantation and 23.14 centimeters and 24.59 centimeters in two pure stands. Teak outperformed the other plants in a mixed plantation.

Khan and Khaliq (2007) observed that crown growth was slightly higher in trees planted at a lower density (230 trees per hectare). The growth of diameter is proportional to the increase in spacing. Crown growth follows a linear relationship with tree spacing, increasing as spacing increases.

Mohsin *et al.*, (1996) reported that *Populus deltoides* attained better height and DBH than their pure stand at early ages (2nd and 3rd years) and advanced (6th and 7th year), when intercropped with Mint and *Cymbopogon spp.* Singh *et al.*, (1998)

Oke and Owoeye (2005) observed that *Grevillea robusta* intercropping with maize resulted in substantially reduced collar diameter and shoot biomasses of *Grevillea robusta*; collar diameter was reduced by 32% and shoot dry weight was reduced by 39% after four months of transplanting, and 18.7% and 13.5 percent, respectively, after 16 months.

## CHAPTER-III

# MATERIALS AND METHODS

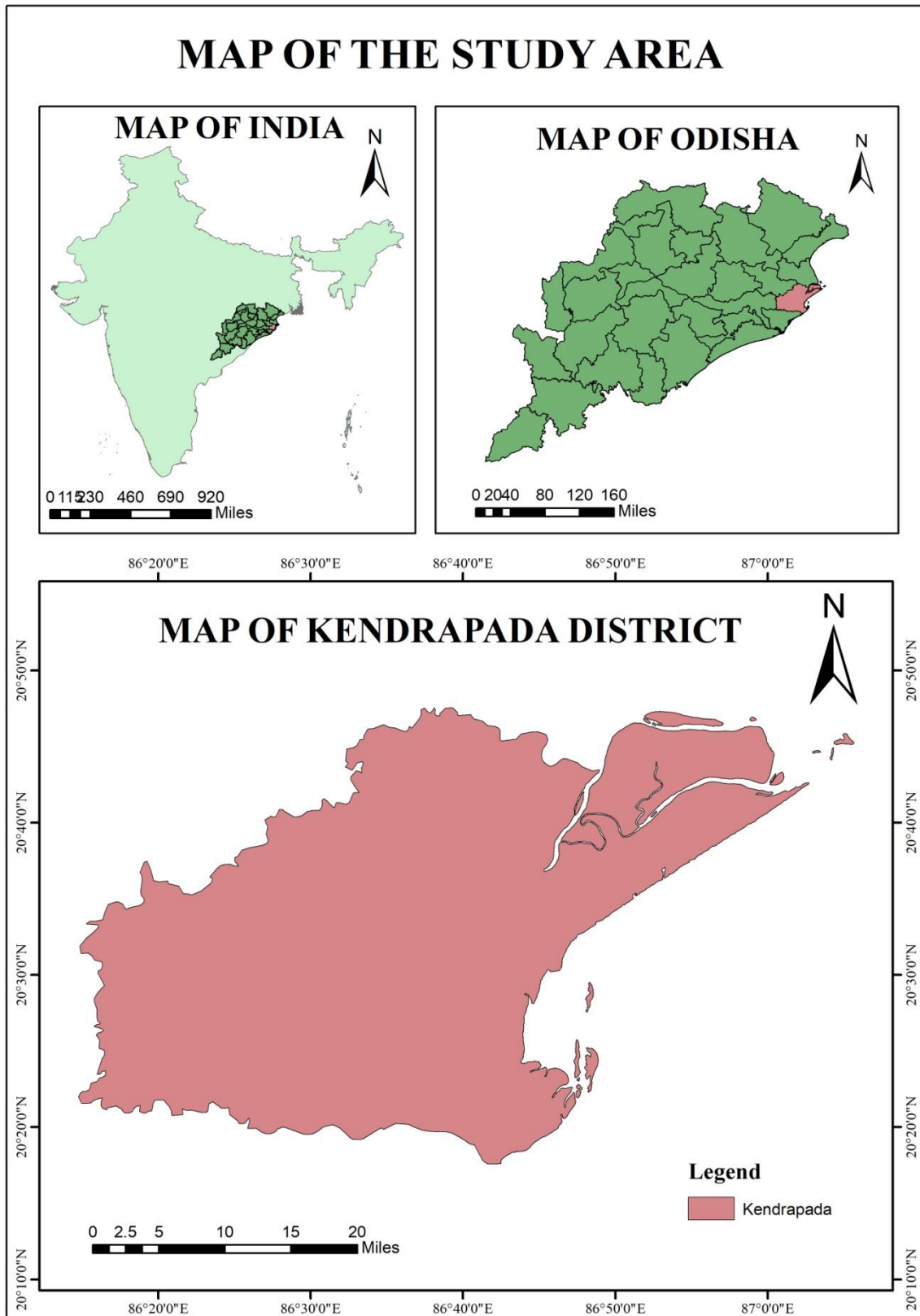
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The present investigation entitled “**Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada, Odisha**” was carried out in the Kendrapada district of Odisha during August 2020-April 2021 in a farmer’s field as well Krishi Vigyan Kendra Kendrapada. Details about the experimental site, material used, and methodology adopted during the course of the investigation are discussed in this chapter.

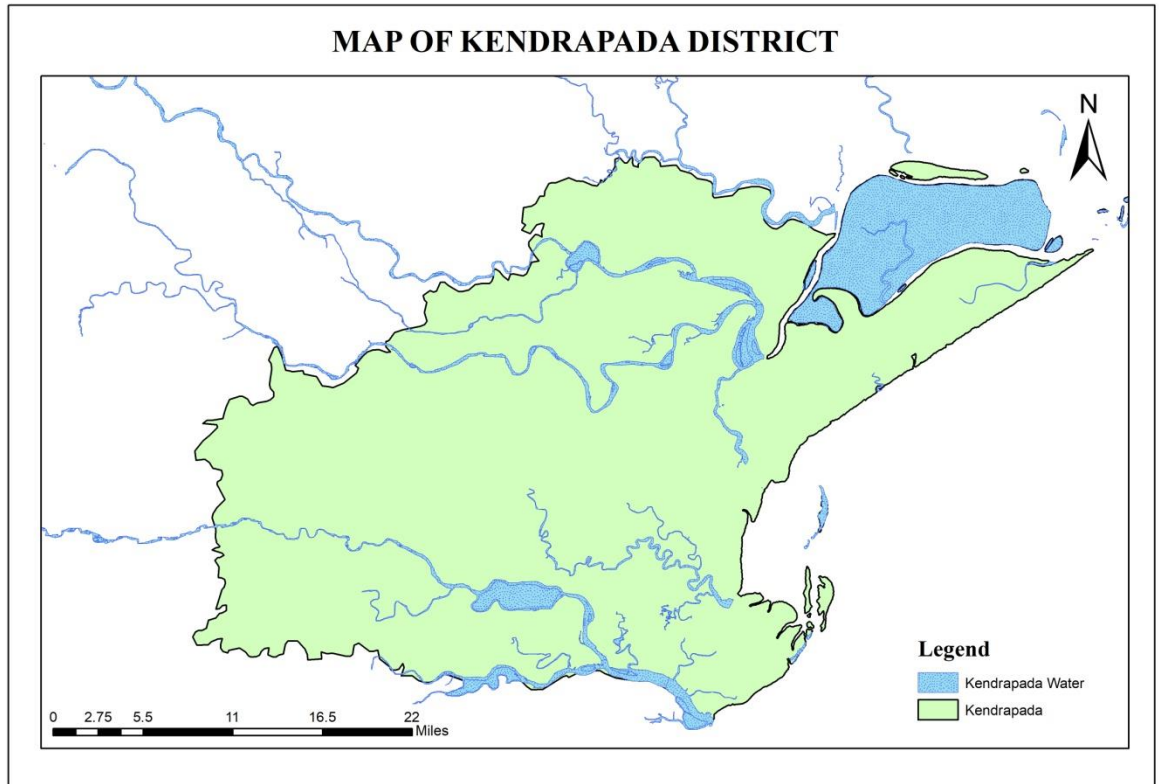
### 3.1 Experimental site

#### 3.1.1 Location

Kendrapada is a district of Odisha State in eastern India. It is located in the central coastal plain region of the Odisha, 20° 20' N To 20° 36' N Latitude and 86° 14' E To 87° 01' E Longitude. It is surrounded by Bhadrak, Jajpur, Cuttack, and Jagatsinghpur districts and the Bay of Bengal to the east. The coastline extends from Dhamra Muhan to Batighar for 48 km. The river Chitroptala (a branch of the Mahanadi) flows through the Kendrapada district. Other rivers in Kendrapada include the Luna, the Karandia, the Gobari, the Brahamani, the Birupa, the Kani, the Hansua, the Baitarani, the Kharasrota, and the Paika. In that district there are Bhitarkanika Mangroves, National Park Bhitarkanika, Gahirmatha Beach and Temple Baladevjew are situated. As of the 2011 Indian census, Kendrapada district has a population of 1,439,891 and Most of the residents of Kendrapada are farmers.



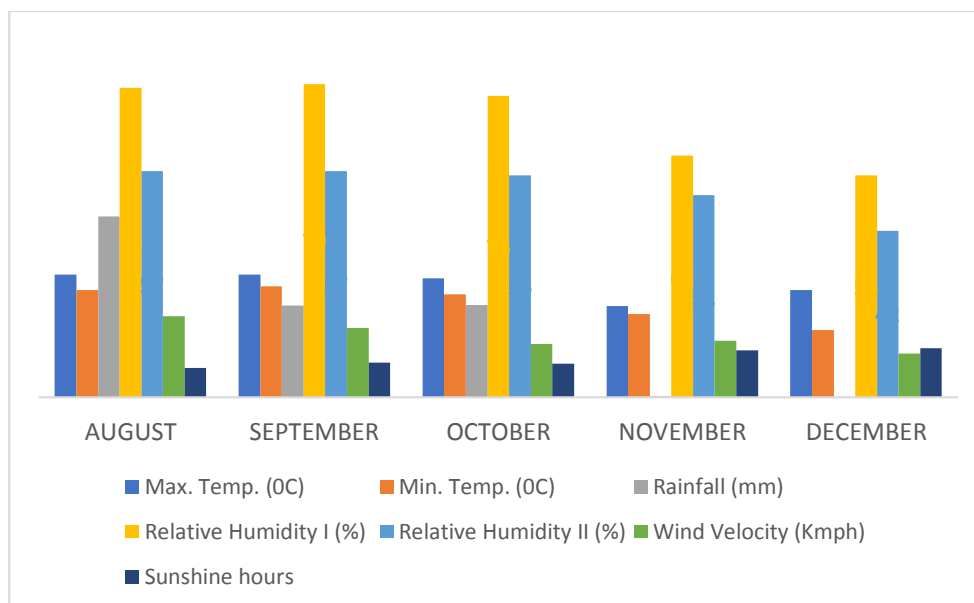
**Plate 1: Political Map of Kendrapada, Odisha**



**Plate 2: River Map of Kendrapada, Odisha**

### 3.1.2 Climate and Weather Condition

Kendrapada has an average wind speed of 3, 6 m/s with a maximum wind speed of approximately 11 m/s. The average environmental temperature is 26.8 degrees, which ranges between 13.9 and 37.8 degrees Celsius. The relative average humidity is approximately 78.5% and ranges from 39.7% to 96.9%. The pressure ranges between 1005 h/Pa which is 988 h/Pa and is approximately 1018 h /Pa on average. Kendrapada's Windrose reveals that the SSW is mostly winding - about 18.99% in all wind directions. Kendrapada District has an average annual rainfall of 1428.61 mm.



**Fig 3.1: Monthly meteorological observations during crop growth period.**

### 3.1.3 Major soils

Tertiary and recent alluvium from river distributors is mostly occupied in the district. The district's soil consists primarily of alluvium and is arable land. The sandy and aeolian soil are mostly in Rajnagar along the coastline and sections of a block of Rajkanika. Mixing grey soil (Inceptisol), which covers 1,43,39023 hectares of the total area, dominates the district soil type (2, 64,400 ha).

### 3.1.4 Agro-climatic/ecological information

The area of Kendrapada covers one agro-climatic area *i.e.* the coastal plain east and south-east. This area is divided up into three agro-ecological situations covering multiple situations, with the aim of producing site-specific technologies that respond to farmers' requirements, on the basis of variations in topography, soil condition, availability of irrigation, and crop patterns.

### 3.1.5 Forest area

The district's total forest area was reported to be just 9707 ha, contributing 9.94% of the total geographical area of the district. The neighborhood is mostly to the north and south of the area. The area is covered by mangrove forests that play an essential role in the control of the sea's high tide and the preservation of its ecological balance. The district's main forest resources are wood firewood, bamboo, and so on.

Because of the lack of rural fuel and most trees being cut for firewood and forage purposes, the lowering parts of the forest area have been decayed.

### 3.2 Experimental details

This experiment was carried out for duration of three months, from October to December in two different paddy fields in Kendrapada District.

The first Paddy Field (Experimental Site-1) was selected in KVK, Kendrapada Premises. The Paddy Variety was Kalachampa, which is a hybrid variety. The Paddy field was rectangular and across one of the sides, there was a bund plantation of some *Acacia auriculiformis* Trees. So One Part of the field was mostly covered by the shade of the bund plantation.

The Second Paddy Field (Experimental Site-2) was a Farmer's Field in Pattamundai Block of Kendrapada. The Paddy variety in the second field was 'Pooja' and similar to the first field it had a bund plantation of *Eucalyptus tereticornis* trees with a part of the field mostly covered in Shade during daytime.

I selected the open area in both the paddy field as 'control Crop' and the shaded area in both the paddy fields as 'Treatment Crop'.

Then I took observations like Height of Paddy plants, Number of Tillers / Plant, Panicle Length, Number of grains in Panicle, Seed weight of 100 grains, and yield across the field in both control and treatment in 10 random quadrates from each section, 3 months duration of paddy to mature the crop for harvest.

**Table 3.1: Specifications about Experimental Site-1)**

Agroforestry system	Bund based Tree Plantation
Location	Krishi Vigyan Kendra, Kendrapada, Odisha University of Agriculture & Technology
Season	Rabi, 2020-21
Crop	Paddy (Kalachampa)
Spacing	20cm x 15cm
Planted in	August Last week
Harvested in	January 1st week
Tree component	<i>Acacia auriculiformis</i>

**Table 3.2: Fertilizer Applied (Both Macro and Micro Nutrients) in Experimental Site-1**

Nitrogen	200 kg/ha
Phosphorous	100 kg/ha
Potassium	100 kg/ha
Zinc	25kg /ha

**Table 3.3: Specifications about Experimental Site-2)**

Agroforestry system	Bund based Tree Plantation
Location	Farmer's field, Balipada, Pattamundai, Kendrapada, Odisha
Season	Rabi, 2020-21
Crop	Paddy (Pooja)
Spacing	20cm x 20cm
Planted in	August Last week
Harvested in	January 1st week
Tree component	<i>Eucalyptus teretricornis</i>

**Table 3.4: Fertilizer Applied (Both Macro and Micro Nutrients) in Experimental Site-2**

Nitrogen	200 kg/ha
Phosphorous	100 kg/ha
Potassium	100 kg/ ha
Zinc	not applied

**3.2.1 Observations recorded for trees**

Observations of growth and yield parameters for tree crops in rice fields have been reported. There have also been considerable findings for access to different parameters of soil nutrients and economies in the method of agroforestry dependent on trees. The reported parameters are outlined.



**Plate 3: Bund Plantation of *Acacia auriculiformis* in Paddy Field at KVK, Kendrapada, Odisha**



**Plate 4: Taking observations in the Paddy Field in KVK, Kendrapada, Odisha**



**Plate 5: Taking observations in the Paddy Field in in the Paddy Field in  
Pattamundai, Kendrapada, Odisha**



**Plate 6: Bund Plantation of *Eucalyptus tereticornis* in the Paddy Field in Pattamundai, Kendrapada, Odisha**



**Plate 7: Taking observations in in the Paddy Field in Pattamundai, Kendrapada, Odish**

### **3.2.1.1 Height of trees present in the field bunds.**

The height increment of the trees which are emerging in rice field areas was measured with Ravi Altimeter from the soil level to the tip of the main shoot. The height and simultaneous average height and Standard deviation were represented in tabular format for each of the trees in the field bunds.

### **3.2.1.2 Numbers of trees**

The number of trees present in rice field bunds has been recorded by the number of different species of trees. In earlier pages, descriptions of different tree elements were identified.

### **3.2.1.3 Diameter at Breast Height (D.B.H.)**

The over bark diameter of the tree was measured with the help of measuring tape. The diameter of the individual trees in the bunds in the field is indicated by tabular format, simultaneously average diameter and standard deviation, respectively.

### **3.2.1.4 Girth at Breast Height (G.B.H.):**

Also measured were the surface bark of individual rice field bund G.B.H. (O.B) trees and their mean value and resulting standard deviation.

### **3.2.1.5 Age of trees**

The age was calculated using Pressler's incremental borer of tree species found in the bunds of the rice field. In contrast, the age of standing trees on rice farms was also recognized by a general questionnaire.

## **3.2.2 Observations recorded for crop**

In each sample plot 1x1 M size quadrat total of 10 quadrates under bund plantation field data was recorded. Whereas, 10 quadrat field data of paddy were recorded from the sole crop field. The other observation like no of tillers per plant, panicle length, grain yield, No. of grain, and straw yield were also recorded. The observations were recorded for computation and for further statistical analysis.

### **3.2.2.1 Height measurement of paddy plants in 30-day interval till the harvest of crop**

Plant height per plant in 90 DAT, 120 DAT, and 150 DAT was recorded 30 days intervals till the final harvest of the crop.

### **3.2.2.2 No. of Tillers /Plant**

For each sample plot, numbers of tillers per hill were counted and data recorded for further computation.

### **3.2.2.3 Panicle length of Paddy**

In all sample plots, panicle length was recorded with the help of a measuring tape during harvesting time.

### **3.2.2.4 Number of grains per panicle**

In each sample plot, the number of grains per panicle has been counted and recorded for computation.

### **3.2.2.5 Seed weight of 100 grains**

Form each sample plot's grain weight was estimated at 100 grains of rice and replicates for further computation.

### **3.2.2.8 Grain yield (q/ha)**

In each paddy sample plot, a 1x1 m<sup>2</sup> square quadrat was laid and harvested manually with the use of a sickle. The whole production was taken out from the quadrat. The paddy grains were weighed in order to produce and processed into the clean grains obtained and calculated the grain yields in kg and recorded for further analysis.

### **3.2.2.9 Straw yield (q/ha)**

Each quadrat sample plot straw yield was recorded by removing the cereal weight from the plants harvested then straw yield was recorded. Straw yield was calculated in kg per sample and converted to q/ha after computation.

#### **3.2.2.10 Biological yield (q/ha)**

The sun-dried plant weighed 15 days and was then processed into organic outputs (q/ha) from all harvested crops.

#### **3.2.2.11 Harvest index (%)**

The crop yield ratio to the biologic yield is the Harvest Index (percent). The formulation of Harvest index = grain yield/biological yield x 1003.7 has been used to enter paddy.

### **3.3 Statistical Analysis:**

Experimental design: T-Test

The tree parameters data were recorded before planting the paddy crop and after harvesting the crop evaluated in various parameters by means of a t-test: 1.37-meter tree diameter, trees height, the width of a canopy, cultivation parameters, amount of tiller per panicle, panicle weight per plant, panicle length per plant, number of filled grains per panicle, grain yields and the straw yield. The variations between care media of all parameters were assessed at 5% or 1% following Snedecor and Cochran for their relevance (1967).

## CHAPTER-IV

# RESULTS AND DISCUSSION

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The results obtained from the present investigations “**Production Potential of Paddy under Bund Plantations in Agri-Silviculture Module under Agroforestry System in Kendrapada, Odisha**” involved studying the growth attributes, and yield attributes such as Height measurement of paddy plants in 30-day interval till the harvest of crop, No. of Tillers /Plant at harvest, Panicle length of Paddy at harvest, Number of grains per panicle at harvest, Seed weight of 100 grains at harvest, Grain yield (q/ha), Straw yield (q/ha), Biological Yield, Harvest index (%), Height of trees present in the field bunds, Diameter at Breast Height (D.B.H.), Girth at Breast Height (G.B.H.) of paddy under sole cropping and *bund* based agroforestry systems in Kendrapada, Odisha. The major findings of the investigation are discussed here with available scientific explanations in literature. The result obtained has been discussed under the following heads:

### **4.1 Yield of paddy under Agri-silviculture under *Acacia auriculiformis* and *Eucalyptus tereticornis* and as a sole crop.**

#### **4.1.1 Growth parameters of paddy (Kalachampa) under *Acacia auriculiformis* and as a sole crop**

##### **4.1.1.1 Plant Height**

The observations and analysis of different plant heights (cm) at various stages of crop growth (90 days after planting, 120 days after planting, and 150 days after planting *i.e.*, at harvest) are presented in Table 4.1 under control conditions and *Acacia auriculiformis* based agroforestry system.

The statistical analysis of plant height observation at 90 days, 120 days, and 150 days showed that the calculated value *i.e.*, t stat value is less than the tabulated value *i.e.*, t critical two-tail value. It indicates that there is a significant difference in plant height of paddy (Kalachampa variety) in both conditions.

Plant height continued to increase with the increase in crop stages and reached a maximum at maturity. Results revealed that the plant height growth of paddy crop

was significantly highest at 90 days after planting in Q7 (89.7 cm) followed by Q8 (89.2 cm), Q2 and Q5 (88.7 cm) under control *i.e.* light condition and lowest in Q5 (85.4 cm) followed by Q9 (85.5 cm) and Q4 (86.2 cm) under bund plantation of *Acacia auriculiformis*. The observation of 120 days after planting showed that the plant height growth of the paddy crop was highest in Q10 (97.7 cm) under control and lowest in Q2 (94 cm) under bund plantation of *Acacia auriculiformis*. At harvesting time *i.e.* 150 days after planting the plant height of paddy was highest in Q8 (106.3 cm) under control and the lowest was in Q1 (101.4 cm) under the bund plantation of *Acacia auriculiformis* tree.

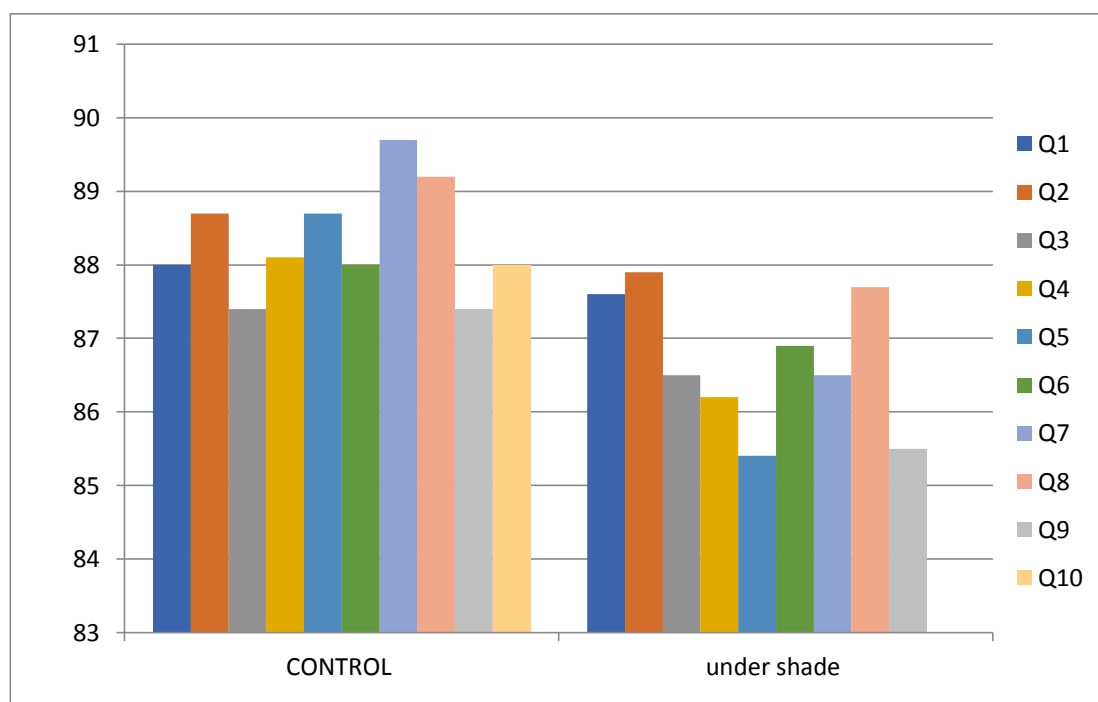
**TABLE 4.1: Plant height (cm) of paddy (Kalachampa) at various growth stages under control farming and *Acacia auriculiformis* based agroforestry system**

Quadrates	Height on 90 days in cm		Height on 120 days in cm		Height on 150 days in cm	
	Control	Under the bund plantation of <i>Acacia auriculiformis</i>	Control	Under the bund plantation of <i>Acacia auriculiformis</i>	Control	Under the bund plantation of <i>Acacia auriculiformis</i>
Q1	88.2	87.6	97	94.8	106.2	101.4
Q2	88.7	87.9	95.9	94	104.2	103.5
Q3	87.4	86.5	97.4	95.7	104.1	102.2
Q4	88.1	86.2	96.9	94.7	104.7	102.7
Q5	88.7	85.4	96.5	95.5	105.3	103.3
Q6	88	86.9	97.1	94.2	103.6	102.2
Q7	89.7	86.5	97.4	97.3	104.2	103.3
Q8	89.2	87.7	96.2	95.1	106.3	103.1
Q9	87.4	85.5	95	95.8	105.9	101.9
Q10	88	87.6	97.7	95.8	104.6	103.9
t Stat	4.82		4.08		4.83	
T critical two-tail	2.26		2.26		2.26	
Significant/non-Significant	Significant		Significant		Significant	

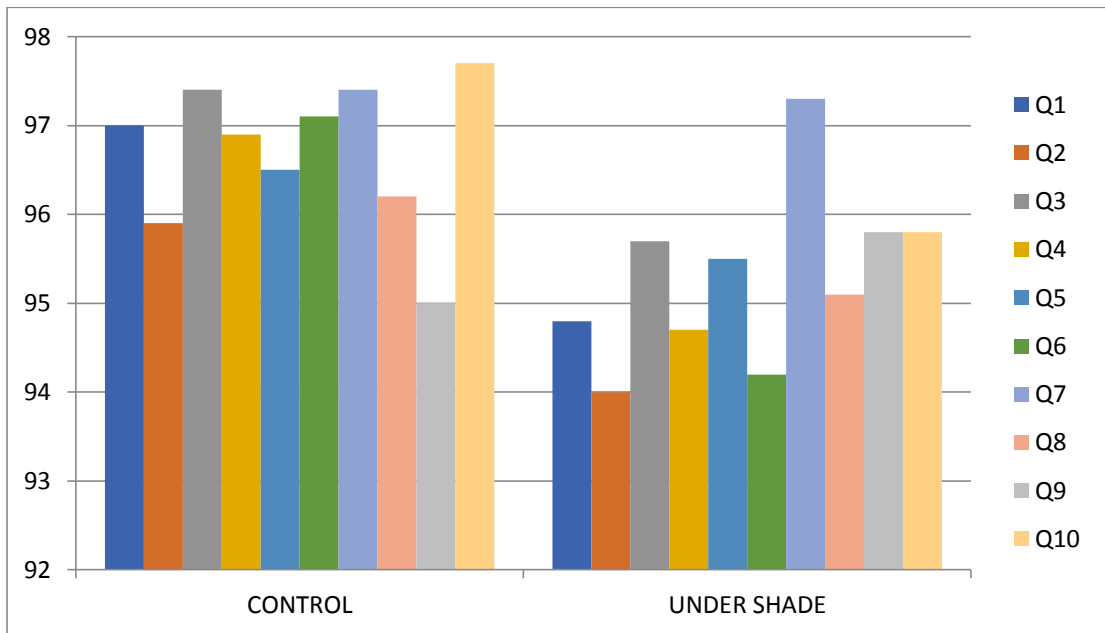
The data on plant height shows that the stem elongation in early stages (up to 90 days after planting) was rapid and subsequently declined at maturity in both conditions under control as well as under the bund plantation of *Acacia auriculiformis*.

The data on plant height also showed that under the bund plantation of *Acacia auriculiformis* growth of paddy was less than under control *i.e.* light condition and as a result, the lowest plant height observed under the bund plantation of *Acacia auriculiformis* and the highest plant height was observed under control condition. Similar observations were also recorded by Bahar (2006), Nazir, *et al.*, (1993), Verma *et al.* (2014).

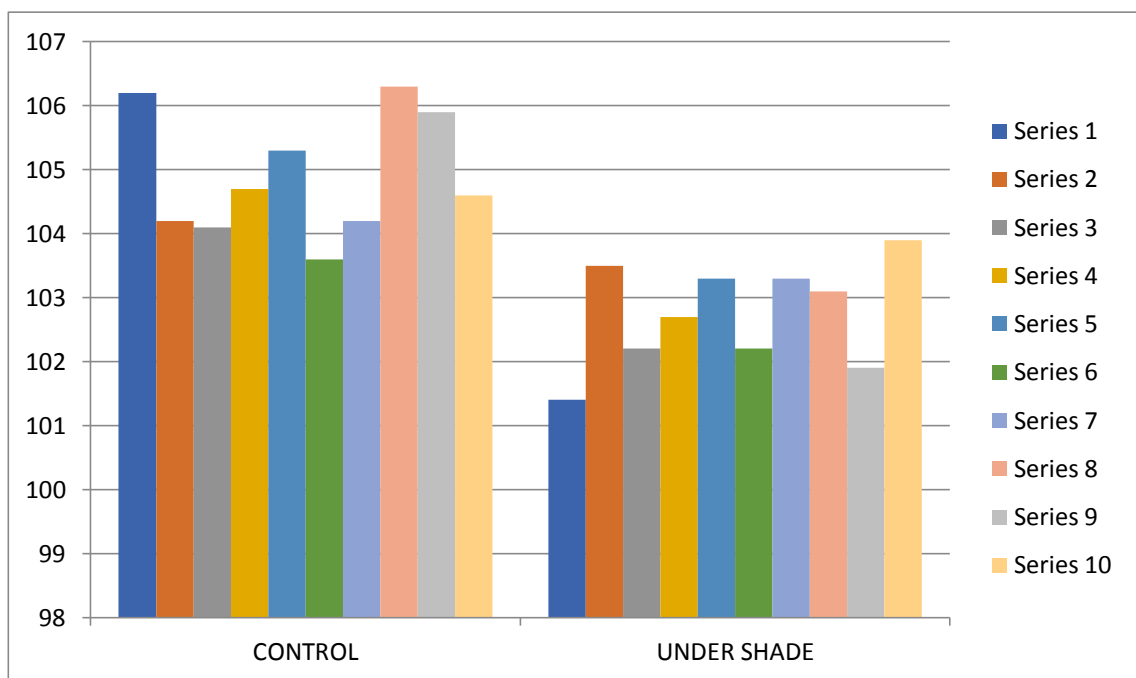
The shading effect of trees and competition for growth factors between trees and crop plants may be the possible reason for the reduction in plant height of paddy under *Acacia auriculiformis* trees. The variation in plant height at different sites may be due to the difference in soil nutrient availability and the difference in the crown spread of the trees.



**Fig 4.1: Height of paddy crop (Kalachampa variety) in control and under shade Condition at 90 DAP in Experimental Site -1**



**Fig 4.2: Height of paddy crop (Kalachampa variety) in control and under shade condition at 120 DAP in Experimental Site - 1**



**Fig 4.3: Height of paddy crop (Kalachampa variety) in control and under shade condition at 150 DAP in Experimental Site - 1**

#### 4.1.1.2 Growth attributes

The data on Growth attributes viz. No of tillers per plant, Panicle length of paddy, no of grains per panicle, seed weight of 100 grains, grain yield, straw yield, biological yield, harvest index are presented and discussed under the following tables.

**TABLE 4.2: No of Tillers Plant<sup>-1</sup>, Panicle length of paddy, No of Grains Panicle<sup>-1</sup>, Weight of 100 grains (g) in the Paddy Field at KVK, Kendrapada, Odisha**

Quadrates	No of Tillers Plant <sup>-1</sup> at harvest		Panicle length of paddy at harvest		No of Grains Panicle <sup>-1</sup> at harvest		Weight of 100 grains (g) at harvest	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
Q1	9.1	9.1	24.7	23.1	319.6	313.2	3.38	2.41
Q2	10.7	10.7	23.8	24.1	326.8	329.2	2.37	1.39
Q3	9.9	9.9	24.5	24.3	340.8	319.2	3.41	2.39
Q4	8.6	8.6	24.6	23.5	347.2	304.8	2.42	2.41
Q5	9.5	9.5	24.4	24.2	359.6	321.2	2.46	1.39
Q6	9.3	9.3	24.1	23.4	312.4	324	2.40	2.36
Q7	10	10	24.3	23.4	358	316.4	2.39	2.42
Q8	9.9	9.9	24.6	24.3	335.2	326.4	3.44	2.41
Q9	10.8	10.8	24.3	24.1	334	324.4	2.40	2.17
Q10	9.1	9.1	25.3	23.3	339.6	304.4	2.92	2.39
t Stat	3.85		3.05		3.06		3.86	
T critical two – tail	2.26		2.26		2.26		2.26	
Significant/non-Significant	Significant		Significant		Significant		Significant	

**TABLE 4.3: Grain, Straw and Biological yield, Harvest index in the Paddy Field at KVK, Kendrapada, Odisha**

Quadrates	Grain yield		Straw yield		Biological yield		Harvest index	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
Q1	4.42	4.16	5.58	5.36	10.00	9.52	44.2	43.67
Q2	4.94	4.06	5.92	5.01	10.86	9.08	45.49	44.76
Q3	4.49	4.01	4.67	4.93	9.16	8.94	49.04	44.82
Q4	4.92	3.97	5.77	5.16	10.69	9.14	46.05	43.46
Q5	4.65	3.89	5.47	4.70	10.13	8.60	45.96	45.33
Q6	4.51	4.02	4.65	5.18	9.16	9.20	49.26	43.73
Q7	4.68	4.05	5.74	4.82	10.42	8.87	44.89	45.65
Q8	4.75	4.16	5.59	5.13	10.34	9.30	45.94	44.79
Q9	4.50	4.03	5.29	5.39	9.795	9.43	45.98	42.8
Q10	4.95	3.93	5.91	4.42	10.87	8.35	45.58	47.11
t Stat	8.49		2.27		4.23		2.32	
T critical two – tail	2.26		2.26		2.26		2.26	
Significant/non -Significant	Significant		Significant		Significant		Significant	

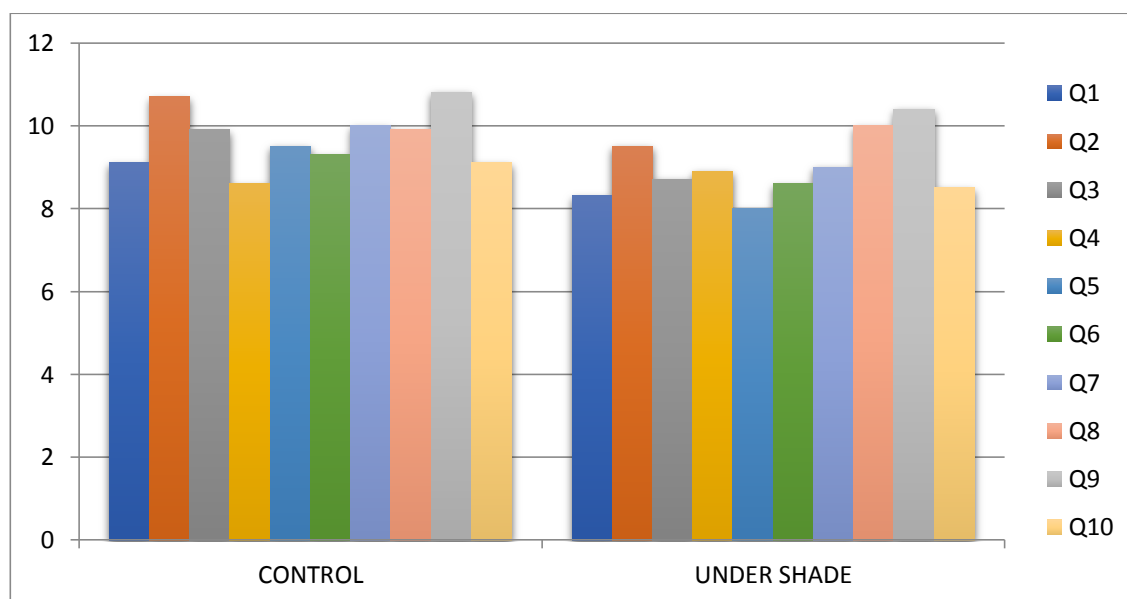
#### 4.1.1.2.1 No of tillers per plant

The statistical analysis of no of tillers per plant observation showed that the calculated value *i.e.* t stat value is less than the tabulated value *i.e.* t critical two-tail value. It indicates that there is a significant difference in no of tillers per plant in both the condition.

The data on a number of tillers per plant has been presented in Table 4.2 showed that the no of tillers per plant was significantly highest in Q9 (10.8/plant) followed by Q2 (10.7/plant) and Q7 (10/plant) under control *i.e.* light condition and lowest in Q5 (8/plant) followed by Q1 (8.3/plant) and Q10 (8.5/plant) under bund plantation of *Acacia auriculiformis*.

The data on no of tillers per plant also showed that under the bund plantation of *Acacia auriculiformis* no of tillers of paddy was less than under control *i.e.* light condition which is in line with the findings of Sharma (1992) and Verma *et al.* (2014).

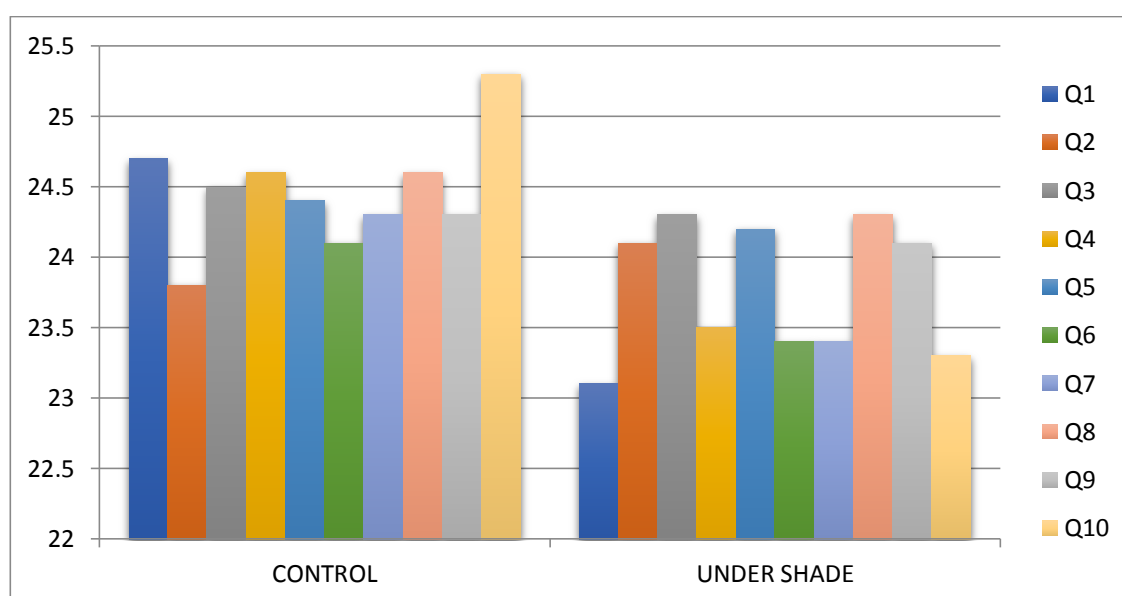
The maximum no of tillers per plant of paddy reported under control condition (fig. 4.4) is maybe due to more interception of solar radiation by paddy crops (Kiran and Agnihotri, 2001). The maximum reduction in no of tillers per plant in shade condition (fig.4.4) can be due to low light intensity and the low temperature caused by bund plantation of *Acacia auriculiformis*.



**Fig 4.4: No of tillers per panicle in control and under shade condition in Experimental Site – 1**

#### 4.1.1.2.2 Panicle length of paddy

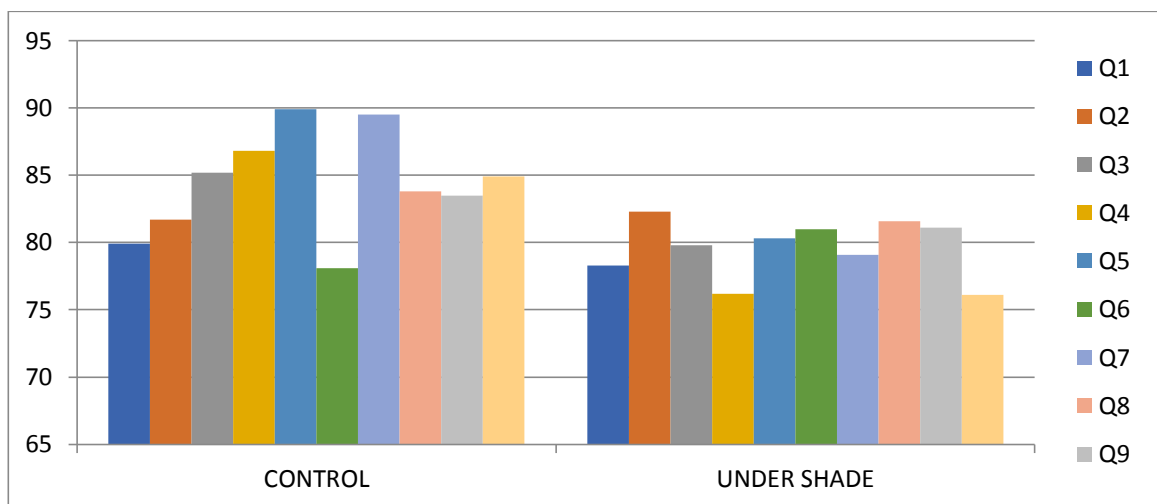
The data of panicle length of paddy in cm and t-test values on panicle length (cm) at harvest has been presented in Table 4.2. T-test value showing that Panicle length differed significantly at both sites as t stat value (calculated value) is greater than t critical two-tail value (tabulated value). Significantly highest panicle length was observed under control condition than under bund plantation of *Acacia auriculiformis*. Significantly highest panicle length was observed in Q10 (25.3 cm) followed by Q1 (24.7cm) and Q4, Q8 (24.6cm) in open condition and lowest in Q1 (23.1cm) followed by Q10 (23.3cm) and Q6,Q7 (23.4 cm) under shade condition.



**Fig 4.5: Panicle length of paddy (cm) in control and under shade condition in Experimental Site – 1**

#### 4.1.1.2.3 No of grains per panicle

The data on the number of grains per panicle are presented in Table 4.2. The result revealed that the statistically maximum number of grains per panicle was recorded in Q5 (359.6/panicle) followed by Q7 (358/panicle) and Q4 (347.2/panicle) in open conditions. The minimum number of grains per panicle was found when the crop was grown under bund plantation of *Acacia auriculiformis* in Q10 (304.4/panicle) followed by Q4 (304.8/panicle) and Q1 (313.2/panicle). The number of grains per panicle was significantly influenced by sunlight and bund plantation of *Acacia auriculiformis*.



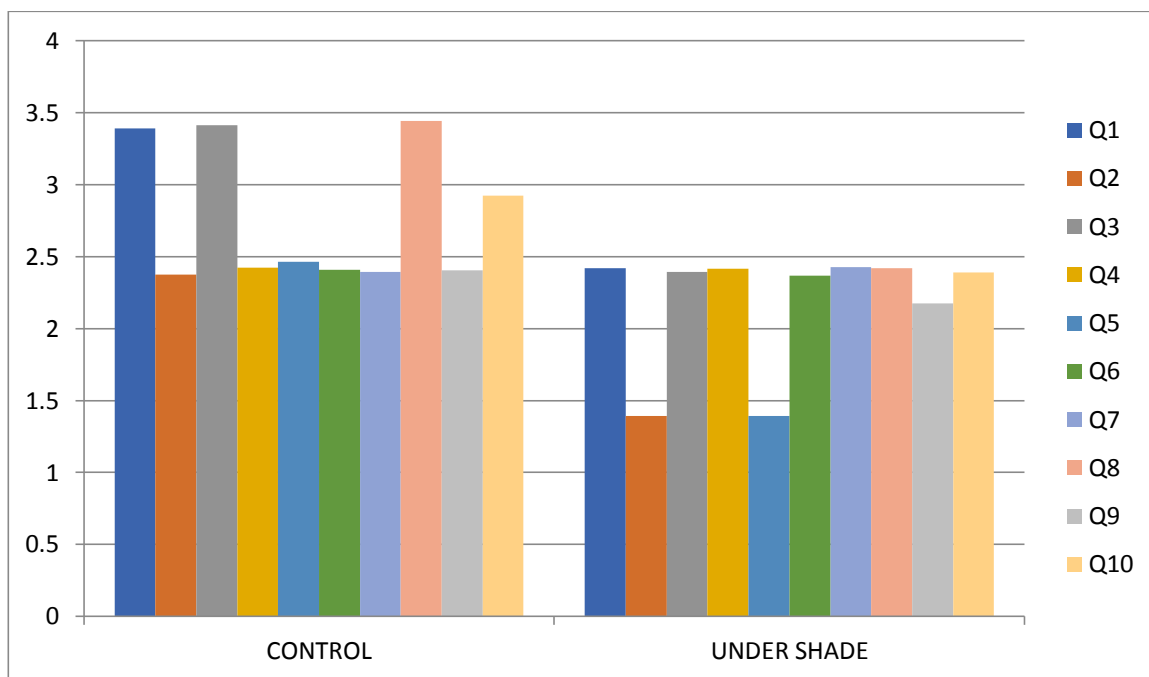
**Fig 4.6: No of grains per panicle in control and under shade condition in Experimental Site – 1**

#### 4.1.1.2.4 Weight of 100 grains in g

The statistical data revealed that there is a significant difference in the weight of 100 grain in both the site as the calculated value is more than the tabulated value.

The data presented in Table 4.2 on 100-grain weight (g) at harvest revealed that the 100-grain weight of paddy crop grown under bund plantation of *Acacia auriculiformis* is lower as compared to open (control) condition. The maximum 100-grain weight was found in Q8 (3.441gm) followed by Q3 (3.413g) and Q1 (3.389g) when the crop was grown at open (control) condition and the minimum was found in Q5 (1.392g) followed by Q2 (1.394g) and Q9 (2.176g) when the crop was grown under bund plantation of *Acacia auriculiformis*. The 100-grain weight was significantly influenced by sunlight and bund plantation of tree components.

Nazir *et al.*, (1993) stated that increasing the duration of shading may decrease the number of 1000-grain weight, grain protein concentration, and grain yield. Similarly, Jiang *et al.*, (1994) stated that total grain yield was affected by the tree crown. The results of the present investigation are also showed a slight decrease in the grain weight confirm that it is a shade effect on plants reducing the photosynthetic activity and its effects on grain weight.



**Fig 4.7: Weight of 100 grains (gm) in control and under shade condition in Experimental Site – 1**

The results revealed that significantly highest yield attributes were observed at the light condition and minimum at under bund plantation of *Acacia auriculiformis*. There was a negligible reduction in panicle length, number of tillers, number of grains per panicle, and 100-grain weight under the *Acacia auriculiformis* based agroforestry system as compared to the open farming system.

The variation in yield attributes of paddy (Kalachampa variety) was may be due to the difference in light availability affecting photosynthesis. The solar radiation is greater in the case of the open areas than those of other factors of the study. Overall, there was a slight reduction in the yield attributes of agricultural crops due to the competition for light, water, and nutrients among trees and paddy crops at both sites. Similar findings have also been reported by Tomar and Srivastava (1986), Newaj *et al.* (2003), and Chauhan *et al.* (2012). A number of workers have also reported a reduction of yield components due to shading effects; for example, reduced number of effective tillers (Kemp and Whingwiri, 1980), reduced number of grains (Rawson and Ruwali, 1972; Fischer 1975), reduced weight of grain (Fischer, 1975; Kemp and Whingwiri, 1980). The results of the above workers confirm the result of the present study.

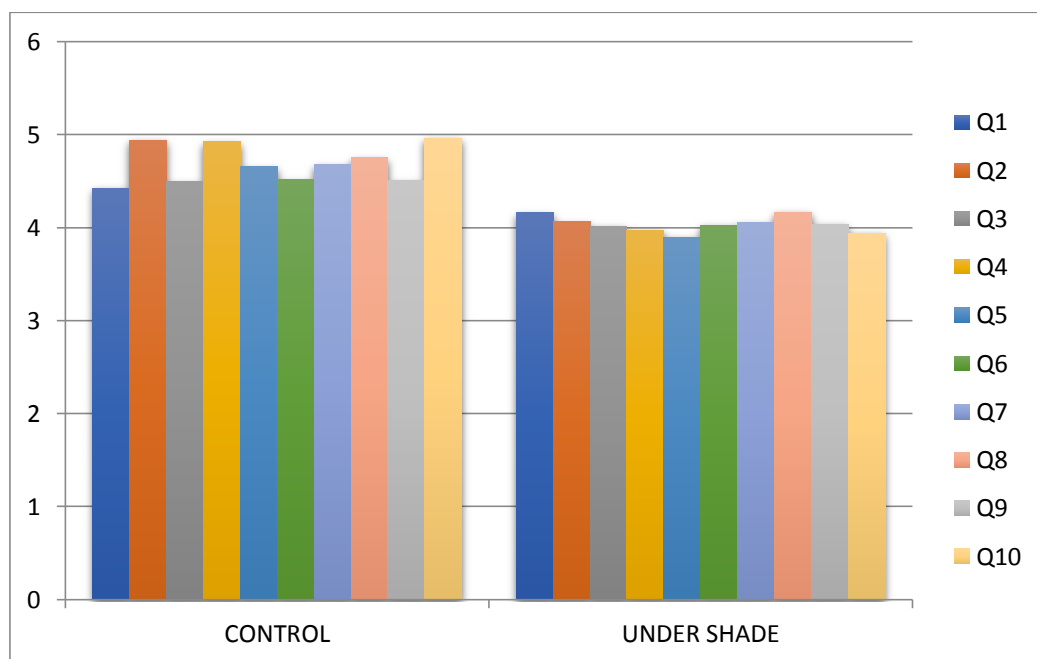
### 4.1.1.3 Yield attributes

#### 4.1.1.3.1 Grain yield

The statistical data revealed that there is a significant difference in grain yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The result on grain yield (tonne ha<sup>-1</sup>) of paddy crop is presented in Table 4.3 and Fig 4.8. At control (without trees) produced significantly higher grain yield than under *Acacia auriculiformis* based agroforestry system. The maximum number of grain yield was found at Q10 (4.957 (tonne ha<sup>-1</sup>) followed by Q2 (4.942 (tonne ha<sup>-1</sup>) and Q4 (4.927 (tonne ha<sup>-1</sup>) and the minimum was found in Q5 (3.899 (tonne ha<sup>-1</sup>) followed by Q10 (3.938 (tonne ha<sup>-1</sup>) and Q4 (3.973 (tonne ha<sup>-1</sup>) under bund plantation of *Acacia auriculiformis*. The grain yield was significantly influenced by light and bund plantation of trees.

Due to the boundary planting of *Acacia auriculiformis*, the grain yield of rice was adversely affected. Similar findings have also been reported by Dhillon *et al.* (1984), Sharma (1992), and Verma *et al.* (2014). Sharma *et al.*, (1992) stated that the reduction in the yield of rice grown in association with trees reflects competition for growth resources such as radiant energy, nutrients, and moisture.

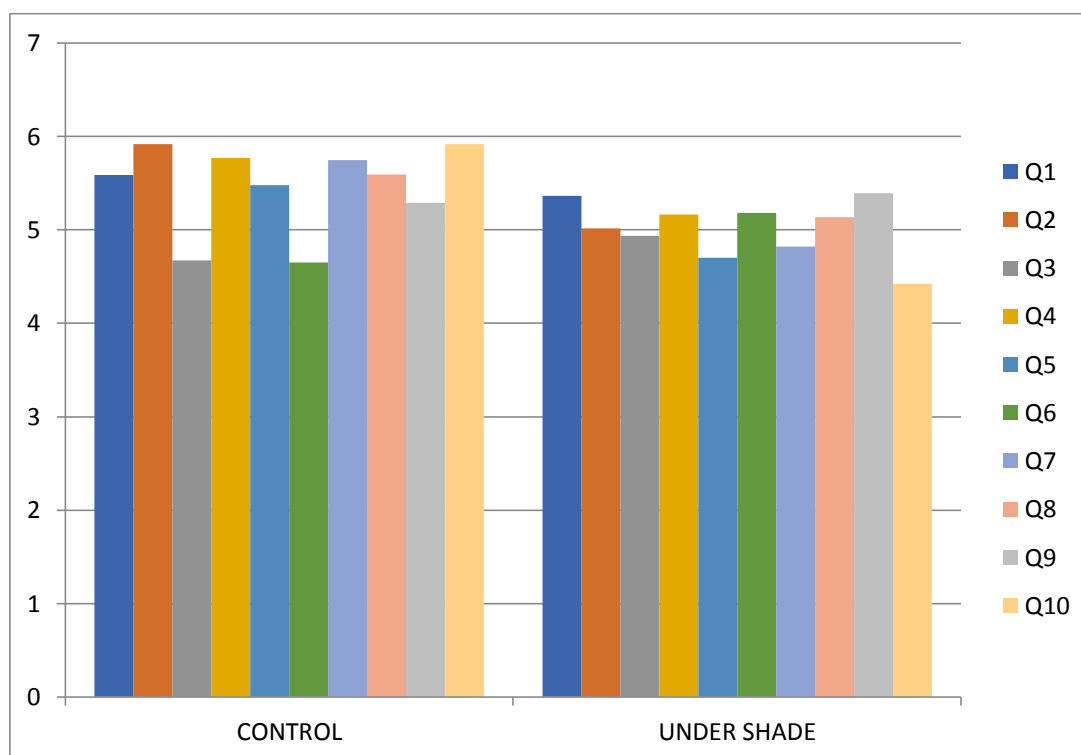


**Fig 4.8: Grain yield per ha (tonne) in control and under shade condition in Experimental Site – 1**

#### 4.1.1.3.2 Straw yield

The statistical data revealed that there is a significant difference in straw yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The result on straw yield (tonne ha<sup>-1</sup>) of paddy is presented in Table 4.3 and Fig 4.9. Paddy crops grown under bund plantation of *Acacia auriculiformis* produced lower straw yield as compared to control. The maximum straw yield was found in Q2 (5.921 tonne ha<sup>-1</sup>) followed by Q10 (5.919 tonne ha<sup>-1</sup>) and Q4 (5.772 tonne ha<sup>-1</sup>) when the crop was grown at open (control) condition and the minimum was found in Q10 (4.421 t ha<sup>-1</sup>) followed by Q5 (4.702t ha<sup>-1</sup>) and Q4 (4.825 t ha<sup>-1</sup>) when the crop was grown under bund plantation of *Acacia auriculiformis*. The straw yield was significantly influenced by light and bund plantation of trees.



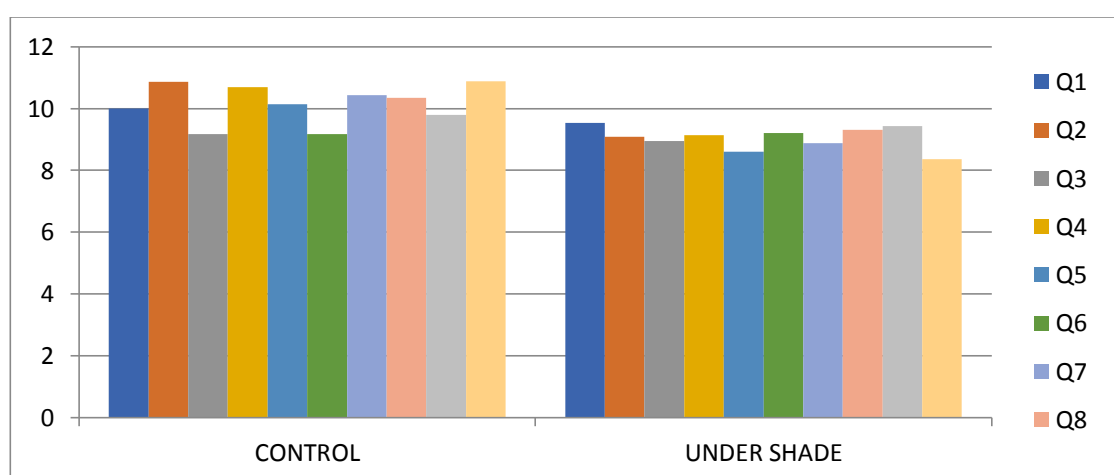
**Fig 4.9: Straw yield per ha (tonne) in control and under shade condition in Experimental Site - 1**

#### 4.1.1.3.3 Biological yield

The statistical data revealed that there is a significant difference in biological yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The data on biological yield (t ha<sup>-1</sup>) is presented in Table 4.3 and Fig 4.9. A significantly higher biological yield was observed in the open (control) condition in Q10 (10.876 t ha<sup>-1</sup>) followed by Q2 (10.863 tonne ha<sup>-1</sup>) and Q4 (10.699 tonne ha<sup>-1</sup>). The minimum biological yield was found in Q10 (8.359tonne ha<sup>-1</sup>) followed by Q5 (8.601 tonne ha<sup>-1</sup>) and Q7 (8.877 tonne ha<sup>-1</sup>) when the crop was grown under bund plantation of *Acacia auriculiformis* tree. The biological yield was significantly influenced by the light and bund plantation of tree.

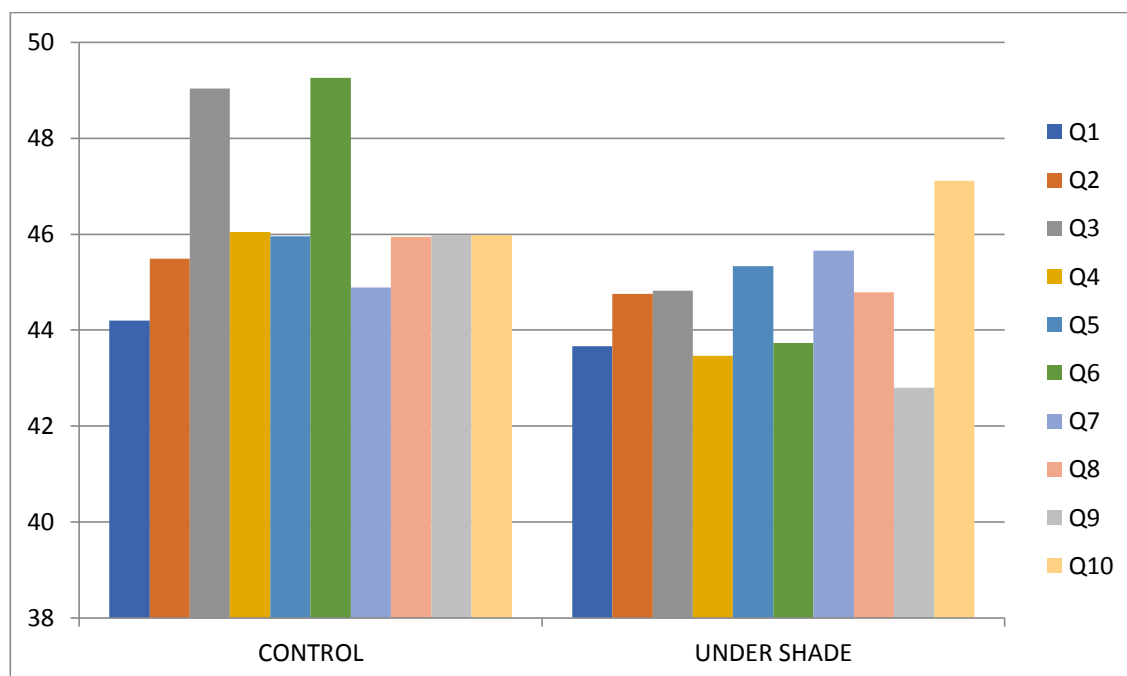
The instantaneous change in light intensity has a profound impact on the crop's photosynthetic response (Knapp and Smith, 1990), and the adverse effect on the yield and yield characteristics of rice might mainly be due to the decreased availability of photosynthetically active radiation (PAR) since it has been found that the rate of biomass production in many cereal crops is proportional to the PAR (Nandal *et.al.*, 1999). Ultimately, the decreased temperature due to the shading effect results in the rice crop's decreased water temperature, leaf temperature, leaf water ability, and leaf water quality and ultimately decreases the crop's yield and yield characteristics (Tripathi *et al.*,2005).



**Fig 4.10: Biological yield per ha (tonne) in control and under shade condition in Experimental Site - 1**

#### 4.1.1.3.4 Harvest index

Data on harvest index are presented in Table 4.3 and Fig 4.11. The differences in harvest index under both the sites were significant as the calculated value is more than the tabulated value. Paddy crops grown under bund plantation of *Acacia auriculiformis* produced a lower harvest index as compared to control. Maximum harvest index was found in Q6 (49.26 %) followed by Q3 (49.04%) and Q4 (46.05%) when the crop was grown in open (control) condition and the minimum was found in Q9 (42.8%) followed by Q4 (43.46%) and Q1 (43.67%) under bund plantation of *Acacia auriculiformis*. The harvest index (%) was significantly influenced by light and bund plantation of tree.



**Fig 4.11: Harvest index (%) in control and under shade condition in Experimental Site - 1**

Overall the reduction in the yield of intercrops due to the presence of trees may be attributed to differential patterns of canopy spread resulting in variation in light interception (shade effects) and competition of the tree roots for nutrients and moisture. These results are in confirmation with the findings of Sharma *et al.* (1996). The reduction of biological yield was due to the reduction in yield contributing factors (plant height, no of tillers and 100-grain weight), which may have been affected by the micro-environmental changes *i.e.* solar radiation and air temperature under the canopy. The variation in harvest index between different sites may be due to the fact that different

sites differ with respect to their grain and biological yield potential. These results are similar to those reported by Dhillon *et al.* (1984), Vityakon *et al.* (1995), Bhardwaj *et al.* (2005), Chauhan *et al.* (2012).

#### **4.1.2 Growth parameters of paddy (Pooja) under *Eucalyptus tereticornis* and as a sole crop**

##### **4.1.2.1 Plant Height**

The results on plant height (cm) at various stages of crop growth (90 days after planting, 120 days after planting, 150 days after planting *i.e.*, at harvest) are presented in Table 4.4 under control conditions and *Eucalyptus tereticornis* based agroforestry system.

The statistical analysis of plant height observation at 90 days, 120 days, and 150 days showed that the calculated value *i.e.*, t-stat value is less than the tabulated value *i.e.*, t critical two-tail value. It indicates that there is a significant difference in plant height of paddy (Pooja variety) in both the condition.

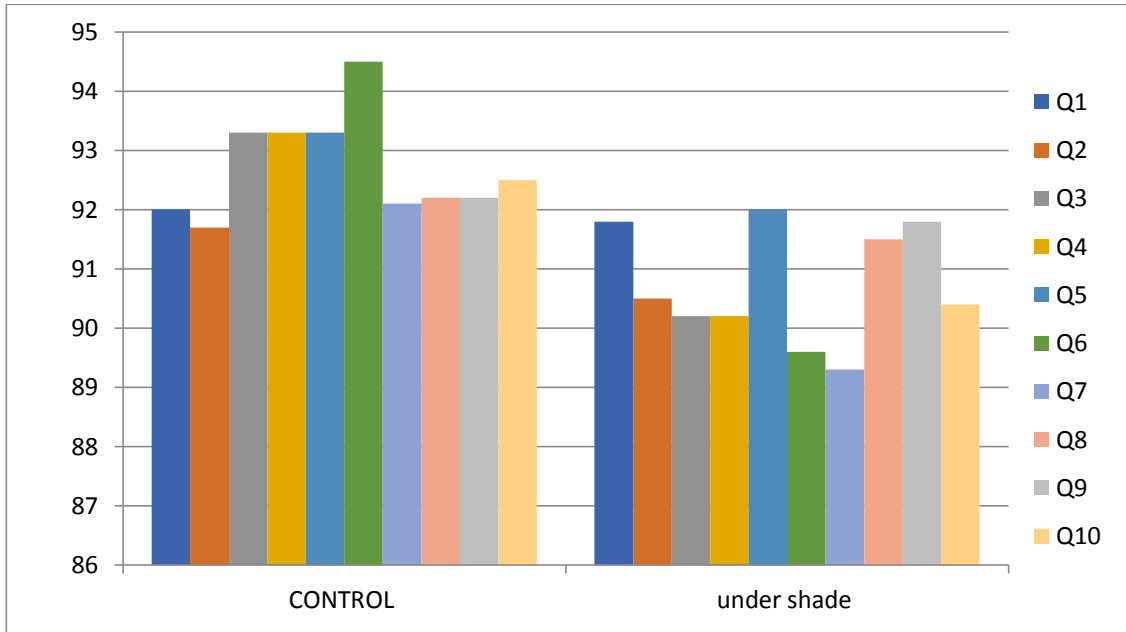
Plant height continued to increase with the increase in crop stages and reached a maximum at maturity. Results revealed that the plant height growth of paddy crop was significantly highest at 90 days after planting in Q6 (94.5 cm) followed by Q3, Q4, Q5 (93.3 cm), and Q10 (92.5 cm) under control *i.e.* light condition and lowest in Q7 (89.3 cm) followed by Q6 (89.6 cm) Q3 and Q4 (90.2 cm) under bund plantation of *Eucalyptus tereticornis*. The observation of 120 days after planting showed that the plant height growth of paddy crop was highest in Q10 (113.9 cm) followed by Q3 (113.4 cm) under control and lowest in Q3 (108.9 cm) followed by Q6 (109.1 cm) under bund plantation of eucalyptus. At harvesting time *i.e.* 150 days after planting the plant height of paddy was highest in Q9 ( 127.8 cm) under control and the lowest was in Q2 and Q8 (123.5cm ) under the bund plantation of *Eucalyptus tereticornis* tree.

**Table 4.4: Plant height (cm) of paddy (Pooja) at various growth stages under control farming and *Eucalyptus tereticornis* based agroforestry system**

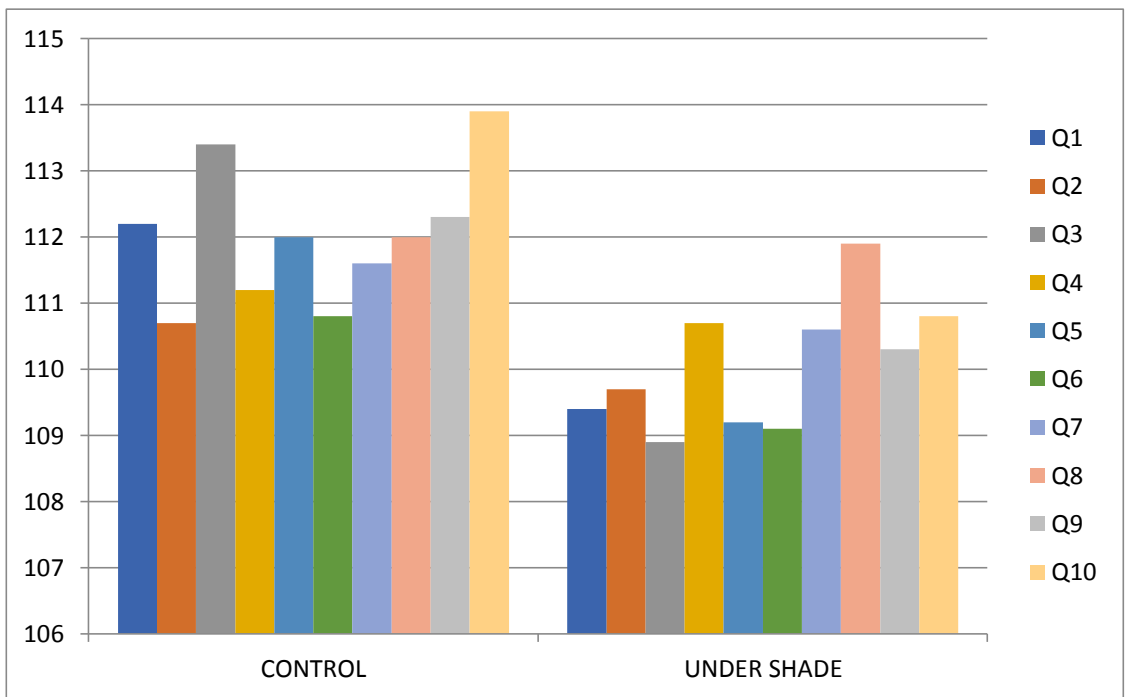
Quadrates	Height on 90 days in cm		Height on 120 days in cm		Height on 150 days in cm	
	Control	Under the bund plantation of eucalyptus	Control	Under the bund plantation of eucalyptus	Control	Under the bund plantation of eucalyptus
<b>Q1</b>	92	91.8	112.2	109.4	124.8	124.8
<b>Q2</b>	91.7	90.5	110.7	109.7	127.6	123.5
<b>Q3</b>	93.3	90.2	113.4	108.9	126.4	124.7
<b>Q4</b>	93.3	90.2	111.2	110.7	124.9	124.8
<b>Q5</b>	93.3	92	112	109.2	126.9	123.6
<b>Q6</b>	94.5	89.6	110.8	109.1	127.2	125.6
<b>Q7</b>	92.1	89.3	111.6	110.6	127.1	124
<b>Q8</b>	92.2	91.5	112	111.9	125.7	123.5
<b>Q9</b>	92.2	91.8	112.3	110.3	127.8	125.9
<b>Q10</b>	92.5	90.4	113.9	110.8	125.2	124
<b>t Stat</b>	4.19		4.53		4.58	
<b>T critical two-tail</b>	2.26		2.26		2.26	
<b>Significant /non significant</b>	Significant		Significant		Significant	

The data on plant height also showed that under the bund plantation of *Eucalyptus tereticornis* growth of paddy was less than under control *i.e.* light condition and as a result, the lowest plant height was observed under the bund plantation of eucalyptus and the highest plant height was observed under control condition. Similar observations were also recorded by Bahar (2006), Nazir, *i.e.*, (1993), Verma *et al.*(2014).

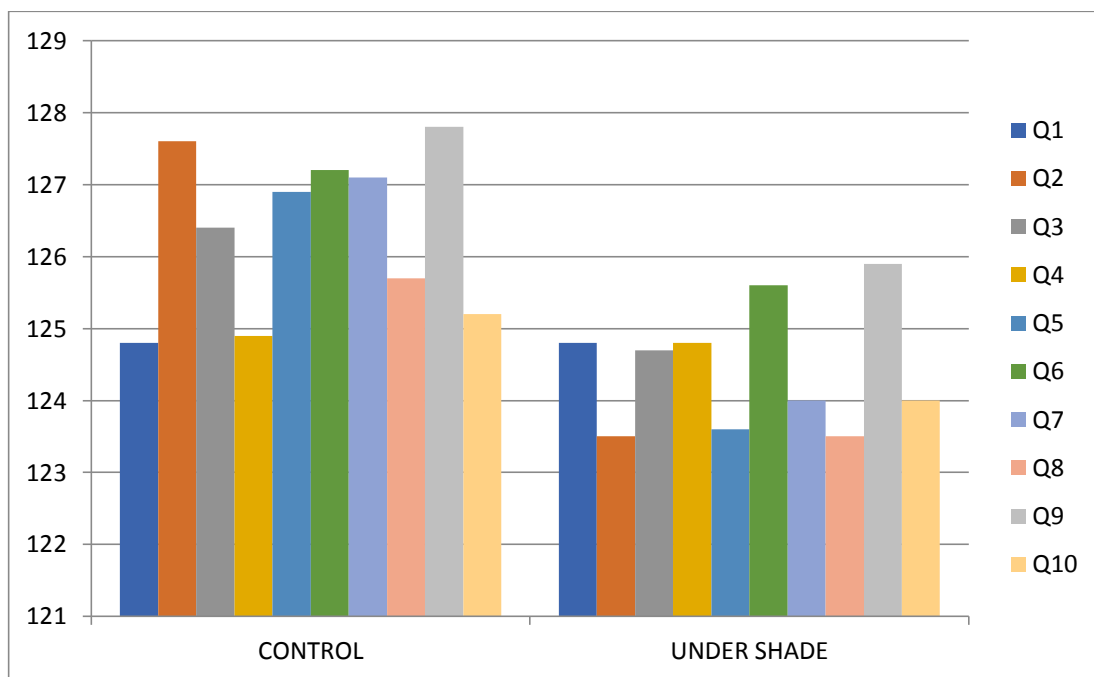
The shading effect of trees and competition for growth factors between trees and crop plants may be the possible reason for the reduction in plant height of paddy under eucalyptus trees. The variation in plant height at different sites may be due to the difference in soil nutrient availability and the difference in crown spread.



**Fig 4.12: Height growth of paddy (Pooja variety) in control and under shade condition at 90 DAP in Experimental Site – 2**



**Fig 4.13: Height growth of paddy (Pooja variety) in control and under shade condition at 120 DAP in Experimental Site - 2**



**Fig 4.14: Height growth of paddy (Pooja variety) in control and under shade condition at 150 DAP in Experimental Site - 2**

#### 4.1.2.2 Growth attributes

The data on growth attributes viz. No of tillers per plant, Panicle length of paddy, no of grains per panicle, seed weight of 100 grains, grain yield, straw yield, biological yield, harvest index are presented and discussed under the following tables.

**Table4.5: No of Tillers Plant<sup>-1</sup>, Panicle length of paddy, No of Grains Panicle<sup>-1</sup>, Weight of 100 grains (g) in the Paddy Field in Pattamundai, Kendrapada, Odisha**

Quadrates	No of Tillers Plant <sup>-1</sup> at harvest		Panicle length of paddy at harvest		No of Grains per Panicle at harvest		Weight of 100 grains (g) at harvest	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
<b>Q1</b>	9.7	10.3	25	24.1	296.4	298.8	2.292	2.098
<b>Q2</b>	10.6	9.7	25.5	24.4	302.4	290	2.134	2.08
<b>Q3</b>	10	9.4	25.5	23.1	304.4	301.6	2.145	2.138
<b>Q4</b>	10	9.6	24.6	23.6	289.6	292	2.208	2.011
<b>Q5</b>	10.1	9.5	25	24.9	313.6	300.8	2.125	2.074
<b>Q6</b>	10.5	10.2	25.6	23.3	305.2	300.8	2.211	2.124
<b>Q7</b>	9.8	9.5	25.1	24.4	314.4	280.8	2.153	2.012
<b>Q8</b>	9.5	9.3	25	23.1	296.8	292	2.281	2.16
<b>Q9</b>	10	9.5	25.2	24.4	301.2	287.2	2.117	2.099
<b>Q10</b>	10	10	24.5	24.6	313.6	290.4	2.159	2.013
<b>t Stat</b>	2.48		4.13		2.85		4.67	
<b>T critical two – tail</b>	2.26		2.26		2.26		2.26	
<b>Significant /non-Significant</b>	Significant		Significant		Significant		Significant	

**Table4.6 : Grain yield, Straw yield, Biological yield, Harvest index in the Paddy Field in Pattamundai, Kendrapada, Odisha**

Quadrates	Grain yield		Straw yield		Biological yield		Harvest index	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
<b>Q1</b>	4.524	4.26	5.685	5.467	10.20	9.72	44.31	43.8
<b>Q2</b>	4.842	4.01	5.821	4.936	10.66	8.94	45.41	44.82
<b>Q3</b>	4.596	4.066	4.772	5.019	9.368	9.08	49.06	44.76
<b>Q4</b>	4.927	3.973	5.772	4.421	10.69	8.39	46.05	47.33
<b>Q5</b>	4.758	3.899	5.577	4.702	10.33	8.60	46.04	45.33
<b>Q6</b>	4.616	4.127	4.751	5.281	9.367	9.40	49.28	43.87
<b>Q7</b>	4.78	4.052	5.845	4.825	10.62	8.87	44.99	45.65
<b>Q8</b>	4.851	4.169	5.691	5.139	10.54	9.30	46.01	44.79
<b>Q9</b>	4.604	4.137	5.391	5.496	9.995	9.63	46.06	42.95
<b>Q10</b>	4.957	3.973	5.919	5.167	10.87	9.14	45.58	43.47
<b>t Stat</b>	9.09		2.45		4.50		2.38	
<b>T critical two – tail</b>	2.26		2.26		2.26		2.26	
<b>Significant/n on-Significant</b>	Significant		Significant		Significant		Significant	

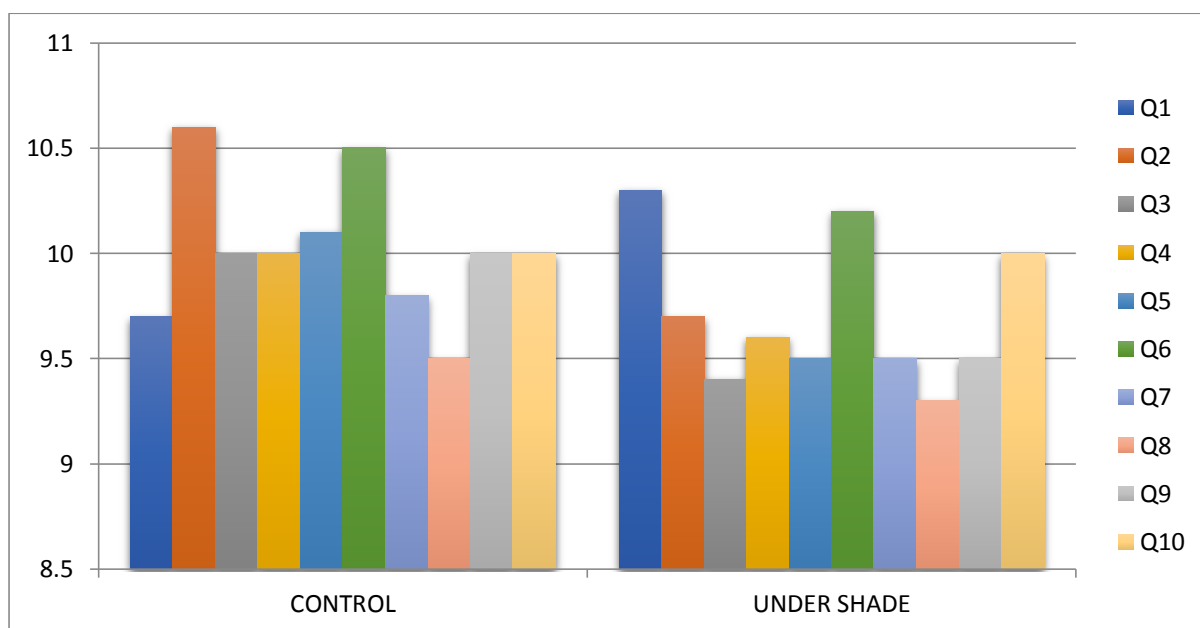
#### 4.1.2.2.1 No of tillers per plant

The statistical analysis of no of tillers per plant observation showed that the calculated value *i.e.*, t stat value is less than the tabulated value *i.e.*, t critical two-tail value. It indicates that there is a significant difference in no of tillers per plant in both the condition.

The data on a number of tillers per plant has been presented in Table 4.5 showed that the no of tillers per plant was significantly highest in Q2 (10.6/plant) followed by Q6 (10.5/plant) and Q5 (10.1/plant) under control *i.e.* light condition and lowest in Q8 (9.3/plant) followed by Q3 (9.4/plant) and Q5, Q7, Q9 (9.5/plant) under bund plantation of *Eucalyptus tereticornis*.

The data on no of tillers per plant also showed that under the bund plantation of *Eucalyptus tereticornis* no of tillers of paddy was less than under control *i.e.*, light condition which is in line with the findings of Sharma (1992) and Verma *et al.* (2014).

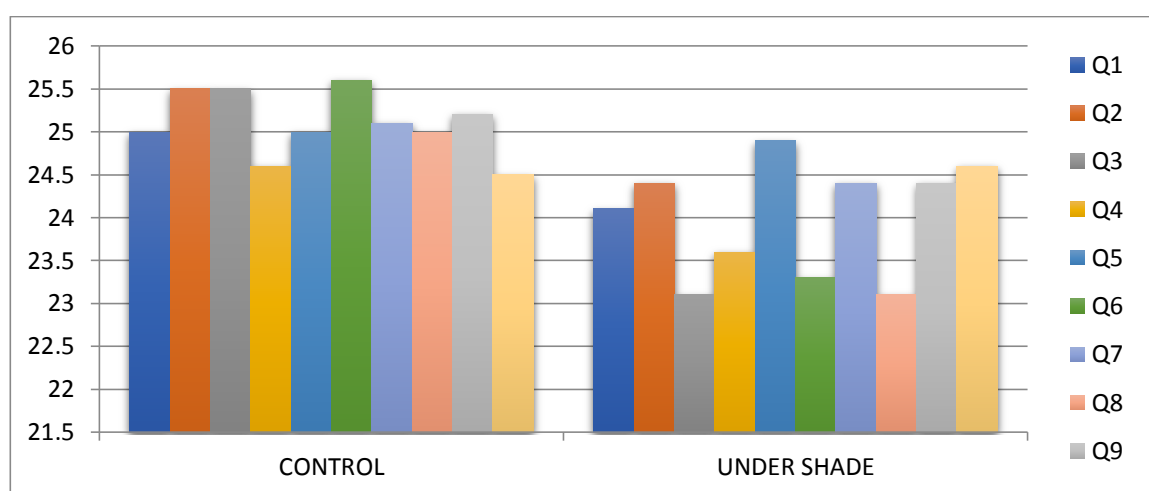
The maximum no of tillers per plant of paddy reported under control condition is may be due to more interception of solar radiation by paddy crops (Kiran and Agnihotri, 2001). The maximum reduction in no of tillers per plant in shade condition (fig.4.4) can be due to low light intensity and the low temperature caused by bund plantation of eucalyptus.



**Fig 4.15: No of tillers per panicle in control and under shade condition in Experimental Site - 2**

#### 4.1.2.2.2 Panicle length of paddy

The data of panicle length of paddy in cm and t-test values on panicle length (cm) at harvest has been presented in Table 4.5. T-test value showing that Panicle length differed significantly at both sites as t stat value (calculated value) is greater than t critical two-tail value (tabulated value). Significantly highest panicle length was observed under control condition than under bund plantation of eucalyptus. Significantly highest panicle length was observed in Q6 (25.6 cm) followed by Q2, Q3 (25.5 cm), and Q9 (25.2 cm) in open condition and lowest in Q3, Q8(23.1cm) followed by Q6(23.3cm) and Q4 (23.6 cm) under shade condition.

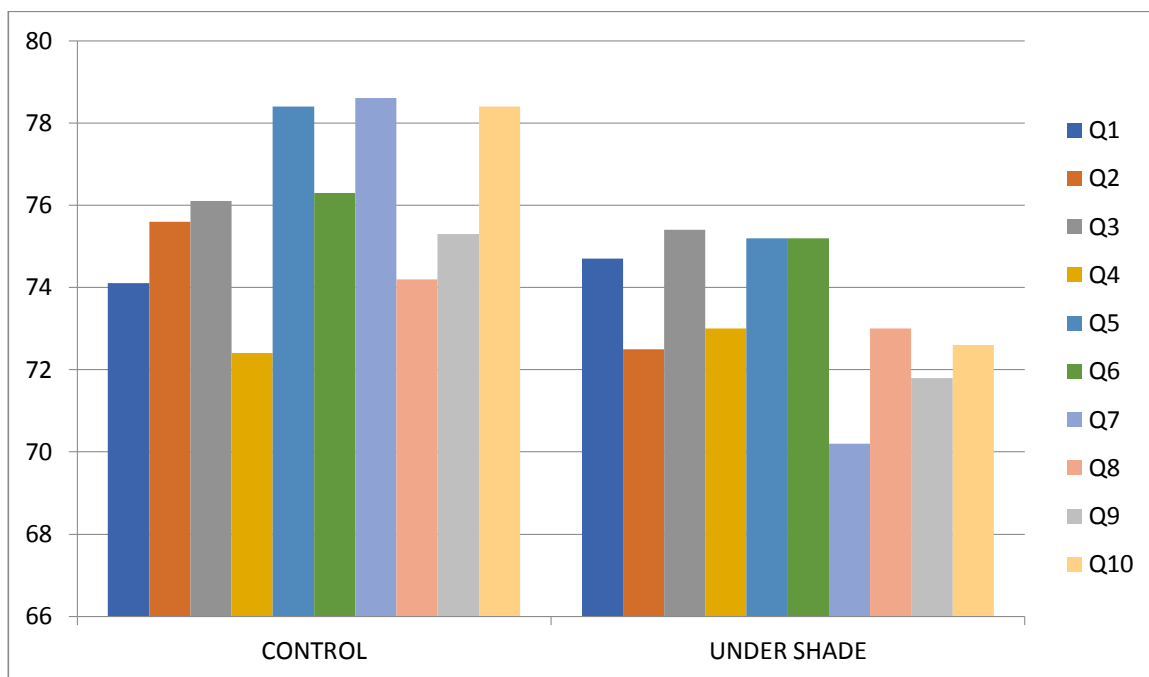


**Fig 4.16: Panicle length of paddy (cm) in control and under shade condition in Experimental Site – 2**

#### 4.1.2.2.3 No of grains per panicle

The data on the number of grains per panicle are presented in Table 4.5.

The result revealed that a statistically maximum number of grains per panicle was recorded in Q7 (314.4/panicle) followed by Q5, Q10 (313.6/panicle), and Q6 (305.2/panicle) in open conditions. The minimum number of grains per panicle was found when the crop was grown under bund plantation of eucalyptus in Q7 (280.8/panicle) followed by Q9 (287.2/panicle) and Q2 (290/panicle). The number of grains per panicle was significantly influenced by sunlight and bund plantation of eucalyptus.



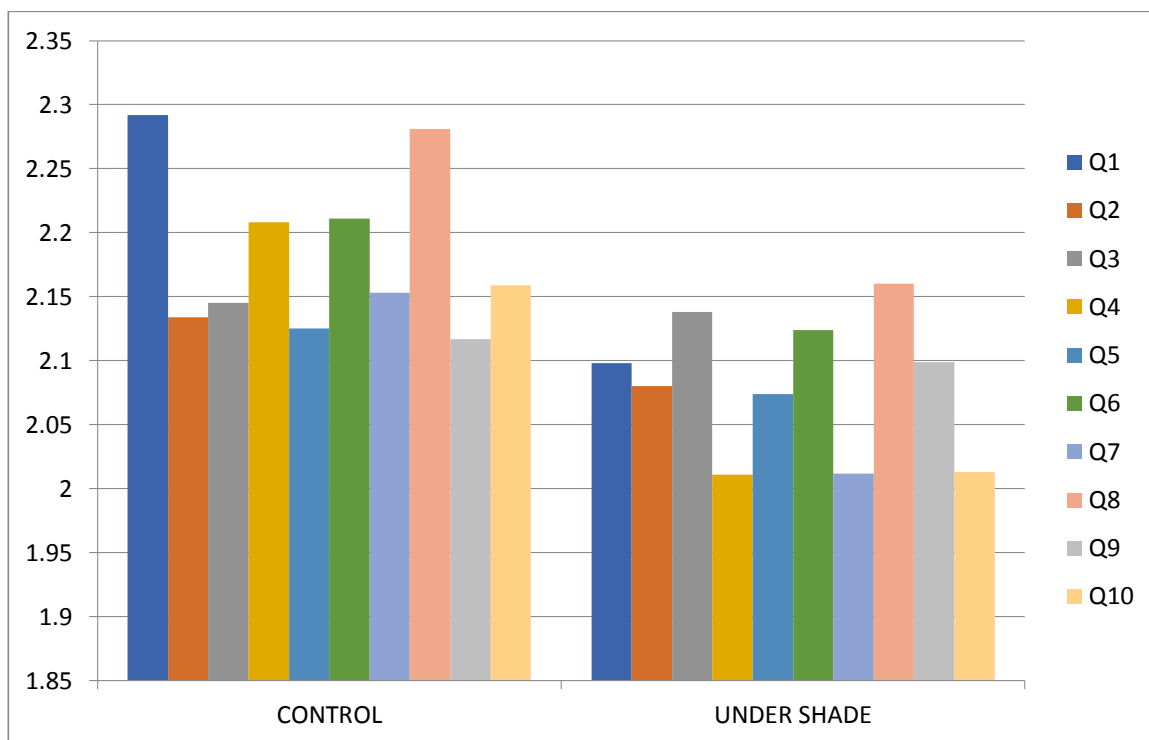
**Fig 4.17: No of grains per panicle in control and under shade condition in Experimental Site – 2**

#### 4.1.2.2.4 Weight of 100 grains in g

The statistical data revealed that there is a significant difference in the weight of 100 grain in both the site as the calculated value is more than the tabulated value.

The data presented in Table 4.5 on 100-grain weight (g) at harvest revealed that the 100-grain weight of paddy crop grown under bund plantation of eucalyptus is lower as compared to open (control) condition. The maximum 100-grain weight was found in Q1 (2.292 gm) followed by Q8 (2.281 gm) and Q6 (2.211 gm) when the crop was grown at open (control) condition and the minimum was found in Q4 (2.011 gm) followed by Q7 (2.012 gm) and Q10 (2.013gm) when the crop was grown under bund plantation of *Eucalyptus tereticornis*. The 100-grain weight was significantly influenced by sunlight and bund plantation of tree components.

Nazir *et al.*, (1993) stated that increasing the duration of shading may decrease the number of 1000-grain weight, grain protein concentration, and grain yield. Similarly, Jiang *et al.*, (1994) stated that total grain yield was affected by the tree crown area.



**Fig 4.18: Weight of 100 grains (gm) in control and under shade condition in Experimental Site – 2**

The results revealed that significantly highest yield attributes were observed at light condition and minimum at under bund plantation of eucalyptus. There was a reduction in panicle length, number of tillers, number of grains per panicle, and 100-grain weight under the eucalyptus-based agroforestry system as compared to the open farming system.

The variation in yield attributes of paddy (Pooja variety) may be due to the difference in light availability. The solar radiation is greater in the case of the open areas than those of other factors of the study. Overall, there was a slight reduction in the yield attributes of agricultural crops due to the competition for light, water, and nutrients among trees and paddy crops at both sites. Similar findings have also been reported by Tomar and Srivastava (1986), Newaj *et al.* (2003), and Chauhan *et al.* (2012). A number of workers have also reported a reduction of yield components due to shading effects; for example, reduced number of effective tillers (Kemp and Whingwiri, 1980), reduced number of grains (Rawson and Ruwali, 1972; Fischer 1975), reduced weight of grain (Fischer, 1975; Kemp and Whingwiri, 1980).

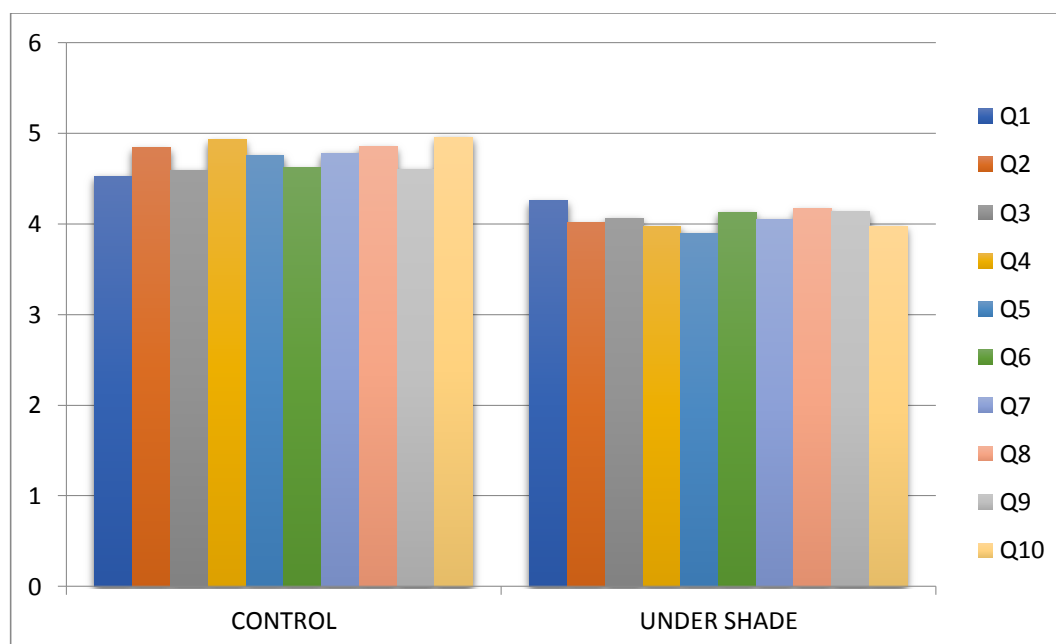
### 4.1.2.3 Yield attributes

#### 4.1.2.3.1 Grain yield

The statistical data revealed that there is a significant difference in grain yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The result on the grain yield (tonne ha<sup>-1</sup>) of paddy crops is presented in Table 4.6. At control (without trees) produced significantly higher grain yield than under eucalyptus based agroforestry system. The maximum number of grain yield was found at Q10 (4.957 tonne ha<sup>-1</sup>) followed by Q4 (4.927 t ha<sup>-1</sup>) and Q8 (4.851 t ha<sup>-1</sup>) and the minimum was found in Q5 (3.899 t ha<sup>-1</sup>) followed by Q4, Q10 (3.973 tonne ha<sup>-1</sup>) under bund plantation of eucalyptus. The grain yield was significantly influenced by light and bund plantation of tree.

Due to the boundary planting of *Eucalyptus tereticornis*, the grain yield of rice was slightly adversely affected. Similar findings have also been reported by Dhillon *et al.* (1984), Sharma (1992), and Verma *et al.* (2014). Sharma *et al.*, (1992) stated that the reduction in the yield of rice grown in association with trees reflects competition for growth resources such as radiant energy, nutrients, and moisture.

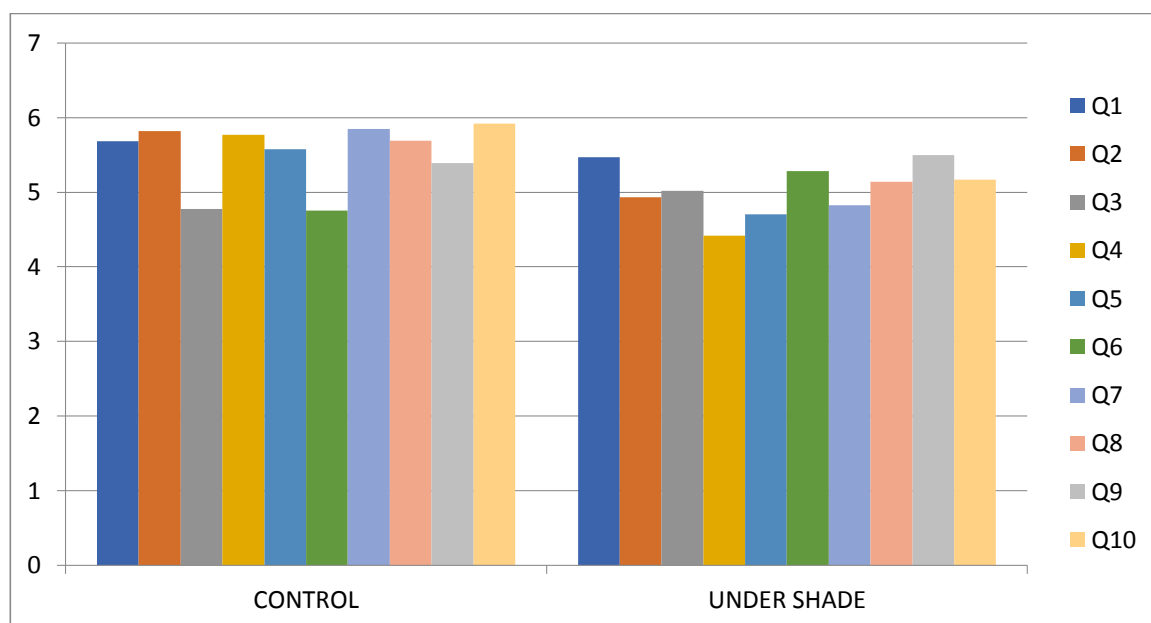


**Fig 4.19: Grain yield per ha (tonne) in control and under shade condition in Experimental Site – 2**

#### 4.1.2.3.2 Straw yield

The statistical data revealed that there is a significant difference in straw yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The result on straw yield (t ha<sup>-1</sup>) of paddy is presented in Table 4.6. Paddy crops grown under bund plantation of eucalyptus produced lower straw yield as compared to control. The maximum straw yield was found in Q10 (5.919 tonne ha<sup>-1</sup>) followed by Q7 (5.845 tonne ha<sup>-1</sup>) and Q2 (5.821 tonne ha<sup>-1</sup>) when the crop was grown at open (control) condition and the minimum was found in Q4 (4.421 t ha<sup>-1</sup>) followed by Q5 (4.702t ha<sup>-1</sup>) and Q7 (4.825 t ha<sup>-1</sup>) when the crop was grown under bund plantation of eucalyptus. The straw yield was significantly influenced by light and bund plantation of tree.



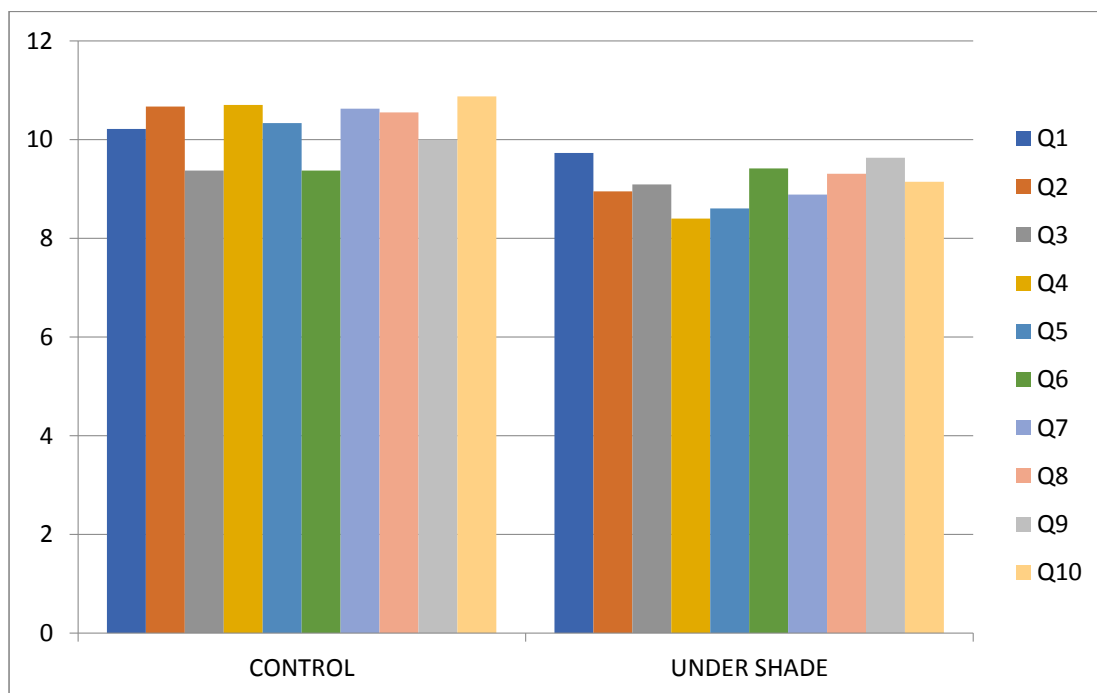
**Fig 4.20: Straw yield per ha (tonne) in control and under shade condition in Experimental Site – 2**

#### 4.1.2.3.3 Biological yield

The statistical data revealed that there is a significant difference in biological yield (tonne ha<sup>-1</sup>) in both the site as the calculated value is more than the tabulated value.

The data on biological yield (t ha<sup>-1</sup>) is presented in Table 4.6. A significantly higher biological yield was observed in the open (control) condition in Q10 (10.876 t ha<sup>-1</sup>) followed by Q4 (10.699 tonne ha<sup>-1</sup>) and Q2 (10.663 tonne ha<sup>-1</sup>). The minimum biological yield was found in Q4 (8.394tonne ha<sup>-1</sup>) followed byQ5 (8.601 tonne ha<sup>-1</sup>) and Q7 (8.877 tonne ha<sup>-1</sup>) when the crop was grown under bund plantation of the eucalyptus tree. The biological yield was significantly influenced by the light and bund plantation of tree.

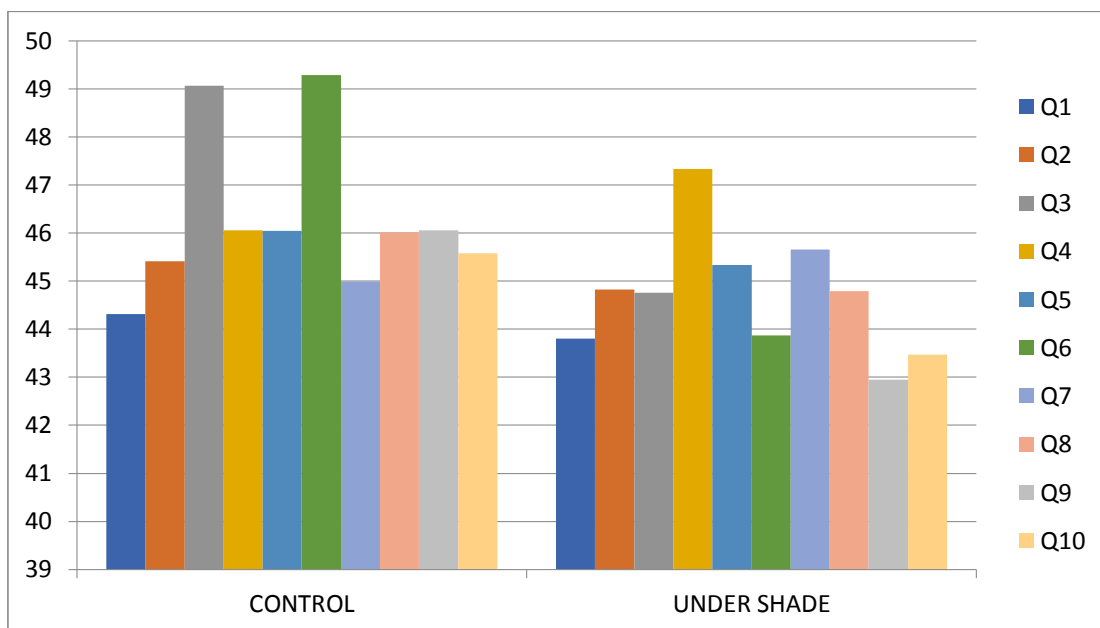
The instantaneous change in light intensity has a profound impact on the crop's photosynthetic response (Knapp and Smith, 1990), and the adverse effect on the yield and yield characteristics of rice might mainly be due to the decreased availability of photosynthetically active radiation (PAR) since it has been found that the rate of biomass production in many cereal crops is proportional to the PAR (Nandal *et al.*, 1999). Ultimately, the decreased temperature due to the shading effect results in the rice crop's decreased water temperature, leaf temperature, leaf water ability, and leaf water quality and ultimately decreases the crop's yield and yield characteristics (Tripathi *et al.*,2005).



**Fig 4.21: Biological yield per ha (tonne) in control and under shade condition in Experimental Site – 2**

#### 4.1.2.3.4 Harvest index

Data on harvest index are presented in Table 4.6. The differences in harvest index under both the sites were significant as the calculated value is more than the tabulated value. Paddy crops grown under bund plantation of eucalyptus produced a lower harvest index as compared to control. Maximum harvest index was found in Q6 (49.28 %) followed by Q3 (49.06%) and Q9 (46.06%) when the crop was grown in open (control) condition and minimum were found in Q9 (42.95%) followed by Q10 (43.47%) and Q1 (43.8%) under bund plantation of eucalyptus. The harvest index (%) was significantly influenced by light and bund plantation of tree.



**Fig 4.22: Harvest index (%) in control and under shade condition in Experimental Site – 2**

Overall the reduction in the yield of intercrops due to the presence of trees may be attributed to differential patterns of canopy spread resulting in variation in light interception (shade effects) and competition of the tree roots for nutrients and moisture. These results are in confirmation with the findings of Sharma *et al.* (1996). The reduction of biological yield was due to the reduction in yield contributing factors (plant height, no of tillers and 100-grain weight), which may have been affected by the micro-environmental changes *i.e.* solar radiation and air temperature under the canopy. The variation in harvest index between different sites may be due to the fact that different sites differ with respect to their grain and biological yield potential. These results are similar to those reported by Dhillon *et al.* (1984), Vityakon *et al.* (1995), Bhardwaj *et al.* (2005), Chauhan *et al.* (2012).

#### **4.2 Comparative study of BC ratio of paddy under Agri-silviculture system *Acacia auriculiformis* and *Eucalyptus tereticornis* based bund plantation**

##### **4.2.1B-C ratio of *Acacia auriculiformis* and paddy (Kalachampa) based agri-silviculture system**

The costs and returns of the *Acacia auriculiformis* based agri-silviculture system and control farming are present in table no 4.7. Observation of table 4.7 is showing that in agri-silviculture system cost of cultivation is more than control system

but the gross return is more in agri-silviculture system (Rs.167952 ha<sup>-1</sup>) than control system ((Rs.103000 ha<sup>-1</sup>). The B-C ratio is significantly higher in *Acacia auriculiformis* and paddy-based agri-silviculture system (3.00) than in control farming (2.09).

In comparison to control farming *Acacia auriculiformis* based agri-silviculture system provides more benefit. The reason behind more benefit in the agri-silviculture system than control farming is the production of wood from tree components. These results are similar to those reported by Rani *et al.*, (2016) and Wannawong (1991).

**Table4.7: Cost of cultivation (Rs. ha<sup>-1</sup>), Gross return (Rs. ha<sup>-1</sup>), net return (Rs. ha<sup>-1</sup>) &B-C ratio of both the Experimental sites**

	<i>Acacia auriculiformis</i> and paddy (Kalachampa) based agri-Silviculture system		<i>Eucalyptus tereticornis</i> and paddy (Pooja variety) based agri-Silviculture system	
	sole crop	Under acacia based agri-silviculture system	Sole crop	Under eucalyptus based agri-silviculture system
<b>Cost of cultivation (Rs. ha<sup>-1</sup>)</b>	49,250	55,980	45,650	52,390
<b>Gross return (Rs. ha<sup>-1</sup>)</b>	1,03,000	1,67,952	1,01,500	1,33,760
<b>Net return (Rs. ha<sup>-1</sup>)</b>	53,750	1,11,972	55,850	81,370
<b>B-C ratio</b>	2.09	3.00	2.22	2.55

#### **4.2.2 B-C ratio of *Eucalyptus tereticornis* and paddy (Pooja variety) based agri-silviculture system**

The costs and returns of the eucalyptus-based agri-silviculture system and control farming are present in table no 4.7. Observation of table 4.7 is showing that in agri-silviculture system cost of cultivation is more than control system but the gross return is more in agri-silviculture system (Rs.133760 ha<sup>-1</sup>) than control system ((Rs.101500 ha<sup>-1</sup>). The B: C ratio is significantly higher in the eucalyptus and paddy-based agri-silviculture system (2.55) than in control farming (2.22).

In comparison to control farming eucalyptus-based agri-silviculture system provide more benefit. The reason behind more benefit in the agri-silviculture system than control farming is the production of wood from tree component. These results are similar to those reported by Rani *et al.*, (2016) and Wannawong (1991).

### **4.3 Growth increment in DBH and height of the tree component *Acacia auriculiformis* and *Eucalyptus tereticornis* will be observed before and after harvesting of the crop.**

#### **4.3.1 Growth of *Acacia auriculiformis***

##### **4.3.1.1 Height (m)**

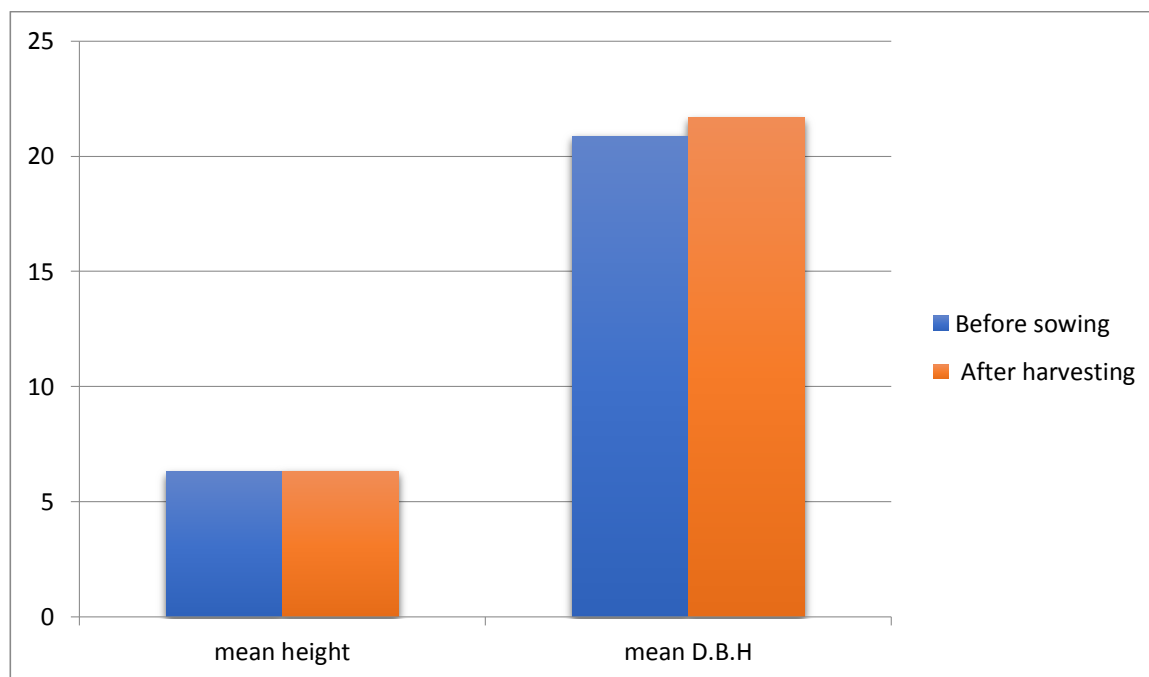
The data on the height of *Acacia auriculiformis* is presented in Table 4.8. The data of table 4.8 is revealed that there is a significant increase in tree height in the period of planting of paddy to the harvesting of paddy crop. The initial mean height of *Acacia auriculiformis* before planting of paddy was 6.30m and after harvesting of crop, the tree height increases to 6.33 m.

##### **4.3.1.2 D.B.H (cm)**

The data on D.B.H of *Acacia auriculiformis* is presented in table 4.8 is showing that there is a significant difference in D.B.H of *Acacia auriculiformis* at before planting of paddy and after harvesting of paddy. D.B.H of *Acacia auriculiformis* has increased after harvesting of paddy from the D.B.H of *Acacia auriculiformis* before planting of paddy. The initial mean D.B.H of *Acacia auriculiformis* was 20.87cm and after harvesting of paddy, the D.B.H of *Acacia auriculiformis* increases to 21.68cm.

**Table 4.8: D.B.H (cm) and Height of *Acacia auriculiformis* before and after harvesting of Paddy**

Name of species	Mean D.B.H (cm)		Mean Height (m)	
	Before planting of paddy crop	After harvesting of paddy crop	Before planting of paddy crop	After harvesting of paddy crop
<i>Acacia auriculiformis</i>	20.87	21.68	6.30	6.33
<i>Eucalyptus tereticornis</i>	24.23	24.96	8.60	8.64



**Fig 4.23: D.B.H (cm) and Height (m) of *Acacia auriculiformis* before and after harvesting of the crop in Experimental Site - 2**

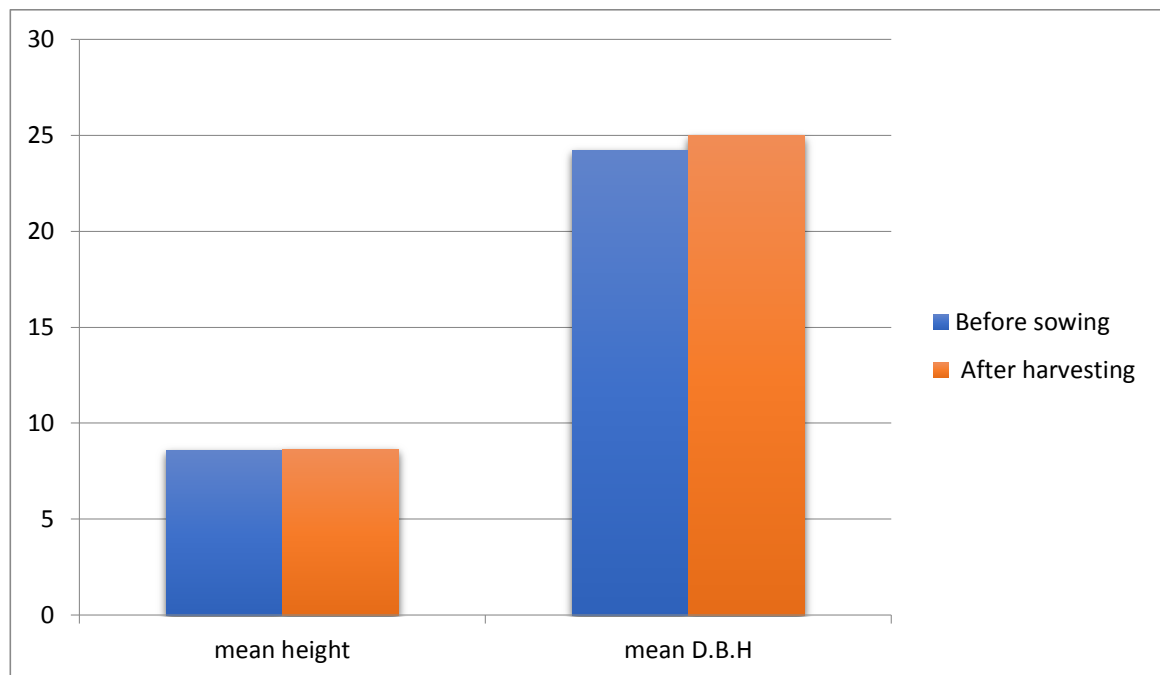
### 4.3.2 Growth of *Eucalyptus tereticornis*

#### 4.3.2.1 Height (m)

The data on the height of the eucalyptus are presented in Table 4.8. The data of table 4.8 is revealed that there is a significant increase in tree height in the period of planting of paddy to the harvesting of paddy crop. The initial mean height of *Eucalyptus tereticornis* before planting of paddy was 8.60m and after harvesting of crop the tree height increases to 8.64 m.

#### 4.3.2.2 D.B.H (cm)

The data on D.B.H of *Acacia auriculiformis* is presented in table 4.8 is showing that there is a significant difference in D.B.H of eucalyptus at before planting of paddy and after harvesting of paddy. D.B.H of eucalyptus has increased after harvesting of paddy from the D.B.H of eucalyptus before planting of paddy. The initial mean D.B.H of eucalyptus was 24.23cm and after harvesting of paddy the D.B.H of eucalyptus increases to 24.96 cm.



**Fig 4.24: D.B.H (cm) and Height (m) of *Eucalyptus tereticornis* before and after harvesting of the crop in Experimental Site - 2**

From the above observation, it is revealed that the tree height and DBH both increase when intercropped with paddy and tree growth and survival are unaffected by paddy crop and no disease or pests are found in either the forest or agricultural plants. The mean D.B.H and mean height of eucalyptus and *Acacia auriculiformis* both significantly increased from initial cropping time to the harvesting time of the crop. These results are similar to those reported by Couto and Gomes (1995), Mohsin *et al.*, (1996).

## CHAPTER-V

### SUMMARY AND CONCLUSION

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The study entitled “**Production Potential of Paddy under bund plantations in Agri-Silviculture Module under Agroforestry system in Kendrapada, Odisha**” was conducted during 2020-2021 in Kharif season. The experiment was carried out in KVK (Kendrapada, OUAT) and farmer’s fields (Balipada, Pattamundai, Kendrapada) at two different sites.

The experiment results revealed that the boundary plantation of *Acacia auriculiformis* and *Eucalyptus tereticornis* had an adverse effect on the growth and yield of paddy due to the shade effect of the tree.

#### **GROWTH AND YIELD ATTRIBUTES OF RICE**

Plant height of paddy at different stages of growth significantly reduced under both acacia and eucalyptus trees as compared to control. The maximum plant height (cm) at 90DAT, 120 DAT, 150DAT was found in light condition *i.e* control condition and the minimum plant height at 90DAT, 120 DAT, 150DAT was found in shade condition *i.e* under acacia and paddy (Kalachampa) based agri-silviculture system. Similarly, the maximum plant height (cm) at 90DAT, 120 DAT, 150 DAT was found in control farming and the minimum plant height at 90DAT, 120 DAT, 150DAT was found in shade condition *i.e* under eucalyptus and paddy (Pooja) based agri-silviculture system.

Due to low light intensity and the low temperature caused by the shade of acacia and eucalyptus, the no of tillers per plant is reduced in shade conditions than control.

The maximum no. of tillers per plant was recorded under control *i.e.*, light condition and the minimum was recorded under shade condition *i.e.*, in acacia and paddy (Kalachampa) based agri-silviculture system. Similarly, the no of tillers per plant was reduced in the eucalyptus and paddy-based agri-silviculture system compare to control farming.

Significantly maximum panicle length of paddy (cm) was found under control condition and minimum panicle length of paddy (cm) was found under an agri-

silviculture system in both the sites (acacia based and eucalyptus based agri-silviculture system).

The panicle length of paddy is reduced significantly in the agri-silviculture system than in control farming due to the shade effect of tree component at both sites.

The no of grains per panicle of paddy was recorded significantly higher at control than the agri-silviculture system in both the sites. The maximum no of grains per panicle of paddy was found under control conditions and the minimum no of grains per panicle of paddy was found under acacia and paddy (Kalachampa) based agri-silviculture system. Similarly, in the eucalyptus and paddy (Pooja) based agri-silviculture system no grains per panicle was found less compare to the control farming system.

The weight of 100 paddy grains in g is significantly higher in control farming compare to acacia and paddy (Kalachampa) based agri-silviculture system and as well as eucalyptus and paddy (Pooja) based agri-silviculture system recorded reduced weight of 100 paddy grain (g) compare to control farming system.

In Acacia and paddy-based agri-silviculture system, higher grain yield per ha was observed compared to the control farming system, and similarly, in the eucalyptus and paddy-based agri-silviculture system, less grain yield per ha was found compare to the control farming system. Due to the boundary planting of acacia and eucalyptus, the grain yield of paddy is adversely affected.

The straw yield of paddy (Kalachampa) was found significantly higher in light condition (control farming system) comparing to under shade of a tree (acacia and paddy based agri-silviculture system) and as well as in eucalyptus and paddy (Pooja) based agri-silviculture system straw yield was found lower than control farming system.

Lower Biological yield was observed in acacia and paddy (Kalachampa) based agri-silviculture system than control farming and similarly, the biological yield was higher in control farming compare to eucalyptus and paddy (Pooja) based agri-silviculture system.

In acacia-paddy based agri-silviculture system harvest index was observed lower comparing to control farming system *i.e* light condition and in eucalyptus-paddy

based system also lower harvest index was found under the shade of tree compare to light condition (Control farming system).

The above observation showed that in the agroforestry system the different yield attributes of paddy crop such as plant height, no of tillers per plant, panicle length, no of grain per panicle, the weight of 100 grains, grain yield per ha was reduced compared to control farming where paddy was grown as a sole crop. The reason behind this reduction of paddy yield may be due to the shade effect of tree components as well as a reduced amount of solar radiation and competition among the crop and tree components for moisture and nutrient.

### **ECONOMIC ATTRIBUTES OF RICE**

In the agroforestry system, the maximum gross return or B-C ratio was obtained from the acacia-paddy (Kalachampa) based agri-silviculture system, and on the other hand gross return / B-C ratio from control farming was found lower than acacia-paddy (Kalachampa) based agri-silviculture system. Similarly, the higher gross return / B-C ratio was found in the eucalyptus-paddy (Pooja) based agri-silviculture system, and on the other hand gross return / B-C ratio from control farming was found lower than agroforestry system.

The above observation revealed that there is more benefit in the agroforestry system compare to the traditional farming system where paddy is grown as a sole crop. Although the grain yield of paddy was reduced slightly in the agroforestry system due to the shade effect of tree component compare to control farming but in the end, the loss of grain yield would be overcome through the wood yield from the tree component and overall agroforestry system will give more economic benefit to the farmer than traditional farming of paddy *i.e.*, as a sole crop.

### **GROWTH OF TREE**

The increased mean height and mean diameter at breast height of *Acacia auriculiformis* was recorded at the harvesting of paddy crop from the time of transplanting of paddy crop in acacia and paddy (Kalachampa) based agri-silviculture system. Similarly, in the eucalyptus and paddy (Pooja) based agri-silviculture system the mean height and mean diameter at breast height of *Eucalyptus tereticornis* was

found to increase compare to initial (during transplanting of paddy crop) mean height and mean diameter at breast height.

The above observation revealed that the paddy crop does not has any adverse effect on the growth of tree components in both the system *i.e.* *Acacia auriculiformis* and paddy (Kalachampa) based agri-silviculture system and *Eucalyptus tereticornis* – paddy (Pooja) based agri-silviculture system.

Thus it can be concluded that the farmers should go with an agroforestry system instead of traditional farming in the region of Kendrapada district of Odisha for more economic benefit from a single piece of land by appropriate utilization of moisture and nutrient of the land through agroforestry system.

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## APPENDIX

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### APPENDIX I: Monthly Meteorological Data

Month	Temperature (°C)		Rainfall (cm)	Relative humidity (%)		Wind velocity (Kmph)	Sunshine hours
	Maximum	Minimum		I	II		
<b>August</b>	31	27	45.63	78	57	20.4	7.35
<b>September</b>	31	28	23.12	79	57	17.5	8.75
<b>October</b>	30	26	23.25	76	56	13.4	8.45
<b>November</b>	28	21	0.22	61	51	14.3	11.9
<b>December</b>	27	17	0	56	42	11	12.4

**Appendix II: cost of inputs used in production of rice (Kalachampa)**

S.No.	Particulars	Inputs	Rate (Rs)	Total Cost (Rs/ha)
<b>1.</b>	<b>Land preparation</b>			
	Ploughing	2 tractors (2 hr ha <sup>-1</sup> )	Rs. 1000 hr <sup>-1</sup>	<b>4000</b>
	Harrowing	1 tractor (1hr ha <sup>-1</sup> )	Rs.1000 hr <sup>-1</sup>	<b>1000</b>
	Leveling	1 tractor (1.25 hr ha <sup>-1</sup> )	Rs.1000 hr <sup>-1</sup>	<b>1250</b>
<b>2.</b>	<b>Sowing</b>			
	Seed	<b>30 kg</b>	<b>Rs. 90 kg<sup>-1</sup></b>	<b>2700</b>
	Labour	10	Rs. 450	<b>4500</b>
<b>3.</b>	<b>Transplanting</b>			
	Labour	25	Rs. 450	<b>11250</b>
<b>4</b>	<b>irrigation</b>			
	Irrigation	4	Rs. 475	<b>1900</b>
	Labour cost	7	Rs. 450	<b>3150</b>
<b>5</b>	<b>Fertilizer</b>			
	N	200kg	Rs. 6	<b>1200</b>
	P	100	Rs. 6	<b>600</b>
	K	100	Rs.18	<b>1800</b>
	Zn	25	Rs.64	<b>1600</b>
<b>6</b>	<b>Plant protection</b>			
	Pesticide	5 unit	355	<b>1775</b>
	Herbicide	5 unit	355	<b>1775</b>
	Labour cost	1	Rs.450	<b>450</b>
<b>7</b>	<b>Harvesting</b>			
	Harvesting	6 Labour	Rs.450	<b>2700</b>
	Threshing and winnowing	6 Labour	Rs.450	<b>2700</b>
<b>8</b>	<b>Transportation</b>			
		2 Tractor	Rs. 1325	<b>2650</b>
<b>9</b>	<b>Certification</b>			
				<b>750</b>
<b>10</b>	<b>Packaging</b>			
				<b>1500</b>
<b>Total Cost in rice cultivation = (Rs/ha)</b>				<b>=49250</b>

**Appendix III: cost of inputs used in production of *Acacia auriculiformis*.**

S.No.	Particulars	Inputs	Rate (Rs)	Total Cost (Rs/ha)
1	Seedling	23	Rs. 10 per seedling	<b>230</b>
2	Transplanting	1 labour	Rs. 500	<b>500</b>
3	Pruning	10 labour	Rs. 500	<b>5000</b>
4	Manure	200 kg	Rs. 5 kg	<b>1000</b>
<b>Total Cost in tree cultivation = (Rs/ha)</b>				<b>= 6730</b>

**Appendix IV: cost of inputs used in production of rice (pooja)**

S.No.	Particulars	Inputs	Rate (Rs)	Total Cost (Rs/ha)
<b>1.</b>	<b>Land preparation</b>			
	Ploughing	2 tractors (2 hr ha <sup>-1</sup> )	Rs. 1000 hr <sup>-1</sup>	<b>4000</b>
	Harrowing	1 tractor (1hr ha <sup>-1</sup> )	Rs.1000 hr <sup>-1</sup>	<b>1000</b>
	Leveling	1 tractor (1.5 hr ha <sup>-1</sup> )	Rs.1000 hr <sup>-1</sup>	<b>1500</b>
<b>2.</b>	<b>Sowing</b>			
	Seed	<b>30 kg</b>	<b>Rs. 95 kg<sup>-1</sup></b>	<b>2850</b>
	Labour	7	Rs. 450	<b>3150</b>
<b>3.</b>	<b>Transplanting</b>			
	Labour	25	Rs. 450	<b>11250</b>
<b>4</b>	<b>irrigation</b>			
	Irrigation	4	Rs. 475	<b>1900</b>
	Labour cost	7	Rs. 450	<b>3150</b>
<b>5</b>	<b>Fertilizer</b>			
	N	200kg	Rs. 6	<b>1200</b>
	P	100	Rs. 6	<b>600</b>
	K	100	Rs.18	<b>1800</b>
<b>6</b>	<b>Plant protection</b>			
	Pesticide	5 unit	355	<b>1775</b>
	Herbicide	5 unit	355	<b>1775</b>
	Labour cost	1	Rs.450	<b>450</b>
<b>7</b>	<b>Harvesting</b>			
	Harvesting	6 Labour	Rs.450	<b>2700</b>
	Threshing and winnowing	6 Labour	Rs.450	<b>2700</b>
<b>8</b>	<b>Transportation</b>			
		2 Tractor	Rs. 1325	<b>2650</b>
<b>10</b>	<b>Packaging</b>			
				<b>1200</b>
<b>Total Cost in rice cultivation = (Rs/ha)</b>				<b>=45650</b>

**Appendix V: Cost of inputs used in production of *Eucalyptus tereticornis*.**

S.No.	Particulars	Inputs	Rate (Rs)	Total Cost (Rs/ha)
1	Seedling	24	Rs. 10 per seedling	<b>240</b>
2	Transplanting	1 labour	Rs. 500	<b>500</b>
3	Pruning	10 labour	Rs. 500	<b>5000</b>
4	Manure	200 kg	Rs. 5 kg	<b>1000</b>
<b>Total Cost in tree cultivation = (Rs/ha)</b>				<b>= 6740</b>

**RESUME**

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