

**PERFORMANCE OF TURMERIC (*Curcuma longa* Rosc.)
UNDER BAMBOO (*Dendrocalamus strictus* (Roxb.) Nees
BASED AGROFORESTRY SYSTEM IN CHHATTISGARH**

M.Sc. (FORESTRY) THESIS

by

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**DEPARTMENT OF FORESTRY
COLLAGE OF AGRICULTURE
FACULTY OF AGRICULTURE
INDIRA GHANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.)
2020**

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Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

RUPESH KUMAR

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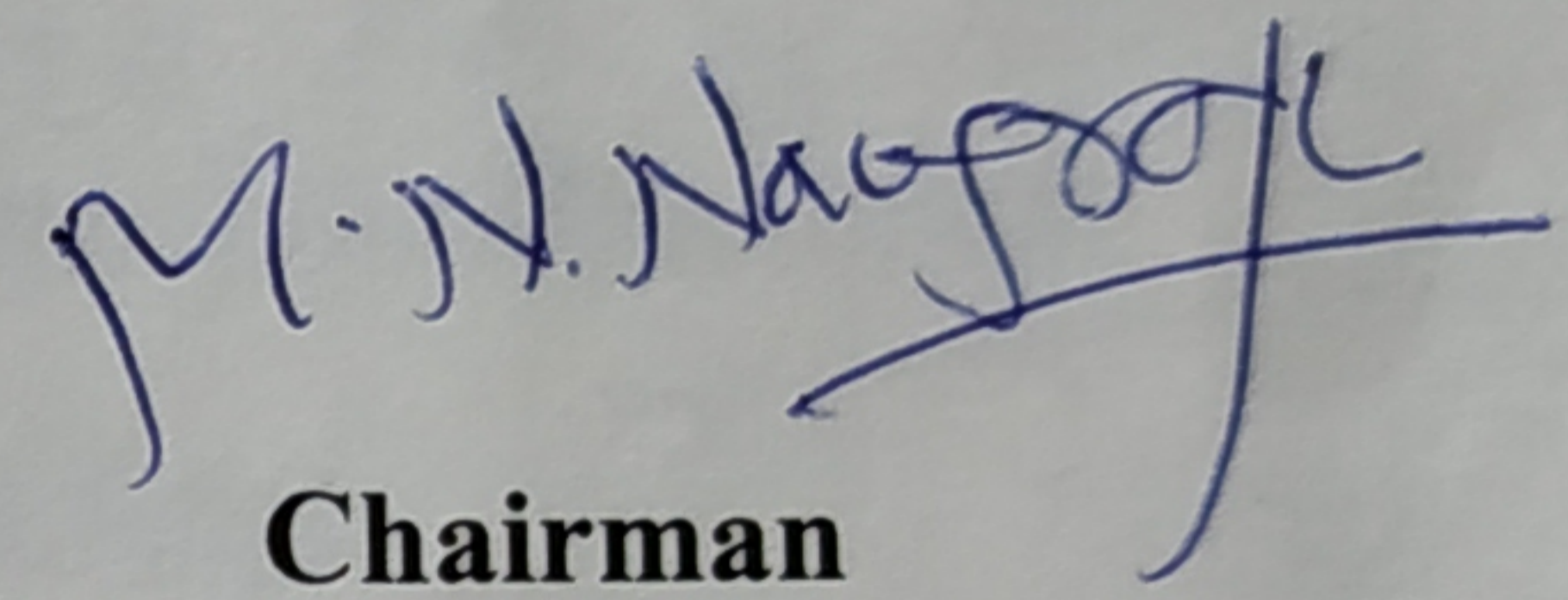
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CERTIFICATE - I

This is to certify that the thesis entitled "**Performance of Turmeric (*Curcuma longa* Rosc.) Under Bamboo (*Dendrocalamus strictus* (Roxb.) Nees based Agroforestry System in Chhattisgarh**" submitted in partial fulfilment of the requirements for the degree of "**Master of Science in Forestry**" of the **Indira Gandhi Krishi Vishwavidyalaya, Raipur**, is a recorded of the bonafide research work carried out by **Rupesh kumar** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory committee and 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.

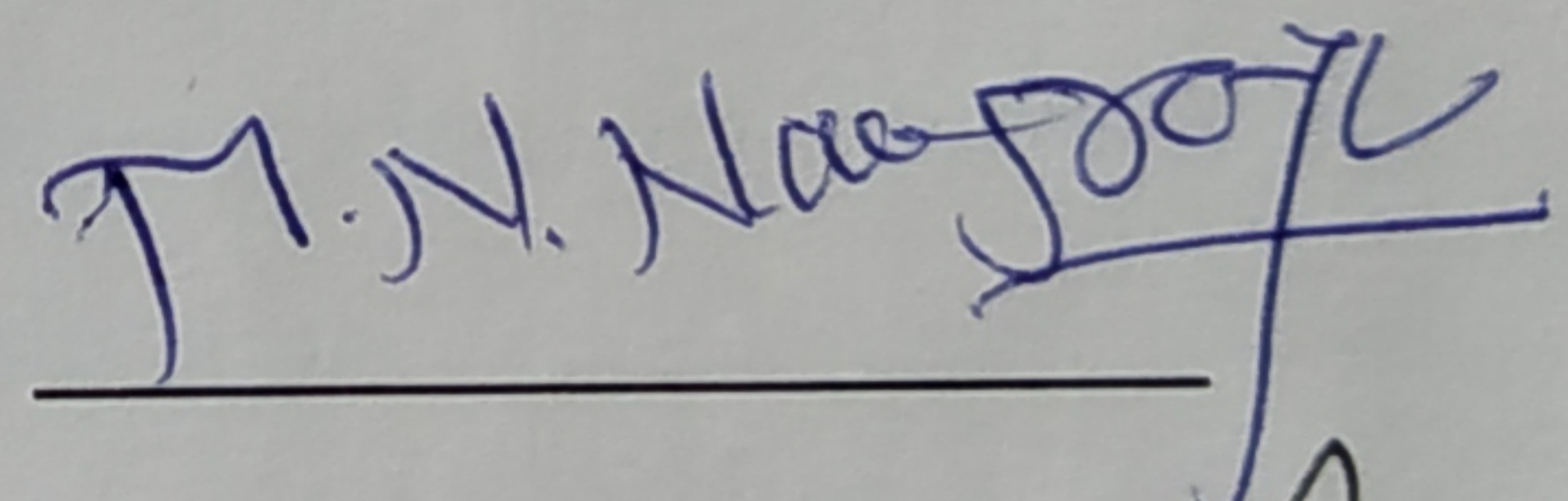
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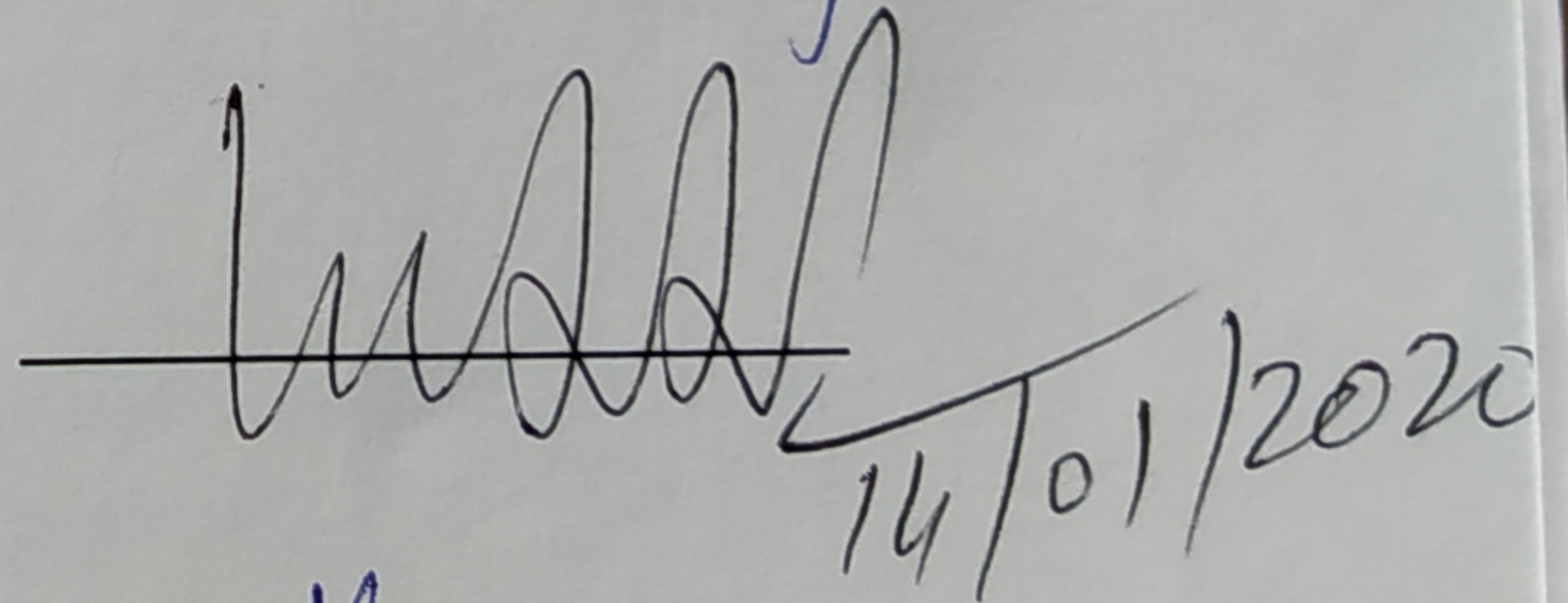
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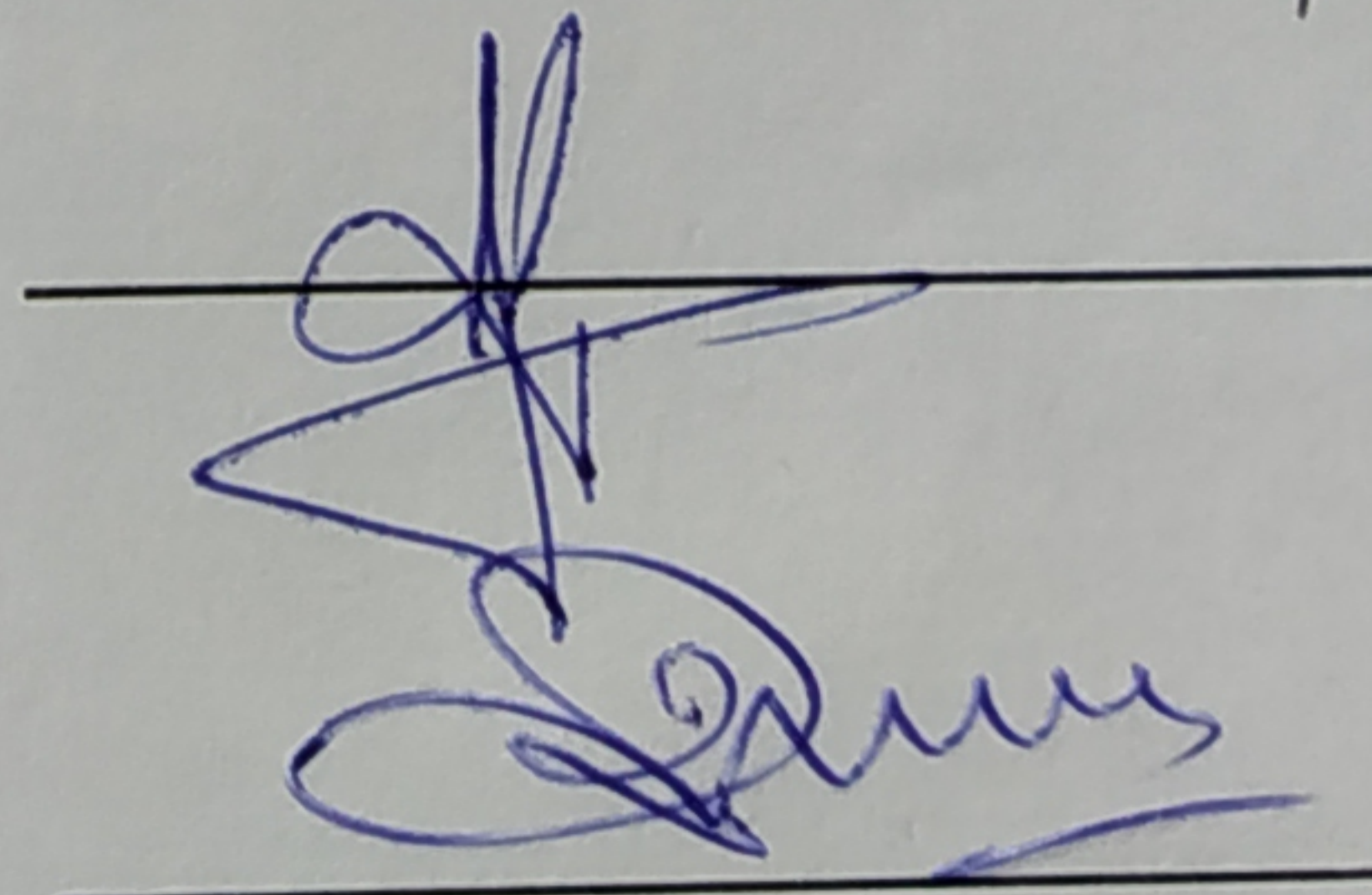
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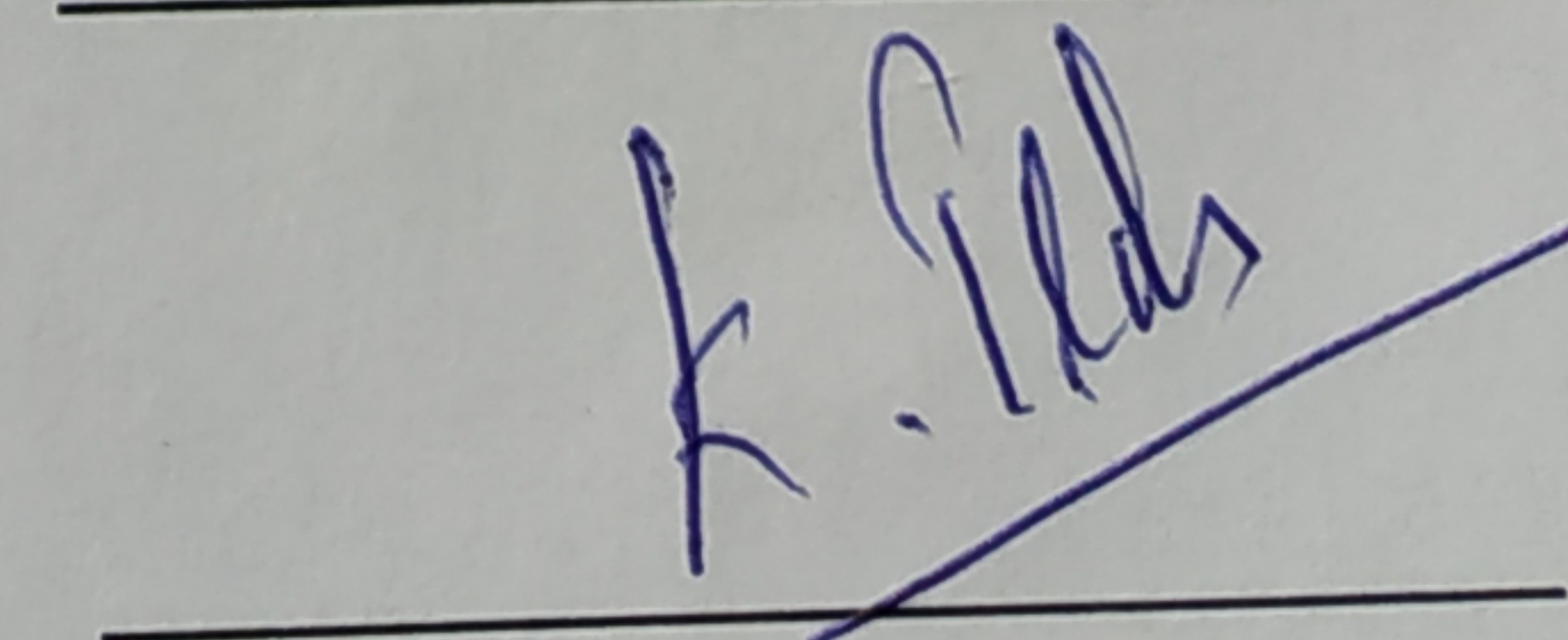
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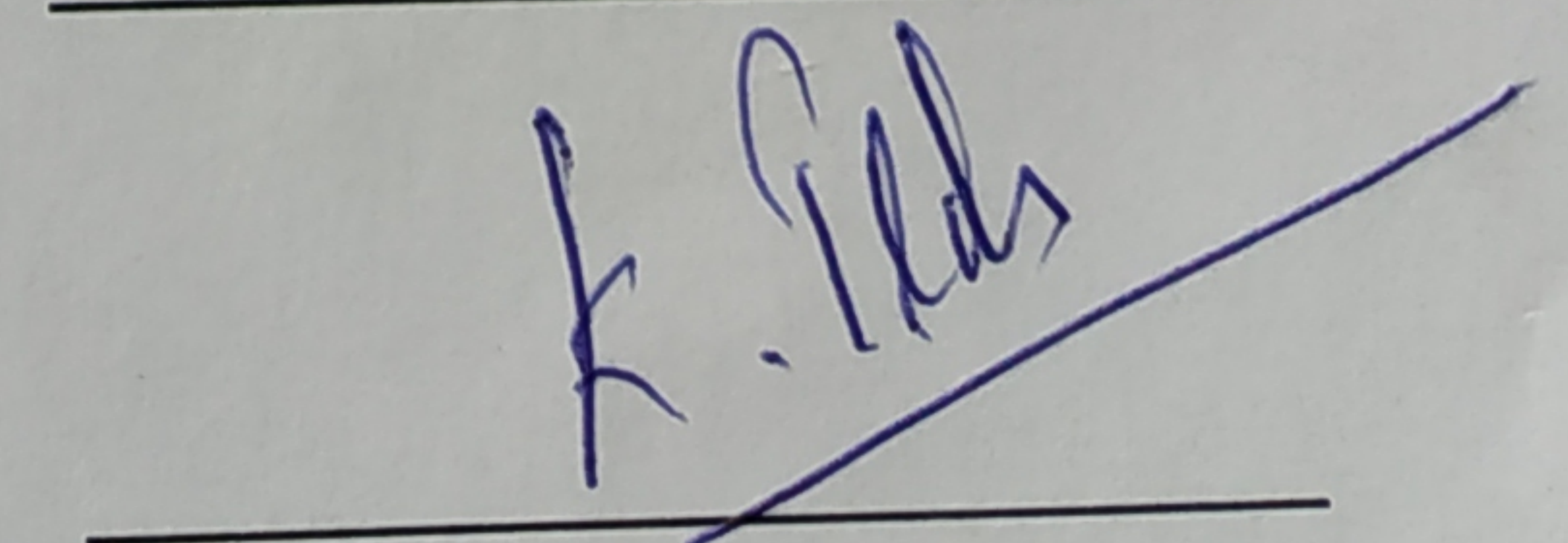
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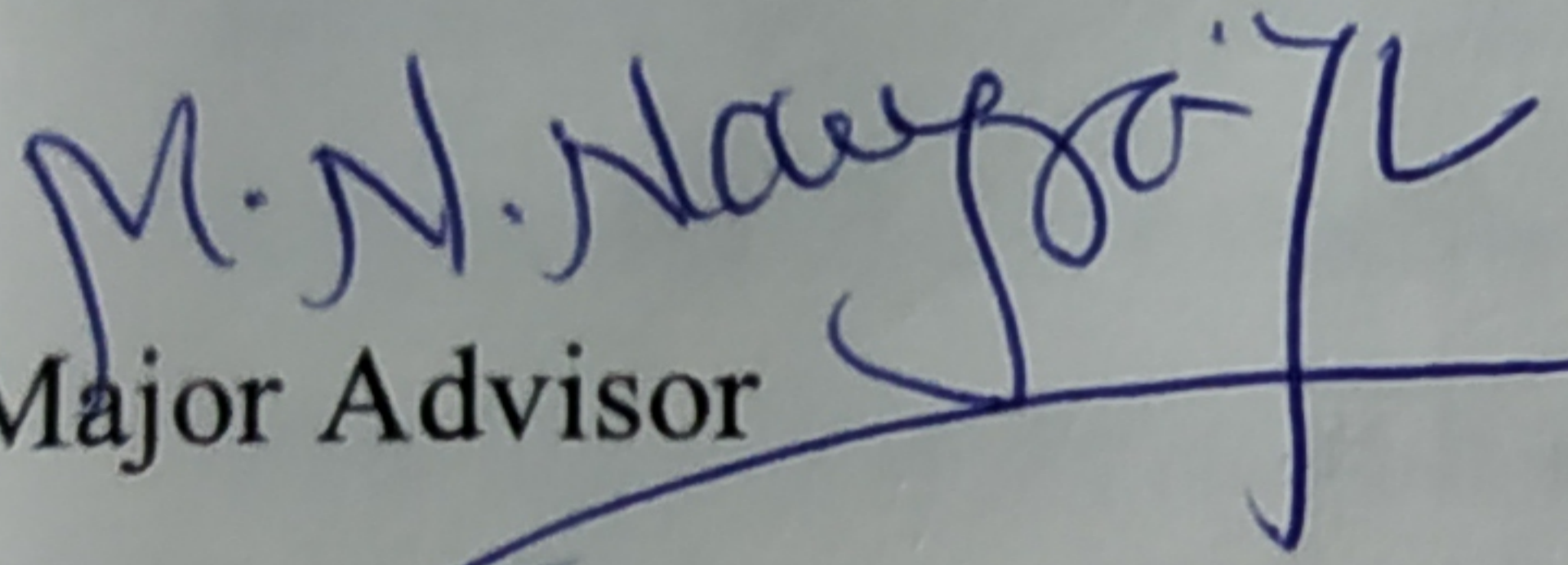


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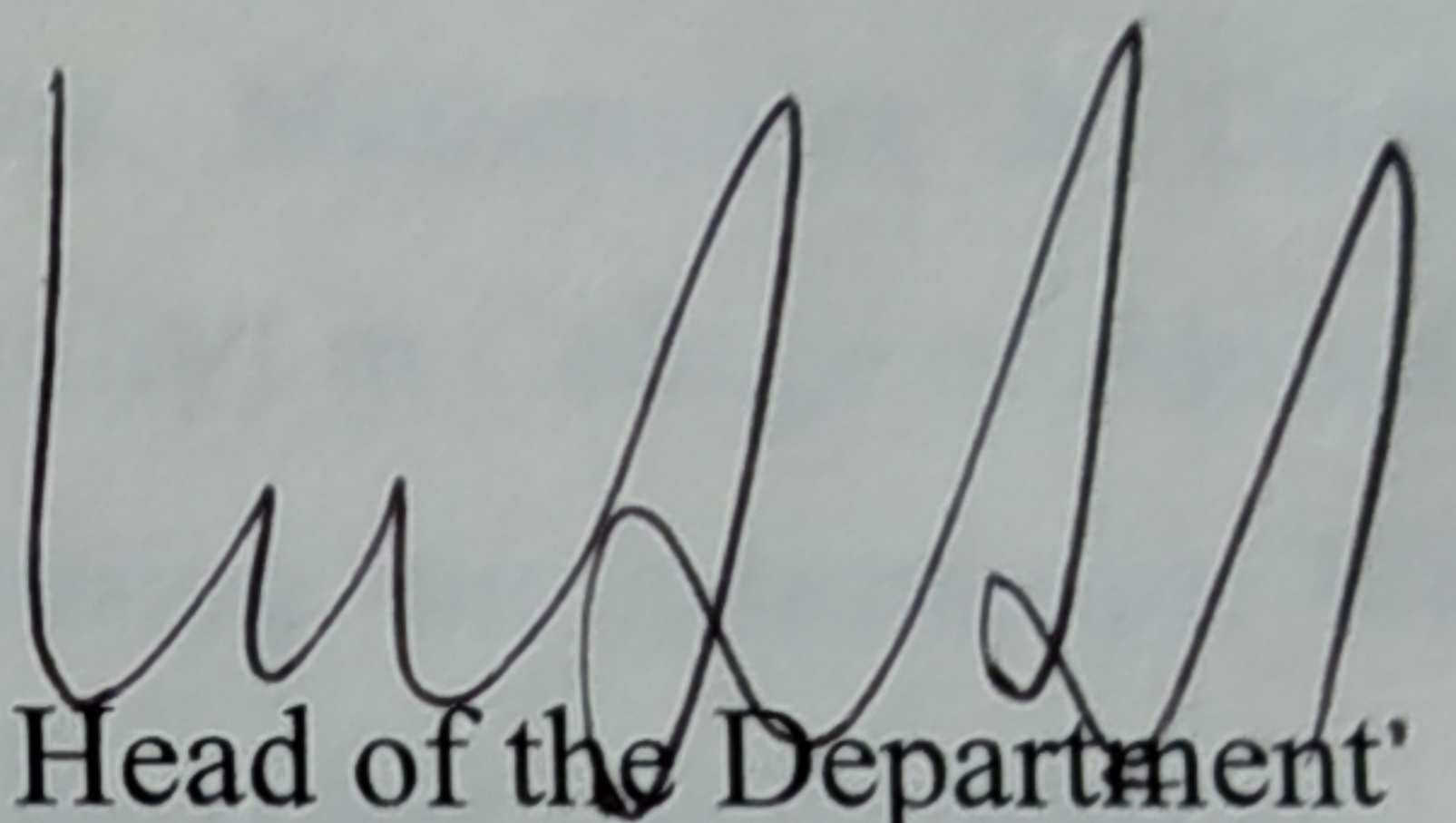


CERTIFICATE -II

This is to certify that the thesis entitled "**Performance of Turmeric (*Curcuma longa* Rosc.) Under Bamboo (*Dendrocalamus strictus* (Roxb.) Nees based Agroforestry System in Chhattisgarh**" submitted by **Rupesh kumar** to the Indira Gandhi Krishi Vishwavidyalaya , Raipur, in partial fulfillment of the requirements for the degree of **Master of Science** in the **Department Forestry** has been approved by the external evaluator and Student's Advisory Committee after oral examination, *under the chairmanship of Head of the Department.*


Major Advisor

Dr.M.N.Naugraiya


Signature of Head of the Department'

Name - Dr. Lalji Singh

Date: 18/03/2020

Faculty Dean

.....

Approved/ Not approved

Director of Instruction

.....

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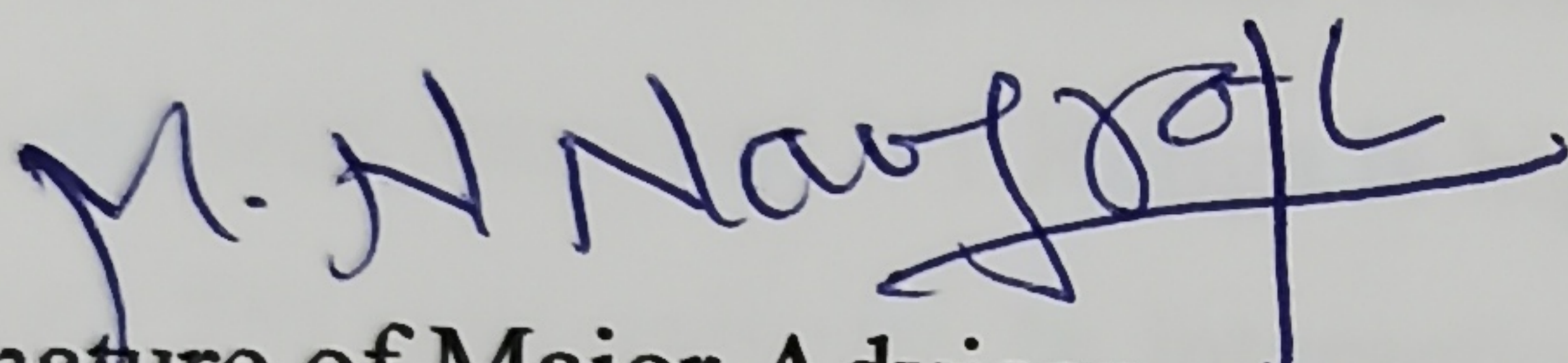
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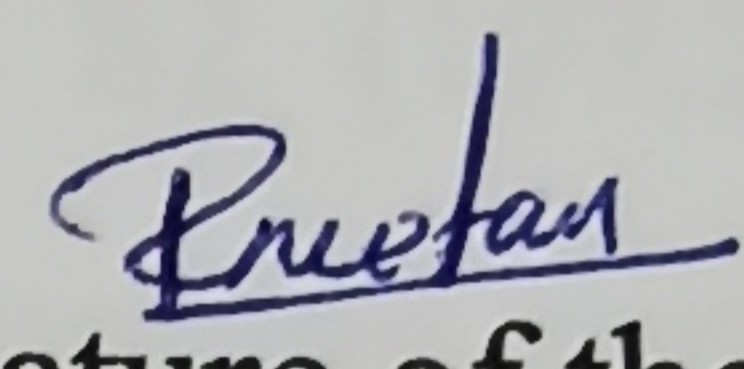
LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
%	Percent
&	And
<	Less Than
=	Equal to
>	More Than
≤	Less than equal to
≥	Greater than equal to
AFS	Agroforestry System
°C	Degree centigrade
c.d.	Collar diameter
C.G.	Chhattisgarh
cm	Centimeter
cm ²	Centimeter square
DAS	Days After Sowing
DBH	Diameter at breast height
ESR	Eastern Side Row
<i>et al</i>	And others/co-workers
Fig.	Figure
ha ⁻¹	per hectare
<i>i.e.</i>	that is
Kg ha ⁻¹	kilogram per hectare
Km	kilometer
LAR	Leaf Area Ratio
LEV	Land equivalent value
m	Meter
m ²	Meter square
NS	Non- significant
S	Significant
SEm	Standard error of mean
SEd	Standard error of difference
RBD	Randomized Block Design

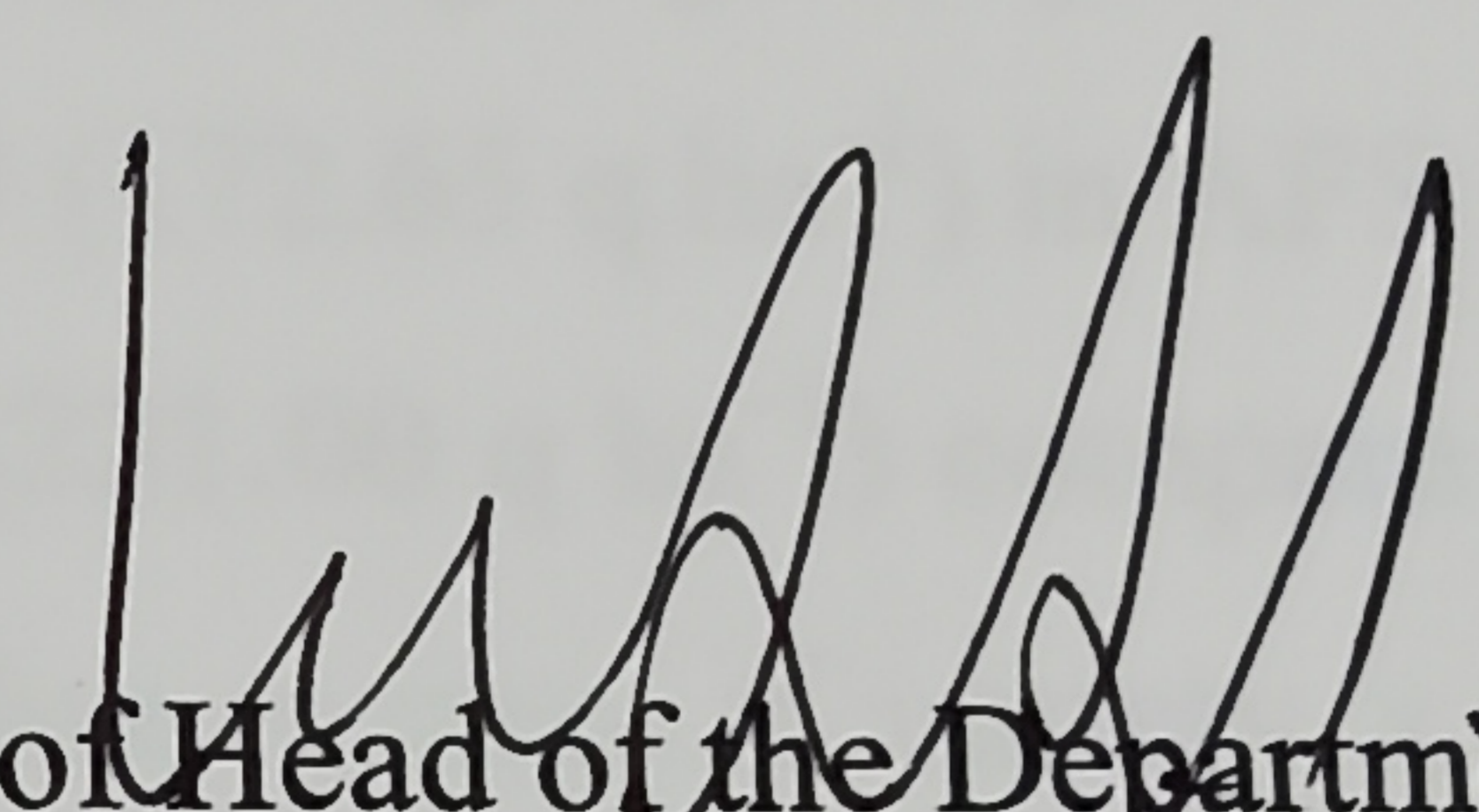
THESIS ABSTRACT

- a) Title of the Thesis : Performance of Turmeric (*Curcuma longa* Rosc.) under Bamboo (*Dendrocalamus strictus* (Roxb.) Nees based Agroforestry System in Chhattisgarh
- b) Full Name of the Student: : Rupesh kumar
- c) Major Subject: : Forestry
- d) Name and Address of the Major Advisor: : Dr. M.N. Naugraiya, Principal Scientist, IGKV, Raipur (C.G.)
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Signature of Major Advisor


Signature of the Student

Date: 14.1.2020


Signature of Head of the Department

ABSTRACT

The present investigation entitled “Performance of Turmeric (*Curcuma longa* rosc.) Under Bamboo (*Dendrocalamus strictus* (Roxb.) Nees based Agroforestry System in Chhattisgarh” was carried out during session of 2017-18 at the research farm of Department of Forestry, IGKV, Raipur. 492012 Chhattisgarh. The experiment was laid out in Factorial RBD with 2 cropping systems viz; bamboo species (*Dendrocalamus strictus*) and open field condition and three spacing viz; S1 (50 x50cm), S2 (50 x 30cm) and S3 (40 x 30cm) having four replications. In the study the growth parameters and yield parameters viz; height of turmeric crop, numbers of tillers, leaves numbers, leaves length, and Rhizome length, Rhizome width, root length , number of finger, fresh and oven dry weight of rhizome were measured.

The maximum plant height of turmeric crop (83.67cm), were recorded in open field while numbers of tillers (3.08), numbers of leaves (20.79cm) and size of leaves (210.78cm) were recorded maximum in AFS at 120 DAS. The yield parameters showed higher growth in rhizome width (9.58cm), number of finger (4.88pp), length of finger (4.90cm), fresh weight of rhizome (69.30gm/plant) and oven dry weight of rhizome (18.84gm/plant) in open field and rhizome length (4.63cm), root length (14.93cm), in AFS.

The yield of fresh weight turmeric was received 225.79 q ha⁻¹ from open field crop as compare to Agroforestry systems (161.46 q ha⁻¹). The variety Ranga is highest yield 206.71 q ha⁻¹ compare to variety Roma 180.55 q ha⁻¹. The spacing S-1 gave highest yield of 209.44 q ha⁻¹ followed by S3 (194.16 q ha⁻¹) and S2 (177.29 q per ha) respectively with significant variation. In case of interaction cropping system x variety yield was received V1 Ranga is highest in both CS-1 x V1 (245.67 q ha⁻¹) and CS-2 x V1 (167.75) respectively. In interaction of cropping system x spacing highest yield observed was CS-1 x S1 (246.31 q ha⁻¹) in open field and CS-2 x S3 (172.65 q ha⁻¹) in AFS system. Interaction of variety x spacing highest yield is S1 x V1 (221.00 q ha⁻¹) compare to S1 x V2 (197.88 q ha⁻¹) respectively. In interaction of cropping system x variety x spacing highest yield is Cs1 x V1 x S1 (252.8 q ha⁻¹) as compare to Cs2 x V1 x S1 (189.2 q ha⁻¹) respectively.

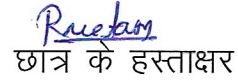
The bamboo population was 44.92 culm clump⁻¹ thus in July and it increased by 8.17±2.79 new culm with 4.88m diameter of clumps. The average height of culm on harvesting of matured culm was 8.98±1.44 m with 3.87cm diameter at 3rd internodes of culm and it produced 12.39 kg culm⁻¹ biomass with share of culm (7.30±0.79 kg), branches (3.44±0.91 kg) and leaves (1.66±0.31 kg). Thus average 14.1 matured culms per clump can be harvested from bamboo based Agroforestry system to generate more revenue along with yield of turmeric crop.

शोध ग्रंथ सारांश

- (अ) शोध का शीर्षक : छत्तीसगढ़ के मैदान में बांस (डेंड्रोकेलमस स्ट्रिक्टस रॉक्सब) आधारित कृषि वानिकी पद्धति के तहत हल्दी (कुरकुमा लौंगा रोस्क) का प्रदर्शन
- (ब) विद्यार्थी का पूरा नाम : रूपेश कुमार
- (स) प्रमुख विषय : वानिकी विभाग
- (द) प्रमुख सलाहकार का नाम व पता : डॉ. महेन्द्रनाथ नौगरैया , (प्रमुख वैज्ञानिक)
वानिकी विभाग, कृषि महाविद्यालय रायपुर
(छत्तीसगढ़)
- (इ) डिग्री से सम्मानित किया जाना है : वानिकी स्नातकोत्तर



मुख्य सलाहकार के हस्ताक्षर


छात्र के हस्ताक्षर

दिनांक : 14.01.2020


विभाग प्रमुख के हस्ताक्षर

सारांश

हल्दी का प्रदर्शन (कुरकुमा लौंगा रोस्क) बांस (डेंड्रोकेलामस स्ट्रिक्टस रॉक्सब) छत्तीसगढ़ में आधारित कृषि वानिकी पद्धति के तहत वर्तमान शोध को 2017-18 सत्र के दौरान वानिकी विभाग, इंदिरा गांधी कृषि विश्वविद्यालय रायपुर के छत्तीसगढ़ के अनुसंधान फार्म में

(197.88 क्विंटल प्रति हेक्टेयर) पायी गई सीएस-1 X वी-1 X एस-1 के पारस्परिक प्रभाव से अधिकतम पैदावार (252.8 क्विंटल प्रति हेक्टेयर) पायी गई जबकि सीएस-2 X वी-1 X एस-1 में पैदावार (189.2 क्विंटल प्रति हेक्टेयर) पायी गई।

बांसों के वृक्षारोपण में जुलाई में बांसों की संख्या 44.9 बांस प्रति भिरा थी और हल्दी फसल के बाद इसमें प्रति भिरा 8.17 ± 2.79 की नये बांसों वृद्धि हुई इन भिरों का औसत व्यास 4.88 मीटर था। कटाई किये जाने वाले परिपक्व बांस की औसत ऊँचाई 8.98 ± 1.44 मीटर थी जिसके तीसरे अंतः संधिपर्व का व्यास 3.87 सेमी था और इससे 12.39 किग्रा प्रति बांस जैवभार का उत्पादन हुआ, जिसमें बांस तने (7.30 किग्रा), शाखाएं (3.44 किग्रा) और पत्तियां (1.66 किग्रा)की भागीदारी रही। इस प्रकार बांस आधारित कृषि आधारित प्रणाली से हल्दी की उपज के साथ परिपक्व बांसों की कटाई प्रति भिरा 14.17 बांस प्राप्त अधिक राजस्व लाभ लिया जा सकता है।

CHAPTER-I

INTRODUCTION

Agroforestry is a new name for set of ancient practice. Agro-forestry is a combine name for land-use practices and techniques where woody perennials (viz. trees, shrubs, bamboos, etc.) are consciously used on the same piece of land-management/use units as agricultural crops and animals, in some form of structural organization or secular sequence. In Agroforestry systems there are pair ecological and economical interrelations between the various components (Lundgren and Rain tree, 1982). Bamboo-based Agroforestry is an encouraging option for long term land use practices in India. Suitable management of bamboo-based mixed cultivars production systems necessary to understanding of bamboo interspacing, root activity and dispensation of bamboo roots and the soil nutrient uptake of the site. Bamboo are grasses existing the family named *Poaceae* – previously named *Graminae* – which include about 65 families with more than 10,000 species. The Bamboo sub-family is named the *Bombusoideae* and known as a type of grass *monocotyledonous*. In Chhattisgarh, Bamboo crop up in almost all the locations and *Dendrocalamus strictus* is disseminate over broad areas. The annual estimated cultivation of Bamboo in the Madhya Pradesh and Chhattisgarh is approximately 0.317 million tonnes (Naugraiya and Puri, 1997). Usually known as ‘Male bamboo’ *Dendrocalamus strictus* (Roxb.) Nees belongs to the sub-family Bambusoideae of the Poaceae family. It is ephemeral in nature and popularly found bamboo species, origin in India (Saxena and Dhawan 1999).

Agroforestry, the combination of woody perennials within farming practices, has been methods as a conventional land use and livelihood options since time forever. The scientific and well research on tree-crop inter-actions, in India, was started in late 1971's. Agroforestry or agro silvi-culture is a management of land use system in which trees or crops are grown among crops or pasture-land. It correlate with agricultural and

forestry techniques to make more productive, profitable and sustainable land-use systems. The practice of agro-forestry in the mountains has been observed ecologically and socioeconomically valuable and has hold the farmers in better state of many years because a major part of their fuel wood and leaf fodder or both acquired were being met from these sources.

A preliminary estimate indicated that area across Agroforestry in India as 26.32 million ha or 8.6% of the total geographical area of the country (Dhyani *et al.* 2014). The estimated total tree green cover in the Agroforestry system in the country is estimated as 111,554 sq. km which is 3.40 per cent of country's geographical area. Of which, Himachal Pradesh has 2,303 sq km tree green cover out of 55,673 sq km geographical area (FSI, 2013).

Bamboo is a perennial, broad, woody grasses under the group-angiosperms (Chapman, 1996) and the order-monocotyledon (Latif *et al.*, 1990). It belongs to the grass family-Poaceae, subfamily Bomboideae. Bamboo species are found in various climate conditions, from cold mountains regions to hot tropical regions. According to Grosser and Liese (1971) bamboo are grown especially good in the tropics and subtropics, but few areas are also grow in the cold climatic conditions of Japan, China, Chile and the USA. Lee *et al.*, (1994) observed that the dwarf bamboo species are commonly found in temperate latitudes and the largest ones are adequate in the tropic and subtropic areas. Latif and Razak (1991) reported that bamboo should be grown from MSL (mean sea level) to as high as 2500 meter. Bamboo is preferable for well drained sandy loam to clay loam soil with pH of 5.0 to 6.5. They grow in plains, hilly and high altitude hilly areas and in many types of soils, except sodic soils, marsh and desert (Wang and Shen, 1987). Bamboo is a highly renewable resource. For many nations bamboos have an essential role in the daily use of life in the people of tropical nations (Sharma, 1980; Zhou, 1983). The bamboo culm or stem had been made into an elongated change of products are use from daily usable products to industrial uses.

India is second to China in bamboo diversity and hence potential for development of bamboo based industries in the country is very high. Bamboo based Agro-forestry work as a saver for farmers to conserve, drought prone areas, prevent and improve environment. The economic buffet of the Agroforestry with bamboo significantly effects general economic development. This system is very important and considerable for developing countries like India and others. Agriculture land near bamboo can be effectively utilized for growing shade loving crops like ginger, turmeric, large cardamom, orchard grass and Johnson grass upto a distance of 12-15m from the bamboos rows (Singh *et al.*, 1992).

Turmeric (*Curcuma longa*) is herbaceous perennial plant of the ginger family, Zingiberaceae. It (*Curcuma longa*) is origin to Asia particularly India and occupies about 5.9% of the total area along the spices and condiments in India. India is the largest consumer, producer and exporter of turmeric that data about 91%, 81% and 61% share, respectively of the world total (Anonymous, 2012). In India, maximum area under turmeric cultivation is in Andhra Pradesh, followed by Orissa and West Bengal, respectively. But, productivity of turmeric is highest in Gujarat. It can be grown in adverse tropical regions from sea level to 1600 meters above sea level, at the temperature range from 21-35°C, with an annual rainfall of 1400 mm or above, under rainfed and irrigated areas. Though, it can be grown on various types of soils, it would best in well drained sandy loam or clay loam soils with a pH range of 4.6-7.5 with better organic status. Turmeric is mainly used as spices in cosmetic, coloring product, flavourant and preservative and also described globally to its aromatic, provoke and carminative natures. Economically, it is traded as a dye, spices, oleo-resin and source of industrial starch. Turmeric has been revealed to possess hepatoprotective, antitumor, antiviral, anti-inflammatory and anti-cancerous nature and used in treating respiratory disorders and gastrointestinal (Polasa *et al.*, 1991, and Anwarul *et al.*, 2006). In India, turmeric has been used conventionally for thousands of years as a remedy for stomach and liver problems, as well as heals sores, basically for its

antimicrobial properties (Chaturvedi, 2009). Current data also suggested that curcumin and other antioxidant products from the dried rhizome are useful in the prevention or cures of some age-related declinatory processes (Miquel *et al.*, 2002). The demand and use of turmeric is extend globally, hence cultivation of turmeric rich in curcuminoid contents, namely Curcumin, must be enhanced to meet out the local and globally demand by increasing both the area of production and the productivity per unit area. Turmeric being a long duration (240-270 days) and exhaustive crop, responds good to nutrition. Hence, optimal dose of nutrients are required to get better yield. Chemical fertilizers, herbicides and pesticides used for enhancing yield and controlling weeds and pests could contaminated the air, water and food, declining soil health, restraining growth of soil biomass and risking human wealth and health (Parr *et al.*, 1991). These effects of agricultural works should be overturned by the proper management of manures and crop residues used within the cropping system either sole or in together with organic manure (Mandal *et al.*, 2007).

Mulching is one of the most useful agronomical practices beneficial in conserving and preventing the soil moisture, cover up the weeds, enhancing soil health (organic mulches are used) and upgrading the soil physical properties (Yoo-Jeong *et al.*, 2003). The surface mulch effect on the physical situations of the soil surface layer is dependent on mulch quality, structure and type (Teasdale and Mohler, 2000). Organic sources have good impacts on soil structure, drainage and water holding capacity which in turn help good growth and development of turmeric (Kale *et al.*, 1991). Keeping in view the benefits of mulch and bamboo species, cultivation of turmeric with bamboo using mulch could be better option for soil health or fertility improvement and more productivity of turmeric for economic security of small holder farmers adopting this system. However, successful cultivation requires information on species compatibility, screening of proper mulch material. Intercropping may have several advantages over sole cropping. The tree crop combinations along with mulching which have been included in this study have scarcely been explored.

Turmeric, the sacred and nostalgia spice of India, known as 'Indian saffron' is an important economical value spice crop grown in India. It is used in variable forms as a coloring agent, condiment and flavoring and as a principal ingredient in Indian culinary as curry powder. It has anti-cancerous and anti viral properties and hence, finds use in the drug and cosmetic industry. 'Kum-kum' which is a by-product of turmeric is popular among house-wives. It finds a place in offerings on religious and ceremonial time. Turmeric is widely used as a flavoring agent and food coloring agent for curries and all South Asian dishes. However, it also use as a medicinal plant in both Ayurvedic (a form of medical practice origin to the Indian sub-continent) and conventionally Chinese medicine for centuries.

The study is undertaken with the following objectives: -

1. To study the growth yield and performance of varieties of Turmeric under Bamboo based Agroforestry system.
2. To study the performance of bamboo under Agroforestry system.

CHAPTER-II

REVIEW OF LITERATURE

Shanmughavel and Francis (2001) conduct a study in Tamil Nadu on the pigeon pea, soybean, turmeric and ginger intercropped with *Bambusa bambos* on the growth, yield and land equivalent ratios, pigeon pea and soybean appear to provide most beneficial. It's in terms of productivity.

Kittur *et al.*, (2015) studied showed that for sustainable land management in India the t bamboo-based Agroforestry is a promising option. As compared to the open plot bamboo shows, 89 % decline in P absorption by turmeric at closest spacing of bamboo due to the competition. It was also observed that if light transmittance is between 66 and 86 % may perform better as turmeric is a shade tolerant Zingiberaceae crop, and for the optimal performance of the under storey turmeric in mixed species systems, wider bamboo spacing's beyond 8 9 8 m are recommended.

Banerjee, *et al.*, (2009) reported that bamboo is an extremely versatile plant can be used different purposes and capable of providing ecological, economic and livelihood security to the people and bamboo based Agroforestry system with various intercrops. Income is much than sole bamboo plantation. However, it was observed that the yield of all intercrops was higher in wider spacing i.e. 12 × 10 m as compared to closer spacing i.e. 10 × 10 m.

Naugraiya *et al.*, (2008) conducted a survey in Chhattisgarh and find that only 11% area is under Bamboo forest with 10 species having national production of 65,000 ton per year and there is a wide gap of 35,000 national ton of Bamboo, because of lack of raw Bamboo the 'Bansod' community of Bamboo artisan has been shifting in other profession like field labor, animal husbandry and farming. They suggested that the area under bamboo cultivation must be increased either as Agroforestry or as a continuity plantation in order to fulfill the state requirement.

Latif and Razak (1991) reported that the bamboo plant could grow 3000m as high above the sea level. A well drained sandy to clay loam soil with pH of 5.0 to 6.5 is most suitable for bamboo cultivation.

ICAR- Indian Institute of Spices Research, Kozhikode,(2015) Turmeric is obtained from the underground rhizome of the plant. In country the different numbers available which are name locally according to the region to region where they are cultivated. Some of the popular cultivars are Amalapuram, Erode local, Salem, Alleppey, Duggirala, Tekkurpet, Sugandham, Moovattupuzha and Lakdong.

Polasa *et al.*, (2006) Turmeric has been reported to possess anti-inflammatory, hepatoprotective, antitumor, antiviral and anticancer us properties, and used in treating gastrointestinal and respiratory disorders

A study by Bhuiyan *et al.* (2012) in Bangladesh revealed that plant height, number of leaves per clump, leaf length and number of tillers were highest turmeric and ginger when grown under severe shade conditions. However, number of mother rhizome, and weight of primary fingers, and weight of secondary fingers, yield of fresh rhizome per clump and yield were found to be highest under partial shade condition.

2.1 Effect of tree species on growth and yield parameters of field crops

An intercropping trial was conducted by Das *et al.* (2011) during 2007–2010 on turmeric, ginger and arbi grown under *Emblica officinalis*. (NA- 7) orchard planted at 6 m × 6 m spacing of 6-year-old The results showed that due to intercrops the production of fruits increases and the maximum production was obtained with turmeric (13.30 ha⁻¹) followed by arbi (11.71 ha⁻¹). On the other hand, in compared to the yield in open area without trees, reduction in yield of intercrops was 7.5–12.0% , 12.2–19.3% , 15.7–25.3% for turmeric, ginger and arbi respectively.

Bisht *et al.* (2000) performed an experiment to evaluate ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) under 10 years old fodder trees, namely *Grewia optiva*, *Celtis austrelis*, *Quercus leucotrichophora* and *Bauhinia variegata*. The result concluded that the yield of ginger and turmeric was affected by the different fodder trees. In *Quercus leucotrichophora* both shows the highest yield

i.e. turmeric (12.04 t ha^{-1}) and ginger (7.98 t ha^{-1}). However, the highest leafy green fodder of trees was harvested from *Bauhinia variegata* (7.7 kg tree^{-1}). Between light intercepted by the trees and yield of under grown ginger and turmeric crops a Negative correlation ($r = -0.77$) was obtained. The most suitable and remunerative silvi-horti combination was found with the Intercropping of *Quercus leucotrichophora* with turmeric and ginger.

Chandra (2014) investigated growth of two intercrops *Amorphophallus paeoniifolius* (Var-Gajendra-1) and *Curcuma longa* (Var- Narendra haldi-1) in 11 year old guava (Var- Allahabadi Safeda) orchard. There is an increment in the survival percent, plant height, number of leaves, collar diameter, leaf length and rhizome length when intercropping is done under *Psidium guajava*. Under intercropping, *C. longa* yielded 150.48 q ha^{-1} and *A. paeoniifolius* gave 304.53 q ha^{-1} , which was 11.57 percent and 17.54 percent higher, respectively than pure crop. The result also showed that due to the intercropping an improvement of 30.25 percent in the emergence of new shoots and increases of 27.45 percent in fruit numbers.

Vikram and Hegde (2014) performed an experiment of turmeric under cashew plantation as an intercrop compared to sole cropping in open area. He observed higher fresh weight of rhizome ($353.52 \text{ g clump}^{-1}$), number secondary rhizome (27.97) and clump size (201.24 cm^2) of turmeric var. PTS- 24 under sole cropping than intercropping ($271.83 \text{ g clump}^{-1}$, 25.53 and 157.88 cm^2 , respectively, with cashew plantation.

Chauhan *et al.* (2013) experimented agri-horti-silvicultural model involving poplar (*Populus deltoides*) fruit trees and agronomic crops viz., turmeric (*Curcuma longa*) and moong (*Vigna radiata*) showed that in open areas for the both crop the net photosynthesis, stomatal conductance and transpiration were higher in compared to shaded ones. Better performance under partial shade in yield was showed initially by agronomic crops and yield contributing parameters, and decreased as advancement in age of poplar canopy.

Chauhan and Dhiman (2002) studied the relative performance of wheat under various tree spacing ($8\text{m}\times 3\text{m}$, $6\text{m}\times 4\text{m}$, $5\text{m}\times 5\text{m}$ and $4\text{m}\times 4\text{m}$) of poplar. The

results showed that the trees grown at 5 × 5 m spacing recorded the highest growth parameters of tree species and wheat grain yield.

Verma *et al.* (2002) observed that the growth and yield of wheat agri-horti-silviculture system found get suppressed due to the different fruit tree crop combinations. The reduction in wheat yield over sole cropping were grevia + almond + wheat (17.85 q ha⁻¹) 17.9, grevia + almond + wheat (17.85 q ha⁻¹) 21.3, grevia+almond+wheat (17.85 q ha⁻¹) 25.2 and morus + wheat (15.61q ha⁻¹) 28.2 per cent with tree-crop combinations, respectively.

Thakur and Singh (2002) observed the effect of *Morus alba* (mulberry) canopy management under rainfed Agroforestry system on performance and light transmission of *Phaseolus mungo* (urd bean) and *Pisum sativum* (pea). The growth and yield parameters were found to have maximum magnitude in control (without trees), followed by plants under least shade (75% crown removal). With the increase in shade (less transmission) the values of urd bean and pea get decreased. It was observed that the better growth and yield on northern compared to the southern ones. With the decrease in light transmission the harvest index also decreased.

2.2 Growth and yield of field crops under bamboo-based Agroforestry system

Seshadri (1985) observed that growing of soyabean as an intercrop of bamboo during the first six years is technically feasible and economically viable. While, Singh *et al.* (1992) studied the effect of *Bambusa nutans* shade on the yield and growth of some agricultural crops in mid hills of eastern Himalaya. They reported that bamboos are planted along farm boundaries or drainage lines, and/or cultivated in the eastern Himalayan region. They also found that agricultural land near exhibited better clump diameter, crown coverage and turmeric rhizome yield, whereas, closest (4×4 m) spacing of bamboo plots recorded least rhizome yield of 8 Mg ha⁻¹; this was 58 % less compared to widest spacing of 12×12 m (19.32 Mg ha⁻¹).

Kittur *et al.* (2015) studied the effect on turmeric as an under storey crop in 7- year *Dendrocalamus strictus* stands of varying spacing treatments (4×4m, 6×6m, 8×8m, 10×10m and 12×12 m) at Kerala Agricultural University Campus, Thrissur, Kerala, India. They observed that widely spaced bamboo exhibited better clump diameter, turmeric rhizome yield and crown coverage, whereas, closest (4×4 m) spacing of bamboo plots results into least rhizome yield of 8 Mg ha⁻¹. It was 58% less than the widest spacing of 12×12 m (19.32 Mg ha⁻¹).

Mishra *et al.* (2000) reported that the highest germination percentage (88 per cent) plant height, number of primary and secondary fingers plant⁻¹ as well as the yield plant⁻¹ yield was improved by mulch application, and mulch applied at the rate of 5 tonnes farmyard manure along with 30:30:30 kg of NPK ha⁻¹, respectively. The experiment also shows that the application of mulches at the rate of 10 tonnes ha⁻¹ conserved more moisture and increased the yield of turmeric by 12 per cent (Kumar *et al.*, 2003). Application of paddy straw mulch resulted in 18 per cent increase in yield over *Gliricidia* mulch. For increasing the growth and yield of the turmeric the quality of mulch was more important and it is more effective in conserving soil moisture.

In a field experiment conducted by Vikram and Hegde, (2014) to assessed the performance of turmeric under cashew plantation as intercrop compared to sole cropping in open area. Interception of PAR (Photo synthetically Active Radiation) by turmeric crop at 150 days after planting as intercrop in cashew plantation was 27390 Lux compared to 30876 Lux in open condition. The yield was recorded higher in open areas in compared to the plantation under cashew intercropping and vice vera for growth of turmeric.

A study conducted by Srikrishnah and Sutharsan (2015) at Eastern University, Sri Lanka. On growth and development of turmeric under four different shade levels vizi open field condition (T1) which was considered as 0% shade level, 50% shade level (T2), 70% shade level (T3) and 80% shade level (T4). It was observed that the leaf ares, biomass and yield were higher in T2 followed by T3 and T1. It was noticed that the in treatment T3 and T4 the solar radiation was

effective for proper photosynthesis process. Therefore, it was concluded that 50% shade level is optimum condition suited for turmeric cultivation.

2.3 Effect of mulch materials on growth and yield parameters of field crops

Gill *et al.* (1999) conducted a field experiment during kharif season of 1995 and 1996 at PAU Ludhiana, to study the outcome of application of FYM and wheat straw mulch on turmeric crop. They reported that there is significant improve in growth and yield of turmeric, compared with the no mulch. The amplification in rhizome yield was 46 and 44 per cent in 1995 and 1996, correspondingly. It was also observed that with the increase in FYM rate the rhizome rate increases and maximum yield (365.4 q ha⁻¹) was attained with 60 tonnes FYM ha⁻¹.

Mishra *et al.* (2000) reported that the highest germination percentage (88 per cent) plant height, number of primary and secondary fingers plant⁻¹ as well as the yield plant⁻¹ yield was improved by mulch application, and mulch applied at the rate of 5 tonnes farmyard manure along with 30:30:30 kg of NPK ha⁻¹, respectively. The experiment also shows that the application of mulches at the rate of 10 tonnes ha⁻¹ conserved more moisture and increased the yield of turmeric by 12 per cent (Kumar *et al.*, 2003). Application of paddy straw mulch resulted in 18 per cent increase in yield over *Gliricidia* mulch. For increasing the growth and yield of the turmeric the quality of mulch was more important and it is more effective in conserving soil moisture.

2.4 Effect of Agroforestry system on soil properties

Patil *et al.* (2004) analyzed the effect of bamboo based Agroforestry system on surface soil properties and soil profile which showed that organic carbon content of these soils ranged from 0.43 to 0.72 per cent. Soil profile analysis showed that all nutrients increased in bamboo based Agroforestry site. The organic carbon of these soils increased from 0.37 to 0.58 per cent and organic matter from 0.63 per cent to 0.99 per cent. In an intercropping trail during 2007–2010 on

turmeric, ginger and arbi grown under 6-year-old aonla (*Emblica officinalis* var. NA-7) orchard planted at 6 m × 6 m spacing.

Das *et al.* (2011) observed that aonla-based agri-horticultural systems were effective in improving the soil properties and soil profile due to the increases in organic carbon and available nitrogen and phosphorus. Similarly, Kittur *et al.* (2015), while studying the performance of turmeric as an under storey crop in 7-year old bamboo *Dendrocalamus strictus* stands of varying spacing treatments (4×4, 6×6, 8×8, 10×10 and 12×12 m) at Thrissur, observed that soil N, P and K at widest spacing were 56, 45 and 33 % less compared to that of the closest spacing.

2.5 Economics of Agroforestry

Chandra (2014) conducted a study on economic parameters of two intercrops *Amorphophallus paeoniifolius* (Var-Gajendra-1) and *Curcuma longa* L. (Var- Narendra haldi-1) in 11 year old guava (Var- Allahabadi Safeda) orchard. He reported that gross profit was Rs. 3.76 lakh ha⁻¹ for *longa* and Rs. 5.48 lakh for *paeoniifolius* in intercropping than pure crops which rendered gross profit of Rs.3.32 lakh ha⁻¹ and Rs. 4.51 lakh ha⁻¹, respectively. The Benefit Cost Ratio (BCR) was recorded 4.74 for Fruit tree + *Curcuma longa* and 2.70 for fruit tree + *paeoniifolius*, respectively while the same parameters computed 2.78 and 1.52 for *Curcuma longa* and *paeoniifolius* with monocropping. The cultivation of *paeoniifolius* proved more remunerative and better intercrop than *longa*. However, Bhardwaj (2012) reported that under the temperate conditions, turmeric crop gives higher returns under both *Dendrocalamus Hamiltonian* as well as *Phyllostachys pubesense*. Although, highest returns (Rs2.71 lakh ha⁻¹ yr⁻¹) were obtained when turmeric was raised Under the *Phyllostachys spubesense* the highest returns was obtained of Rs. 2.71 lakh ha⁻¹ yr⁻¹.

Singh *et al.* (2001) studied the economic and profitability of raising medicinal and aromatic plants as intercrops in four and five year old poplar (*Populus deltoides*) based Agroforestry system. All the crops namely *Mentha arvensis*, *M. gracilis*, *Zingiber officinale*, *Ocimum basilicum*, *Curcuma domestica* and *Piper longum*, except *Costus speciosus*, performed well. Maximum net return was obtained in *Curcuma domestica* (Rs 64,700 and Rs 68,300) and for *Ocimum*

basilicum net return was Rs. 25852 and Rs. 23437 ha⁻¹ in the first and second year, respectively.

Rahangdale *et al.* (2014) conducted intercropping studies in three year old plantation of *B. arundinacea* and *D. strictus* planted at a spacing of 5×5m during rainy season with four intercrops; green gram, soyabean, paddy and sesame were grown. The economic analysis of the system revealed that the economic feasibility of bamboo based agri silviculture system (Rs 21,029 ha⁻¹) gave higher monetary return as compared to sole crop (Rs 9801 ha⁻¹). Growing of green gram with bamboo species gave significantly higher net monetary return (Rs 27,736 ha⁻¹) but at par with sesame (Rs 23,365 ha⁻¹) and was found significantly superior to paddy (Rs 19,693 ha⁻¹) and soyabean (Rs 13,322 ha⁻¹) under bamboo based agri-silviculture. Similarly, in a study at Sonitpur (Assam), it was reported that ginger bamboo system can provide annual income of Rs. 448,060 upto 4th year as compared to Rs. 101,800 from sole bamboo crop (Sharma, 2012).

Lal *et al.* (2005) carried out field experiment during 1998-2003 to determine the economic viability of an Agroforestry based system in Allahabad district, UP. The Rabi (*Cicer arietinum* and *Vigna mungo*) and Kharif (green gram *V. radiata*) crops were intercropped with papaya. It was observed that the cultivation of papaya + crop was more profitable in compared to the traditional cultivation (sole papaya and sole crop). The cost component of papaya + crop was higher than the sole papaya and the initial stage of plantation were higher than the recurring cost. The cost-benefit ratio were higher for the papaya + crop at discounted prices (3.79) in the Agroforestry system under irrigated conditions than the sole papaya crop (2.65).

Bisht *et al.* (2000) performed an experiment to evaluate the performance of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) under 10-years-old fodder trees, namely *Grewia optiva* *Celtis austrelis* (Kharik), *Quercus leucotrichophora* and *Bauhinia veriegata* (kachnar). It was observed that the for different crops the yield of ginger and turmeric were significantly affected. With *Quercus leucotrichophora* both turmeric (12.04 t ha⁻¹) and ginger (7.98 t ha⁻¹) gave the highest yield. However, the highest leafy green fodder of trees was harvested

from *Bauhinia vereigata* (7.7 kg tree⁻¹). Between light intercepted by the trees and yield of under grown ginger and turmeric crops a Negative correlation ($r = -0.77$) was obtained. The most suitable and remunerative silvi-horti combination was found with the Intercropping of *Quercus leucotrichophora* with turmeric and ginger..

Vanlalhluna and Sahoo (2009) conducted the study at the experimental farm, Mizoram to determine the performance of three tree species viz. *Alnus nepalensis*, *Melia Azadirachta* and *Gmelina arborea* and their interactive effects on the crop yield during their establishment period. Ginger and Turmeric were sown in subplots every year from 2003- 2005. The seedlings of the entire tree species survived better under cropped than uncropped plots. No significant crop yield variation could be observed during first two years. However, in third year significant variation in yield was recorded. Ginger registered maximum yield 6.7 t ha⁻¹ under *Alnus nepalensis*, so was the case with turmeric under *Alnus nepalensis* (5.64 t ha⁻¹)

2.6 Growth and yield of crops under bamboo based Agroforestry system

Shanmughavel and Francis (2001a) assessed the growth, yield and land equivalent ratios for pigeon pea, soybean, turmeric and ginger intercropped with *Bambusa bambos*, in Tamil Nadu, India. He found intercropping of pigeon pea and soybean more productive than ginger and turmeric. The land equivalent ratio of intercropping *B.bamboos* with pigeon pea and soybean was equivalent to that of 1.2 ha⁻¹ or 1.1 ha⁻¹ under monoculture. Shanmughavel and Francis (2001b) studied the growth and economic returns from soybean intercropping in bamboo plantation under Kallipatty (TN) conditions, where they intercropped the soybean variety M.A.C. S-58 in 1:1 rows at 3 × 3m spacing(111 plants ha⁻¹) with bamboo seedlings planted at 6 × 6m spacing in 3 ha (250 seedlings ha⁻¹). They recorded decrease in productivity of both soybean (grain yield) as well as bamboo (clump yield) in the intercropped stand as compared to the pure plantations. However, the net profit gained from soybean intercropped with bamboo was Rs. 8300 ha⁻¹.

2.7 Light transmission ratio (LTR)

Satheasan and Ramadasan (1980) studied the performance of turmeric crop grown in the coconut garden relative to as pure crop. Incident radiation at any given time of the day was about 50% less under the coconut canopy. Leaf index and growth rate reach maximum in case of intercrop in compare to the pure crop. The intial period of difference in the rhizome development shows a significant difference in the final yield of the intercrop (4.8t/ha⁻¹) and pure crop (7.0t ha⁻¹). Aiyadurai (1986) reported yield of turmeric ranging from 67.2 to 89.6q ha⁻¹ under partial shade under rainfed conditions. He found that the intercrop was not affected by partial shade.

Nath *et al.* (2008) observed in compared to the closer spacing (10 × 10m) the yield of crop was found to be higher in wider spacing (12 × 10 m) for all the crop. This is attributed to the fact that wider distance between two bamboo plants results into better utilization of sunlight, space, moisture and nutrients by the intercrops with minimum competition among them and between agricultural crops.

Jayachandran *et al* (1991) reported Traits like rhizome ginger sprouting, plant height and tillers per plant were significantly affected by the bamboo species and were maximum (30.13%, 60.86 cm and 8.86 respectively) in *D asper* followed by *D Hamiltonian* and minimum were under open field conditions. This may be due to the shade effect of bamboo species which resulted in higher moisture conservation under the canopies than under control.

A min *et al* (2010) also reported positive influence of shade on rhizome ginger sprouting and tillers per plant of ginger crop. Under the integrated fertilizer nutrients treatment rhizome sprouting and tillers per plant were maximum (32.62% and 8.43 respectively) in treatment involving FYM. This can be owed to the reason that organic fertilizers release macro and micronutrients and improve biological, chemical and physical properties.

Bhardwaj *et al* (2011) also reported higher yield of ginger under *D asper* than *D. hamiltonii* in 4 year old bamboo stand and concluded that under mid-hill sub-humid conditions ginger displayed better performance under *D asper*. Higher

rhizome yield under bamboo canopy than sole crop can be explained based on shade loving nature of crop

Amin et al (2010) also found that partial shade ($50 \pm 5\%$) fostered higher yield of ginger crop. They reported maximum rhizome yield (124.2 q/ha^{-1}) under partial shade of mango trees. In general lower yield (38.04 q/ha^{-1}) was obtained in the present investigation which may be attributed to prevailing drought conditions and critically low moisture content during the month of May 2012 which might have resulted in excessively low rhizome emergence. The yield parameters like rhizome length (7.65 cm), rhizome fresh weight (179.11 g) and yield (40.28 q/ha^{-1}) were reported to be maximum in T2 (FYM on N equivalent ratio + PGPR) which were significantly higher than all other treatments except T5 (50% FYM + 50% VC + PGPR). The increase in yield by the use of organic manure may be due to relatively high level of nutrients. FYM helps to hold soil moisture which has positive impact on yield components of ginger.

Behari (2001) developed successful seven Agroforestry models with three bamboos (*B. bamboos*, *B. nutans* and *D. strictus*). The inter crops tried were: Soybean, Urad, Pigeon, Niger, Moong, Wheat and Mustard. These model were developed to restore and recover the degraded land in Central India. The studies carried out in the abandoned paddy fields in Coorg, (Karnataka) where planting of bamboo (*D. brandisii*) were done at spacing of 6 x 6m, with intercropped of ginger showed the highest NPV (net present value) and LEV (Land expectation value). This may be attributed for the bamboo farming and higher market returns over a long period of time of produce (Viswanath and Rathore, 2007). These land use patterns were characterized with viz. Productivity, Sustainability and Adaptability and hence the adaptive requirements of the system towards the climate change impact as well as to improve and increase the economic and social development of the stakeholders in context of sustainable development. As per reports, the annual incremental biomass production on air-dry basis for a bamboo.

Shanmughavel and Francis, (2001) reported plantation can range from 10 to 40 tonnes ha^{-1} depending on the species, soil, planting density and climate, including slope and aspect of a hill. In India, bamboo plantations are normally

raised at spacing of 6 X 6 m to meet the increasing demand for bamboo products. There are many reports which showed that the attempts for cultivation of various crop in bamboo plantations. In one of the experiments the inter cropping of agricultural crops (pigeon pea, soybean, turmeric and ginger) in established bamboo plantations was tested. The growth, yield and land equivalent ratio (LER) were determined, it is a convenient method for measuring biological productivity which defined as the land area in mono cropping system that would produce the same yield as one hectare of intercropping. The study showed that the LER was 1.2 in the bamboo/ pigeon pea and bamboo/ soybean models but for bamboo/ turmeric and bamboo/ ginger models it was 1.1. This indicates that the productivity of one hectare under intercropping is equivalent to that of 1.2 ha or 1.1 ha under monoculture.

Wagh and Rajput, (1991) studied similar investigations aimed at assessing systematically planted bamboo crop with that of traditional horticultural crops like, cashew nut, mango, jackfruit and kokum (*Curcunia indica*) along with newly introduced crop like rubber in terms of economic products and monetary returns. It results showed that bamboo having the highest cumulative yield at a density of 418 plants ha⁻¹ and it was ranked first in terms of income per hectare followed by cashew nut (120 plants ha⁻¹) and mango (90 plants ha⁻¹) during-early growth period (up to 10 years).

Bhardwaj, (2007) observed an economic analysis of bamboo based Agroforestry system and the results revealed that the tulsi-wheat combination, irrespective of the bamboo displayed maximum return followed by the aloe vera. The tulsi-wheat cropping system displayed the Maximum total net return (Rs. 3, 05,540-to. 4,86,419 y⁻¹) under the *Dendrocalamus asper*. It was observed that the returns were higher in agricultural crops in comparison to that bamboo species.

CHAPTER III

MATERIALS AND METHODS

The present investigation on “Performance of Turmeric (*Curcuma longa*) under Bamboo (*Dendrocalamus strictus*) based Agroforestry System” was carried out during session of (2016-17) at the research farm of Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, and Raipur. The details about the experimental site, materials used and methodology adopted for this study are discussed in this chapter.

3.1 The study area

Location

The experimental site Raipur is situated in the South- Eastern part of Chhattisgarh. It lies at 21°.76’N latitude and 81°.36’E which longitude having an altitude of 295m. Above mean sea level. The experiment was undertaken on bamboo (*Dendrocalamus strictus*) based Agroforestry System.

Climate

The climate of the study area is dry sub-humid tropical with an average rainfall of 1250 mm. Most of the rainfall (90%) is received during monsoon season from mid June to mid September. The average number of rainy days varies from 65 to 79. The mean monthly maximum temperature ranges from 27.3°C in December to 42.3°C in May and the minimum temperature below 08°C in December. Maximum relative humidity varied from mid-June to September while, minimum relative humidity was recorded during April and May.

The Experiment was started in the month of June 2017 and crop was finally harvested up to April 2018. The meteorological data ranges from experiment time in maximum temperature 31 0C and minimum temp. 24.75 0C, relative humidity 93.25%, sun shine 3.575 hours and the rainfall 421.8 mm was recorded in sowing time of seed on September month and the harvesting time temperature and sun shine was increases. Maximum temp. 41.75 0C and min. temp. 25.05, relative humidity 39.75%, sun shine 9.37 hours recorded in month of April.

The mean monthly data on different weather parameter viz. temperature, rainfall, relative humidity, sunshine hours and wind speed during the crop growing period (2016-17) are shown in Table

Geology

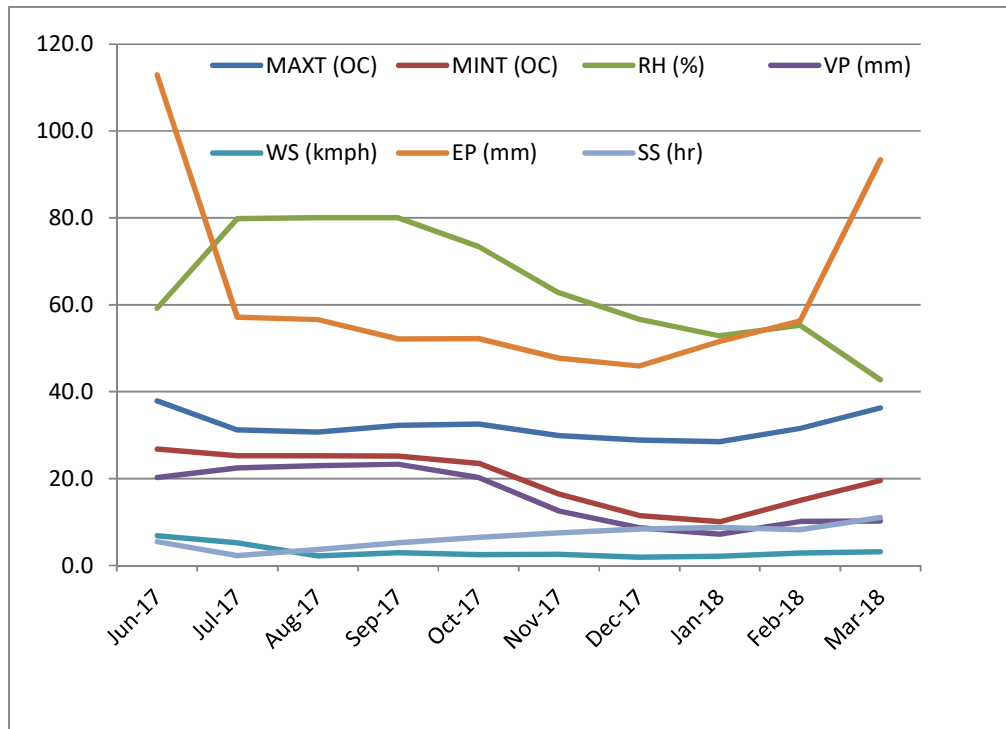
Raipur has three distinct geological formation viz., Bijapur, Cuddaph, Dharwar and Archeau. Lithologically, it is classified in to Raipur shales and limestone, Gunderdehi shale, Khairagarh sandstone, Cuddaph bar charmer limestone rocks and Chandrapur sandstone grit, Dharwar rocks and granite and genesis.

Soil

The soil of Raipur belongs to four different orders viz., Entisols, Vertisols, Inceptisols and Alfisols. The black clayey soil of experimental field belongs to the order Vertisols and it is locally known as Kanhar. This Kanhar soil are characterized by fine texture, sticky nature, angular blocky structure, low to medium Nitrogen, high Potassium and low to medium Phosphorus with low Organic matter. The soil of experimental area is very rich in organic carbon and other nutrient because of the addition of litter in the soil every year.

3.1 Climatic features of Raipur during cropping season June 2017 – March 2018

Months	fortnight	MAXT (OC)	MINT (OC)	RF (mm)	RH I (%)	RH II (%)	Average VP I (mm)	VP II (mm)	Average WS (kmph)	EP (mm)	SS (hr)		
Jun-17	1	39.64	27.48	31.40	68.07	34.33	51.20	21.18	17.24	19.21	6.75	131.50	5.91
	2	36.04	26.10	146.00	82.13	52.47	67.30	22.14	20.57	21.36	6.97	94.30	5.03
Jul-17	1	31.74	25.32	96.00	87.33	69.26	78.30	22.26	21.92	22.09	6.02	58.90	2.09
	2	30.70	25.20	78.60	90.50	72.12	81.31	22.91	22.80	22.86	4.46	55.40	2.48
Aug-17	1	29.58	25.37	82.20	87.86	68.60	78.23	22.38	22.34	22.36	3.19	57.00	3.14
	2	31.83	25.11	77.00	91.50	72.25	81.88	23.54	23.50	23.52	1.21	56.20	4.16
Sep-17	1	32.65	25.54	54.40	92.13	68.13	80.13	24.24	23.16	23.70	2.39	52.80	4.90
	2	31.81	24.83	142.20	92.00	68.00	80.00	22.94	22.81	22.87	3.51	51.50	5.55
Oct-17	1	32.00	24.80	43.80	93.93	69.13	81.53	23.20	23.47	23.33	2.61	46.10	5.20
	2	33.04	22.19	6.60	87.13	43.38	65.25	18.86	15.55	17.21	2.35	58.30	7.76
Nov-17	1	30.19	16.73	0.00	87.33	39.80	63.57	13.79	12.01	12.90	2.71	52.90	8.29
	2	29.55	16.21	1.00	85.73	38.33	62.03	12.99	11.54	12.27	2.48	42.50	6.64
Dec-17	1	29.14	12.56	0.00	84.80	29.13	56.97	9.85	8.56	9.20	2.06	44.60	8.55
	2	28.58	10.47	0.00	85.25	27.44	56.34	8.69	7.56	8.12	1.84	47.20	8.24
Jan-18	1	27.98	10.20	0.00	81.40	24.53	52.97	8.11	6.67	7.39	2.03	44.80	8.32
	2	28.99	9.94	0.00	83.69	21.69	52.69	8.07	6.06	7.06	2.29	58.40	9.12
Feb-18	1	30.81	14.93	16.40	81.21	35.21	58.21	10.90	10.24	10.57	3.40	51.70	7.04
	2	32.25	15.10	0.00	80.71	24.00	52.36	10.90	8.50	9.70	2.24	60.90	9.46
Mar-18	1	35.77	19.45	0.00	67.40	21.80	44.60	12.22	9.15	10.68	3.20	86.80	8.37
	2	36.83	19.73	1.20	60.63	21.13	40.88	11.33	8.41	9.87	3.14	99.90	13.76
Average Total		31.96	19.86	776.80	83.54	45.04	64.29	16.52	15.10	15.81	3.24	1251.70	6.70



3.1 climatic features of Raipur during cropping season (June 2017-
March 2018)

3.2 Experimental details:

1. Crop : Turmeric - *Curcuma longa* Family-Zingiberaceae
2. Variety of Turmeric : Two V-1 Ranga
V-2 Roma
3. Cropping Systems : Two C-1 Open (without bamboo)
C-2 (Bamboo based AFS)
4. Crop spacing : Three S-1 50cm x 50cm,
S-2 50cm x 30cm,
S-3 40cm x 30cm,
- A. Bamboo species : *Dendrocalamus strictus*
- Spacing of Bamboo : 8x6m
5. Date of showing : 28/6/2017
6. Harvesting : 18/3/2018
7. Design of Experiment : Factorial Randomized Block Design
8. Replications + : Four
9. Statistical stractave

	Rep	Cs	V	Sp	csxv	csxsp	vxsp	csxvxsp	Er	Total
n	4	2	2	3	4	6	6	12	-	48
df	3	1	1	1	3	5	5	11	16	47

3.3 Experimental methodology

Field preparation

Land was prepared thoroughly by deep plugging with tractor drawn cultivator three times. Weeds and crop residue were removed manually then FYM was mixed with the soil Plot size 3 x 3 m. was in open field and Bamboo plantation comprises of Total 48 plot in 24 plots in each cropping system. In Bamboo planting demarcation plot ware mode in such a way that two trees come in each plot laid

Characteristics of improved turmeric varieties

Variety	Mean yield (fresh) (t/ha)	Crop duration (days)	Dry Recovery (%)	Curcumin (%)	Oleoresin (%)	Essential (%)
Roma	20.7	250	31.0	9.3	13.2	4.2
Ranga	29.0	250	24.8	6.3	13.5	4.4

Source of planting material -: High Altitude Research Station, Orissa University of Agriculture and Technology, Pottangi - 764 039, Orissa.

Layout and design

The experiment was laid out in a randomized block design (RBD) for 12 treatments with four replications Turmeric was sown as intercrop under bamboo shade conditions. The different between open conditions.

Manure application

After demarcation of plots and before sowing each plot has been treated with the particular treatment according to the designed layout and as per recommended quantity of manure. Followed standard practice of cultivation in maintain spacing of each cropping system and verities with application of 10 ton FYM / ha basal dose. Where NPK application in following manure given in three split dose of N 120 kg /ha,P 80 kg / ha,and respectively K60 kg / ha

	Based	I. showing	II. DAS	III. DAS	Total	Source
Organic(T/ha)	10				10	FYM
N(kg/ha)	-	40	40	40	120	Urea
Pkg/ha)					80	SSP
K(kg/ha)		20	20	20	60	MOP n

Sowing of seed

The Turmeric Rhizome was sown September 2017 in lines as per treatment of spacing Three S-1 50cm x 50cm S-2 40cm x 30cm, and S-3 50cm x 30cm,

Irrigation

After sowing of seeds field was irrigated immediately to obtain better germination. The crop will be irrigated once in 15 days as required.

Weeding

Weeding has to be done thrice at 60, 90 and 120 days after planting depending upon weed intensity.

Harvesting

Depending upon the variety, the crop becomes ready for harvest in 7-9 months after planting during March.

The crop area was moistures by light irrigation day before the harvesting which was done manually and the rhizomes ware gathered carefully .The harvested rhizomes was cleared of mud and other extraneous matter adhering to them.

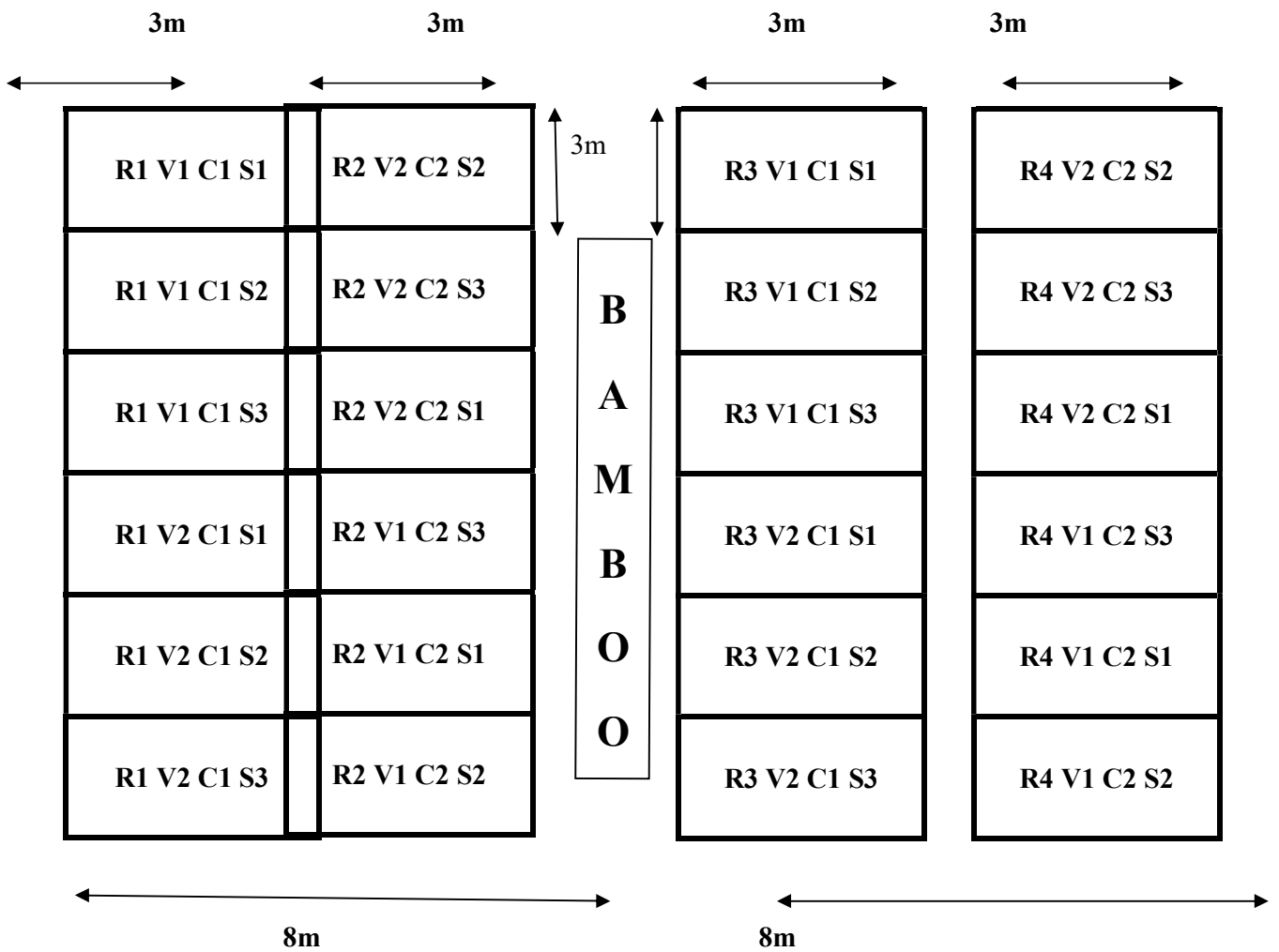


fig. 3.1- Layout plan of the treatment in experimental Agroforestry.

Observations for Turmeric crop

3.4 Vegetative phase Growth Parameters

The following morphological growth parameters on Turmeric, subjected to different treatments were taken on five randomly selected plants from each plot and observations 30 days interval after sowing at 30, 60, 90, 120, 150, 180 and 210 DAS.

i. Plant height

The height of five representative plants per plot was measured by graduated scale in centimeters and recorded for further analysis. The average plant height per plot was calculated for statistical analysis.

ii. No. of leaf

Number of leaves per plant was counted separately from of representative plants. The average number of leaves per plant was recorded for further statistical analysis to know the growth pattern.

iii. Size of leaf

The leaves size (cm) of plants from different treatments was measured by graduated scale in centimeters at 30, 60, 90, 120, and 150 DAS and analyses for statistical significance.

iv. No. of tillers

Average number of tillers per plant was taken on the basis of five randomly selected plants in each plot for all treatments.

3.5 Yield Parameters

i. Rhizome length (cm)

Average rhizome length (cm) was taken on the basis of five randomly selected plants in each bed. Rhizome length (cm) was taken with the help of scale and expressed in cm.

ii. Rhizome width (cm)

The small caller was used to determine width of mother rhizome taking.

iii. Root length (cm)

Length of roots of each sample plots was measured by a centimeter scale.

iv. No. of fingers

Number of primary rhizomes was counted in each sample plants of all 48 plots

v. Yield of fresh and dry Rhizome (Kg ha⁻¹)

Rhizome after harvesting crop the fresh weight g rhizome was recorded for each plots and presented of kg ha⁻¹ yield after statistical analysis.

v. Dry Rhizome yield (Kg ha⁻¹)

After air dry in sunlight the weight of rhizomes were recorded for each plot of all the treatment.

vi. Fresh & dry weight of Mother Rhizome

Fresh weight of mother rhizome was determined by taking average of rhizome fresh weight (g) in 3 square meter plot in each bed and average weight of mother rhizomes were recorded in three replications of all treatments.

vii. Length of finger (cm)

Length of fingers was measured by a meter scale.

3.6 Observations of Bamboo

The growth measurements were made two times *i.e.* in month of July 2017 and in month of March 2018.

i. Diameter of clump (cm)

Girth of clump was measured at base using measuring tape and diameter was calculated as per formula.

ii. Population of Culm / clump

Population of Culm was recorded in per clump each treatment in monthly.

iii. Clump height (m)

The tree height of Bamboo was measured with the help of Ravi Multimeter.

iv. Diameter of 3rd inter node of culms

The diameter of 3rd internode from base was measured with the help of Calliper.

v. Yield of clump (kg)

Clump weight was calculated by multiplying culm dry weight with number of culms.



3.2 Sowing of turmeric in experimental plots



3.3 Observations in turmeric crop



3.4 Measurement of diameter in bamboo (*Dendrocalamus strictus*)



3.5 Turmeric in bamboo based Agroforestry system.



3.6 Growth of turmeric crop in open field



3.7 Growth of Turmeric crop under bamboo based AFS (150DAS)



3.8 Rhizome of turmeric (V1 & V2) at different spacing (S1, S2 & S3) in open field



3.9 Rhizome of turmeric (V1 & V2) at different spacing (S1, S2 & S3) under bamboo based AFS

CHAPTER IV

RESULT AND DISCUSSION

The experimental results and discussion on “Growth and yield of organically grown Turmeric (*Curcuma longa*) under Bamboo (*Dendrocalamus strictus*) based Agroforestry System” are presented in this chapter. Data were recorded for various growth and yield parameters of turmeric crop and bamboo during the study period. All these data were tabulated and subjected to their statistical analysis for interpretation of the results.

For the purpose of easy understanding and convenience the chapter is divided into three parts. The first part deals the growth and yield parameters of turmeric varieties based Agroforestry system and open condition, and second part deals growth and yield in plantation while third part bamboo and open field deal the microclimatic features available to turmeric crop.

I. Turmeric crop

A. Growth Parameters

1. Plant height (cm)
2. No. of leaf
3. Length of leaf
4. No. of tillers

B. Yield Parameters

1. Rhizome length (cm)
2. Rhizome width (cm)
3. Root length (cm)
4. No. of fingers
5. Yield of fresh Rhizome (q ha^{-1})
6. Dry Rhizome yield (q ha^{-1})
7. Fresh & dry weight of Mother Rhizome (kg ha^{-1})
8. Length of finger (cm)

II. Bamboo

1. Diameter of clump (cm)
2. Population of Culm / clump

3. Clump height (m.)
4. Growth in 3rd internode of culms
5. Yield of clump (kg)

III. Microclimatic

1. PAR ($\mu \text{ mol S}^{-1} \text{ m}^{-2}$)
2. Temperature ($^{\circ}\text{C}$)
3. Relative humidity (%)

4.1 Growth parameter of turmeric crop

Results on growth parameters viz; Plant height, Number of leaves, Size of leaves, and Number of tillers are described from 30, 60, 90, 120, and 150 DAS where the peak growth stage was 120 DAS of word crop get mate rip phase hence.

4.1.1 Plant height (cm)

Plant height of turmeric crop was measures at 30, 60, 90, 120 and 150 days after sowing (DAS) and presented in table 4.1 A & B for cropping system, variety and crop spacing's and their interactions.

- a. **Effect of cropping system:** Effect of cropping system on plant height showed statistically significant variation ($P < 0.05$), where 60 to 120 DAS it was consistently higher in crop of open field with maximum plant height of turmeric crop was observed 83.67 cm in open (CS-1) and 77.88 cm in AFS (CS-2), while during early days of growth (30 DAS) average plant height of turmeric plant was observed 28.38 and 29.75 cm in open (CS-1) and AFS (CS-2) respectively with non-significant variation. The growth rate in plant height of turmeric crop in was sums better open (CS-1) than AFS (CS-2).
- b. **Effect of variety:** Effect of variety on plant height was showed statistically significant ($P < 0.05$) at 60 DAS only. Maximum average plant height of turmeric crop was observed 80.79 cm in Ranga (V-1) and 80.79 cm Roma (V-2) at 120 DAS, i.e. peak growth period, while during early days i.e. (30 DAS) the average plant height of turmeric plant was observed 28.71 and 29.42 cm in Ranga (V-1) and Roma (V-2) respectively with non-significant variation. Over all growth in plant height of turmeric crop was recorded better for Roma (V-2) the average plant height of turmeric crop increased much faster in Roma (V-2) than Ranga (V-1).

- c. **Effect of crop spacing:** Effect of crop spacing of turmeric crop on plant height was found statistically non-significant ($P < 0.05$) during growth period. The maximum average plant height of turmeric crop was observed 83.13 cm in S-2 followed by 80.38 and 78.81cm in S-3 and S-2 respectively at 120 DAS. The growth pattern in plant height of turmeric crop was more or less similar during crop season.
- d. **Effect of interaction of cropping system x variety:** The interaction of cropping system and variety showed statistically non-significant results. The average plant height of turmeric crop at 30 DAS was recorded highest for CS-2 x V1 (30.33cm) followed by 29.67cm for CS-1 x V2 with lowest height 27.08cm for CS-1 x V1 interactions, afterward it was remained higher in CS-1 x V-2 followed by CS-1 x V-1 interaction . The average plant height of turmeric crop at 120 DAS was noted highest 84.08cm for CS-1 x V2 followed by 83.25cm for CS-1 x V1, while lowest height was recorded 77.42cm for CS-2 x V2.
- e. **Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and crop spacing was also found statistically non-significant. The average plant height of turmeric crop at 30 DAS was recorded highest for CS-2 x S3 (30.28cm) followed by 29.75cm for CS-2 x S1 with lowest height 28.13cm for CS-1 x S2 interaction, afterward it was remained higher in CS-1 (open) at all spacings. The average plant height of turmeric crop at peak growth stage i.e. 120 DAS was noted highest 84.63cm for CS-1 x S2 followed by 84.38cm for CS-1 x S3 with lowest height 75.63cm for CS-2 x S1.
- f. **Effect of interaction of variety x crop spacing:** The interaction of variety and spacing was also found statistically non-significant. The average plant height of turmeric crop at 30 DAS was recorded highest for V-2 x S3 (30.50cm) followed by 29.88cm for V-2 x S1 with lowest height 27.88cm for V-2 x S2 interaction, afterward it was remained higher in CS-1 (open) for all spacings . The average plant height of turmeric crop at 120 DAS was noted highest 86.13cm for V-2 x S2 followed by 81.75cm for V-1 x S1 with lowest height 75.88cm for V-2 x S1.

g. Effect of interaction of cropping system x variety x crop spacing: The interaction of cropping system, variety and spacing was also showed statistically non-significant result. The average plant height of turmeric crop at 30 DAS was recorded highest for CS-1 x V-2 x S-3 (31.00cm) followed by (30.75cm) for CS-2 x V-1 x S-3 with lowest height (26.00cm) for CS-1 x V-1 x S-1 interaction. How were the average plant height of turmeric crop at 120 DAS was noted highest (89.00cm) for CS-1 x V-2 x S-2 followed by (84.75cm) for CS-1 x V-1 x S-3 with lowest height (72.50cm) for CS-2 x V-2 x S-1.

Table –4.1 A: Height growth (cm) in Turmeric crop under Bamboo based AFS during July 2017 to March 2018.

Treatments	Plant height				
	30 DAS	60DAS	90DAS	120DAS	150DAS
Effect of Cropping system					
Open (Cs-1)	28.38	47.33	76.58	83.67	73.38
AFS (Cs-2)	29.75	39.96	70.83	77.88	74.38
SEm ±	0.92	1.54	1.55	2.03	1.60
SEd±	1.30	2.18	2.19	2.87	2.26
CD	NS	4.37	4.39	5.73	NS
Effect of Variety					
Ranga (V-1)	28.71	40.50	72.38	80.79	73.00
Roma (V-2)	29.42	46.79	75.04	80.75	74.75
SEm ±	0.92	1.54	1.55	2.03	1.60
SEd±	1.30	2.18	2.19	2.87	2.26
CD	NS	4.37	NS	NS	NS
Effect of Spacing					
50x50(S-1)	29.13	43.19	74.06	78.81	76.75
50x30(S-2)	28.63	43.63	73.75	83.13	73.31
40x30(S-3)	29.44	44.13	73.31	80.38	71.56
SEm ±	1.13	1.89	1.90	2.48	1.96
SEd±	1.59	2.67	2.69	3.51	2.77
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety					
Cs-1 x V1	27.08	43.42	73.83	83.25	72.33
Cs-1 x V2	29.67	51.25	79.33	84.08	74.42
Cs-2 x V1	30.33	37.58	70.92	78.33	73.67
Cs-2 x V2	29.17	42.33	70.75	77.42	75.08
SEm ±	1.30	2.18	2.20	2.87	2.26
SEd±	1.84	3.09	3.10	4.05	3.20
CD	NS	NS	NS	NS	NS

DAS- Days after sowing the crop

Table – 4.1 B: Height growth (cm) in Turmeric crop under Bamboo based AFS during July 2017 to March 2018.

Plant height					
Interaction of Cropping system x Spacing					
	30DAS	60DAS	90DAS	120DAS	150DAS
Cs-1 x S1	28.50	48.00	76.13	82.00	76.50
Cs-1 x S2	28.13	47.13	76.50	84.63	72.50
Cs-1 x S3	28.50	46.88	77.13	84.38	71.13
Cs-2 x S1	29.75	38.38	72.00	75.63	77.00
Cs-2 x S2	29.13	40.13	71.00	81.63	74.13
Cs-2 x S3	30.38	41.38	69.50	76.38	72.00
SEm ±	1.59	2.67	2.69	3.51	2.77
SEd±	2.25	3.78	3.80	4.97	3.91
CD	NS	NS	NS	NS	NS
Interaction of Variety x Spacing					
V-1 x S-1	28.38	39.00	71.38	81.75	76.75
V-1 x S-2	29.38	41.88	73.88	80.13	71.38
V-1 x S-3	28.38	40.63	71.88	80.50	70.88
V-2 x S-1	29.88	47.38	76.75	75.88	76.75
V-2 x S-2	27.88	45.38	73.63	86.13	75.25
V-2x S-3	30.50	47.63	74.75	80.25	72.25
SEm ±	1.59	2.67	2.69	3.51	2.77
SEd±	2.25	3.78	3.80	7.02	3.91
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety x Spacing					
Cs-1 x V-1 x S-1	27.00	41.25	71.25	84.75	75.75
Cs-1 x V-1 x S-2	28.25	47.00	76.25	80.25	70.25
Cs-1 x V-1 x S-3	26.00	42.00	74.00	84.75	71.00
Cs-1 x V-2 x S-1	30.00	54.75	81.00	79.25	77.25
Cs-1 x V-2 x S-2	28.00	47.25	76.75	89.00	74.75
Cs-1 x V-2 x S-3	31.00	51.75	80.25	84.00	71.25
Cs-2 x V-1 x S-1	29.75	36.75	71.50	78.75	77.75
Cs-2 x V-1 x S-2	30.50	36.75	71.50	80.00	72.50
Cs-2 x V-1 x S-3	30.75	39.25	69.75	76.25	70.75
Cs-2 x V-2 x S-1	29.75	40.00	72.50	72.50	76.25
Cs-2 x V-2 x S-2	27.75	43.50	70.50	83.25	75.75
Cs-2 x V-2 x S-3	30.00	43.50	69.25	76.50	73.25
SEm ±	2.26	3.78	3.80	4.97	3.92
SEd±	3.19	5.35	5.38	4.97	5.54
CD	NS	NS	NS	NS	NS

DAS- Days after sowing the crop

4.1.2 Number of tillers (per plant)

Number of tillers of turmeric crop was counted at 30, 60, 90, 120, and 150 days after sowing (DAS) and presented in table- 4.2 A & B for role of cropping system, variety and crop spacing and their interactions.

- a. **Effect of cropping system:** Effect of cropping system on number of tillers showed statistically non-significant ($P < 0.05$) results. The maximum average number of tillers per plant in turmeric crop was observed 2.38 per plant in open (CS-1) and 2.67 per plant AFS (CS-2) at 90 and 120 DAS. While during early days of growth (30 DAS) number of tillers per plant turmeric crop was observed 2.38 and 2.17 per plant in open (CS-1) and AFS (CS-2) respectively. Over all number of tillers per plant in turmeric crop was recorded more in AFS (CS-2) as compare to open (CS-1).
- b. **Effect of variety:** Effect of variety on number of tillers per plant showed statistically non-significant ($P < 0.05$) for variation. The maximum average number of tillers per plant was observed 2.67 per plant in Roma (V-2) and 2.38 per plant Ranga (V-1) at 90 and 120 DAS. Through during early days of growth (30 DAS) average number of tillers per plant was counted 2.33 per plant and 2.21 per plant in variety Ranga (V-2) and Roma (V-1) respectively. Over all number of tillers per plant of was formed more in variety Roma (V-2) as compared to Ranga (V-1).
- c. **Effect of crop spacing:** Effect of crop spacing of turmeric crop on number of tillers was found statistically non-significant ($P < 0.05$) during all growth period. The maximum average number of tillers per plant was observed 2.63 per plant in S-3 followed by 2.56 and 2.38 per plant in S-1 and S-2 respectively at 90 and 120 DAS. The formation of tillers per plant was showed more or less same in all the crops. However more or less the number of tillers of turmeric crop was consistently observed higher in S-3 followed by S-1 and S-2. Thus number of tillers per plant was remained less in spacing S-2
- d. **Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant per number of tillers per plant. The average number of tillers per plant in turmeric crop at 30 DAS

was recorded highest for CS-1 x V2 (2.58 plant⁻¹) followed by 2.25 plant⁻¹ for CS-2 x V1 with lowest number of tiller 2.08 plant⁻¹ for CS-2 x V2 interaction, afterward it was showed more or less similar pattern at 60, 90, 120, and 150 DAS, were it was noted higher 2.75 plant⁻¹ for CS-2 x V2 followed by 2.58 plant⁻¹ for CS-2 x V1 with lowest of 2.17 plant⁻¹ for CS-1 x V1 respectively.

- e. ***Effect of interaction of cropping system x crop spacing:*** The interaction of cropping system and spacing was also found statistically non-significant. The average number of tillers per plant in turmeric crop at 30 DAS was recorded highest for CS-1 x S3 (2.50 plant⁻¹) followed by (2.38 plant⁻¹) for CS-1 x S2 with lowest number of tiller (2.00 plant⁻¹) for CS-1 x S2 interaction, afterward it was remained higher in CS-2 x S-2 at 60, 90, 120, DAS per plant. Followed by 2.75 plant⁻¹ for CS-2 x S3 with lowest number of tiller (2.25 plant⁻¹) for CS-1 x S1 interactions.
- f. ***Effect of interaction of variety x crop spacing:*** The interaction of variety and spacing was also showed statistically non-significant results. The average number of tillers per plant in turmeric crop at 30 DAS was recorded highest for V-2 x S3 (2.75 plant⁻¹) followed by for V-1 x S-1 2.50 plant⁻¹ with lowest number of tillers for V-2 x S-1 interaction (2.00 plant⁻¹), and it was remained higher at 60, 90 and 120 DAS. The average number of tillers per plant in turmeric crop at 90 and 120 DAS was noted highest (2.88 plant⁻¹) for V-2 x S-3 followed by 2.63 plant⁻¹ for V-1 x S1 with lowest number of tiller for V-1 x S-2 (2.13 plant⁻¹).
- g. ***Effect of interaction of cropping system x variety x crop spacing:*** The interaction of cropping system variety and spacing was also found statistically non-significant. The average number of tillers per plant in turmeric crop at 30 DAS was recorded highest in four interactions viz; CS-1 x V-1 x S-2 and S-3, CS-2 x V-1 x S-1 and CS-2 x V-2 x S-3 (2.75 plant⁻¹) followed by further in four interactions viz; CS-1 x V-1 x S-3 and S-3, CS-1 x V-2 x S-1, CS-2 x V-1 x S-2 (2.33 plant⁻¹) with lowest number of tillers for CS-2 x V-1 x S-3 CS-2 x V-2 x S-1 and S-2 interactions (1.75 plant⁻¹), was remained constant in all the care at 60, 90 and 120, DAS, where the average number of tiller per plant was

noted higher for CS-2 x V-1 x S-1 and CS-2 x V-2 x S-3 (3.00 plant⁻¹) and the lowest number of tillers per plant was recorded for CS-1 x V-1 x S-2 (2.00 plant⁻¹).

Table -4.2 A: Tiller (plant⁻¹) in Turmeric crop under Bamboo based AFS during July 2017 to March 2018.

Treatments	Number of tiller				
	30 DAS	60DAS	90DAS	120DAS	150DAS
Effect of Cropping system					
Open (Cs-1)	2.38	2.29	2.38	2.38	1.67
AFS (Cs-2)	2.17	2.67	2.67	3.08	1.83
SEm ±	0.17	0.17	0.18	0.18	0.15
SEd±	0.23	0.25	0.26	0.25	0.21
CD	NS	NS	NS	NS	NS
Effect of Variety					
Ranga (V-1)	2.21	2.38	2.38	2.58	1.71
Roma (V-2)	2.33	2.58	2.67	2.88	1.79
SEm ±	0.17	0.17	0.18	0.18	0.15
SEd±	0.23	0.25	0.26	0.25	0.21
CD	NS	NS	NS	NS	NS
Effect of Spacing					
50x50(S-1)	2.25	2.56	2.56	2.78	1.75
50x30(S-2)	2.19	2.38	2.38	2.59	1.69
40x30(S-3)	2.38	2.50	2.63	2.82	1.81
SEm ±	0.20	0.21	0.23	0.22	0.18
SEd±	0.29	0.30	0.32	0.31	0.26
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety					
Cs-1 x V1	2.17	2.17	2.17	2.17	1.58
Cs-1 x V2	2.58	2.42	2.58	2.58	1.75
Cs-2 x V1	2.25	2.58	2.58	3.00	1.83
Cs-2 x V2	2.08	2.75	2.75	3.17	1.83
SEm ±	0.23	0.25	0.26	0.25	0.21
SEd±	0.33	0.35	0.37	0.36	0.30
CD	NS	NS	NS	NS	NS

DAS- Days after sowing the crop

Table - 4.2 B: Tiller (plant⁻¹) in Turmeric crop under Bamboo based AFS during July 2017 to March 2018.

Number of tiller(plant⁻¹)					
Interaction of Cropping system x Spacing					
	30DAS	60DAS	90DAS	120DAS	150DAS
Cs-1 x S1	2.25	2.25	2.25	2.25	1.75
Cs-1 x S2	2.38	2.38	2.38	2.38	1.50
Cs-1 x S3	2.50	2.25	2.50	2.50	1.75
Cs-2 x S1	2.25	2.88	2.88	3.30	1.75
Cs-2 x S2	2.00	2.38	2.38	2.81	1.88
Cs-2 x S3	2.25	2.75	2.75	3.14	1.88
SEm ±	0.29	0.30	0.32	0.31	0.26
SEd±	0.41	0.43	0.45	0.44	0.37
CD	NS	NS	NS	NS	NS
Interaction of Variety x Spacing					
V-1 x S-1	2.50	2.63	2.63	2.85	1.88
V-1 x S-2	2.13	2.13	2.13	2.35	1.38
V-1 x S-3	2.00	2.38	2.38	2.55	1.88
V-2 x S-1	2.00	2.50	2.50	2.70	1.63
V-2 x S-2	2.25	2.63	2.63	2.84	2.00
V-2x S-3	2.75	2.63	2.88	3.09	1.75
SEm ±	0.29	0.30	0.32	0.31	0.26
SEd±	0.41	0.43	0.45	0.44	0.37
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety x Spacing					
Cs-1 x V-1 x S-1	2.25	2.25	2.25	2.25	1.75
Cs-1 x V-1 x S-2	2.00	2.00	2.00	2.00	1.25
Cs-1 x V-1 x S-3	2.25	2.25	2.25	2.25	1.75
Cs-1 x V-2 x S-1	2.25	2.25	2.25	2.25	1.75
Cs-1 x V-2 x S-2	2.75	2.75	2.75	2.75	1.75
Cs-1 x V-2 x S-3	2.75	2.25	2.75	2.75	1.75
Cs-2 x V-1 x S-1	2.75	3.00	3.00	3.45	2.00
Cs-2 x V-1 x S-2	2.25	2.25	2.25	2.70	1.50
Cs-2 x V-1 x S-3	1.75	2.50	2.50	2.85	2.00
Cs-2 x V-2 x S-1	1.75	2.75	2.75	3.15	1.50
Cs-2 x V-2 x S-2	1.75	2.50	2.50	2.93	2.25
Cs-2 x V-2 x S-3	2.75	3.00	3.00	3.43	1.75
SEm ±	0.41	0.43	0.45	0.44	0.37
SEd±	0.57	0.60	0.64	0.62	0.52
CD	1.15	1.20	1.28	NS	1.04

DAS- Days after sowing the crop

4.1.3. Number of leaves (per plant)

Number of leaves per plant in turmeric crop was counted at 30, 60, 90, 120, and 150 days after sowing (DAS) and data are presented in table-4.3 A & B for role of cropping system, variety, crop spacing and their interaction.

- a. **Effect of cropping system:** Effect of cropping system on number of leaves per plant showed statistically non-significant ($P < 0.05$) results at 30 and 120 DAS. The maximum average number of leaves was observed 22.08 plant⁻¹ in AFS (CS-2) and 20.58 plant⁻¹ open (CS-1) at 90 DAS. While during early days of growth (30 DAS) average number of leaves of turmeric plant was observed 7.83 and 7.58 plant⁻¹ in open (CS-1) and AFS (CS-2) respectively with non-significant variation. Over all number of leaves turmeric crop was recorded more in AFS (CS-2) as compared to open (CS-1). The increment in number of leaves per plant was faster crop growth in AFS (CS-2) than open (CS-1).
- b. **Effect of variety:** Effect of variety on number of leaves did not found statistically significant ($P < 0.05$). The maximum average number of leaves was observed 21.96 plant⁻¹ in Ranga (V-1) and 20.71 plant⁻¹ Roma (V-2) at 90 DAS. While during early days of growth (30 DAS) number of leaves per plant was observed 7.83 plant⁻¹ and 7.58 plant⁻¹ in Roma (V-2) and Ranga (V-1) respectively with non-significant variation. Over all number of leaves per plant was recorded more in Roma (V-2) as compared to Ranga (V-1). The increment in number of leaves per plant was observed more or less in similar pattern.
- c. **Effect of crop spacing:** Effect of crop spacing of turmeric crop for number of leaves was found statistically non-significant ($P < 0.05$) during growth period except at 120 DAS. The maximum number of leaves per plant turmeric was observed 22.56 plant⁻¹ in S-1 followed by 21.13 plant⁻¹ and 20.31 plant⁻¹ in S-2 and S-3 respectively at 120 DAS. The growth pattern in number of leaves of turmeric crop was more or less same during crop season.
- d. **Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant at 30, 60, 90 and 150 DAS. The number of leaves per plant turmeric crop at 30 DAS was recorded highest for CS-1 x V2 (8.25 plant⁻¹) followed by 7.75 plant⁻¹ for CS-2 x V1 with

lowest for CS-1 x V-1 and CS-2 x V2 interaction (7.42 plant^{-1}). The number of leaves per plant turmeric crop at 120 DAS was noted highest 21.42 plant^{-1} for CS-1 x V2 followed by 21.00 plant^{-1} for CS-2 x V1 while lowest 19.58 plant^{-1} leaves was counted for CS-1 x V1 with significant variation.

- e. **Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacing was found statistically non-significant. The number of leaves per plant turmeric crop at 30 DAS was recorded 8.38 plant^{-1} for CS-1 x S3 followed by 7.63 plant^{-1} for CS-2 x S3 with lowest of and 7.50 plant^{-1} for CS-2 x S1 interaction, and at increased to maximum level at 90 DAS, where the number of leaves per plant turmeric crop was noted highest 22.75 plant^{-1} for CS-2 x S1 followed by 22.38 plant^{-1} and 22.13 plant^{-1} for CS-2 x S1 and CS-2 x S-2 respectively while the lowest number of leaves was counted 19.25 plant^{-1} for CS-1 x S3 with insignificant variation.
- f. **Effect of interaction of variety x crop spacing:** The interaction of variety and spacing was also found statistically non-significant at all the data of observation. The number of leaves per plant in turmeric crop at 30 DAS was recorded highest for V-2 x S-3 (8.38 plant^{-1}) followed by 7.75 plant^{-1} for V-2 x S-2 while the lowest number of leaves was counted for V-2 x S-1 interaction 7.38 plant^{-1} , the pattern of increment in leaves numbers was more or less similar for all the cases at 60, 90, 120, and 150 DAS. The maximum number of leaves per plant turmeric crop was counted at 90 DAS where it was higher 23.75 plant^{-1} for V-1 x S-1 followed by 21.38 plant^{-1} for V-2 x S1 while the minimum number of leaves 19.63 plant^{-1} was recorded for V-2 x S-3.
- g. **Effect of interaction of cropping system x variety x crop spacing:** The interaction of cropping system, variety and spacing was also found statistically non-significant at all the observations from 30 to 150 DAS. The number of leaves per plant in turmeric crop at 30 DAS was recorded highest for CS-1 x V-2 x S-3 (8.75 plant^{-1}) followed by 8.25 plant^{-1} for CS-2 x V-1 x S-1 and 8.0 plant^{-1} leaves per plant for CS-1 x V-1 x S-3, CS-1 x V-2 x S-1 & S-2, and CS-2 x V-2 x S-3. The lowest number of leaves was counted 6.75 plant^{-1} for CS-2 x V-2 x S-1 interaction. The maximum number of leaves per plant was counted

90DAS. Its range of 24.25 to 17.75 per plant where it was maximum for CS-1 x V-1 x S-1 followed by CS-2 x V-1 x S-1 & S-2 (23.00 plant⁻¹) and CS-2 x V-1 x S-3 (22.00 plant⁻¹) and minimum is CS-1 x V-1 x S-2 (19.25 plant⁻¹) The number of leaves per plant in turmeric crop at 120 DAS was noted highest (22.25 plant⁻¹) for CS-2 x V-1 x S-1 followed by (21.25 plant⁻¹) for CS-1 x V-2 x S-2 with lowest of 17.75 plant⁻¹ for CS-1 x V-1 x S-2.

Table - 4.3: A Number of leaves (plant⁻¹) in turmeric crop under Bamboo based AFS during July 2017 to March 2018.

Treatments	Number of leaves(plant ⁻¹)				
	30 DAS	60DAS	90DAS	120DAS	150DAS
Effect of Cropping system					
Open (Cs-1)	7.83	13.13	20.58	20.50	13.71
AFS (Cs-2)	7.58	15.04	22.08	20.79	17.29
SEm ±	0.28	0.42	0.56	0.33	0.47
SEd±	0.40	0.59	0.79	0.46	0.66
CD	NS	1.18	1.58	NS	1.32
Effect of Variety					
Ranga (V-1)	7.58	14.21	21.96	20.29	15.42
Roma (V-2)	7.83	13.96	20.71	21.00	15.58
SEm ±	0.28	0.42	0.56	0.33	0.47
SEd±	0.40	0.59	0.79	0.46	0.66
CD	NS	NS	NS	NS	NS
Effect of Spacing					
50x50(S-1)	7.50	14.38	22.56	21.56	15.25
50x30(S-2)	7.63	13.75	21.13	20.63	15.69
40x30(S-3)	8.00	14.13	20.31	19.75	15.56
SEm ±	0.35	0.51	0.69	0.40	0.57
SEd±	0.49	0.73	0.97	0.56	0.81
CD	NS	NS	NS	1.13	NS
Interaction of Cropping system x Variety					
Cs-1 x V1	7.42	13.42	21.17	19.58	13.42
Cs-1 x V2	8.25	12.83	20.00	21.42	14.00
Cs-2 x V1	7.75	15.00	22.75	21.00	17.42
Cs-2 x V2	7.42	15.08	21.42	20.58	17.17
SEm ±	0.40	0.59	0.79	0.46	0.66
SEd±	0.57	0.84	1.12	0.65	0.93
CD	NS	NS	NS	1.30	NS

DAS- Days after sowing the crop.

Table - 4.3: B Number of leaves (plant⁻¹) in Turmeric crop under Bamboo based AFS durin July 2017 to March 2018.

Number of leaves (plant⁻¹)					
Interaction of Cropping system x Spacing					
	30DAS	60DAS	90DAS	120DAS	150DAS
Cs-1 x S1	7.50	13.50	22.75	21.50	13.25
Cs-1 x S2	7.63	13.00	20.13	20.75	13.63
Cs-1 x S3	8.38	12.88	18.88	19.25	14.25
Cs-2 x S1	7.50	15.25	22.38	21.63	17.25
Cs-2 x S2	7.63	14.50	22.13	20.50	17.75
Cs-2 x S3	7.63	15.38	21.75	20.25	16.88
SEm ±	0.49	0.73	0.97	0.56	0.81
SEd±	0.69	1.03	1.37	0.80	1.14
CD	NS	NS	NS	NS	NS
Interaction of Variety x Spacing					
V-1 x S-1	7.63	14.25	23.75	21.50	15.63
V-1 x S-2	7.50	14.00	21.13	20.50	15.25
V-1 x S-3	7.63	14.38	21.00	18.88	15.38
V-2 x S-1	7.38	14.50	21.38	21.63	14.88
V-2 x S-2	7.75	13.50	21.13	20.75	16.13
V-2 x S-3	8.38	13.88	19.63	20.63	15.75
SEm ±	0.49	0.73	0.97	0.56	0.81
SEd±	0.69	1.03	1.37	0.80	1.14
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety x Spacing					
Cs-1 x V-1 x S-1	7.00	13.25	24.25	20.75	12.75
Cs-1 x V-1 x S-2	7.25	13.00	19.25	20.25	13.25
Cs-1 x V-1 x S-3	8.00	14.00	20.00	17.75	14.25
Cs-1 x V-2 x S-1	8.00	13.75	21.25	22.25	13.75
Cs-1 x V-2 x S-2	8.00	13.00	21.00	21.25	14.00
Cs-1 x V-2 x S-3	8.75	11.75	17.75	20.75	14.25
Cs-2 x V-1 x S-1	8.25	15.25	23.25	22.25	18.50
Cs-2 x V-1 x S-2	7.75	15.00	23.00	20.75	17.25
Cs-2 x V-1 x S-3	7.25	14.75	22.00	20.00	16.50
Cs-2 x V-2 x S-1	6.75	15.25	21.50	21.00	16.00
Cs-2 x V-2 x S-2	7.50	14.00	21.25	20.25	18.25
Cs-2 x V-2 x S-3	8.00	16.00	21.50	20.50	17.25
SEm ±	0.69	1.03	1.37	0.80	1.14
SEd±	0.98	1.45	1.94	1.13	1.61
CD	NS	NS	NS	NS	NS

DAS- Days after sowing the crop.

4.1.4 Size of leaves (cm)

Size of leaves of turmeric crop was measured at 30, 60, 90, 120, and 150 days after sowing (DAS) and is presented in table- 4.4 A & B for role of cropping system, variety and crop spacing and their interaction.

- a. Effect of cropping system:** Effect of cropping system on size of leaves showed statistically non-significant ($P < 0.05$) results for the observations except 60 DAS. The maximum size of leaves of turmeric crop was observed i.e. 210.78cm in AFS (CS-2) and 10.16cm open (CS-1) at 120 DAS. While during early days of growth (30 DAS) number of 2 leaves it was observed 39.08cm and 35.16cm in AFS (CS-2) and open (CS-1) respectively. Over all size of leaves was recorded higher in AFS (CS-2) as compared to open (CS-1).
- b. Effect of variety:** Effect of variety on Size of leaves showed statistically non-significant ($P < 0.05$) results at 30 and 60DAS afterword there was insignificant variation. The maximum size of leaves of turmeric crop was observed 216.13cm in Roma (V-2) and 204.81cm Ranga (V-1) at 120 DAS. While during early days of growing (30 DAS) size of leaves of turmeric plant was observed 39.58cm and 34.67cm in Roma (V-2) and Ranga (V-1) respectively with significant variation. Over all size of leaves of turmeric crop was recorded higher in Roma (V-2) as compared to Ranga (V-1).
- c. Effect of crop spacing:** Effect of crop spacing on size of leaves was found statistically non-significant ($P < 0.05$) during growth period. The maximum size of leaves was observed 214.03cm in S-2 followed by 213.29cm and 204.08cm in S-3 and S-1 respectively at 120 DAS. The growth pattern in size of leaves of turmeric crop was more or less same during season. The consistently highest size of leaves of turmeric crop was observed in S-2. The size of leaves of turmeric crop was remained less in S-1 at all the observations of growth phase.
- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant. The size of leaves of turmeric crop at 30 DAS was recorded maximum for CS-2 x V2 (41.7cm)) followed by 37.37cm for CS-1 x V2 with lowest 732.9cm for CS-1 x V1 interaction. The average size of leaves of turmeric crop at 120 DAS was noted

highest 217.4cm for CS-1 x V2 followed by 214.8cm for CS-2 x V2 with lowest number of leaves for CS-1 x V1(202.85cm).

e. Effect of interaction of cropping system x crop spacing: The interaction of cropping system and spacing was also found statistically non-significant. The average size of leaves of turmeric crop at 30 DAS was recorded maximum for CS-2 x S1 (39.94cm) followed by 38.66cm for CS-2 x S2 with lowest number of leaves for CS-1 x S1 interaction (33.31cm). The average size of leaves of turmeric crop at 120 DAS was noted highest 215.92cm for CS-2 x S3 followed by 215.10cm for CS-1 x S2 with lowest size of leaves for CS-2 x S1(203.46cm). There was not growth pattern of leaves among the entire discus.

f. Effect of interaction of variety x crop spacing: The interaction of variety and spacing was also found statistically non-significant at all DAS. The average size of leaves of turmeric crop at 30 DAS was recorded highest for V-2 x S-1 (41.07cm) followed by 40.74cm for V-2 x S-2 with lowest of 32.18cm for V-1 x S-1 interaction. The highest size of leaves in turmeric crop was recorded at 120DAS where it was maximum 230.78cm for V-2 x S-3 followed by 220.39cm for V-2 x S2 with lowest of 195.81cm for V-1 x S-3. The increment in growth of leaves was seen in similar pattern with insignificant variation.

g. Effect of interaction of cropping system x variety x crop spacing: The interaction of variety and spacing was also found statistically non-significant. The average size of leaves in turmeric crop at 30 DAS was recorded maximum for CS-2 x V-2 x S-1 (43.47cm) followed by 41.11cm for CS-2 x V-2 x S-3 with lowest of 27.94cm for CS-1 x V-1 x S-1 interaction. The growth in leaves was observed highest at 120 DAS where it was maximum 235.28cm for CS-2 x V-2 x S-3 followed by 227.89cm for CS-1 x V-2 x S-2 with lowest of 195.06cm for CS-1 x V-1 x S-3.

Table – 4.4 (A): Length of leaves in Turmeric crop under bamboo based AFS during July 2017 to March 2018

Treatments	Size of leaves				
	30 DAS	60DAS	90DAS	120DAS	150DAS
Interaction of Cropping system					
Open (Cs-1)	35.16	76.29	182.07	210.16	111.58
AFS (Cs-2)	39.08	81.25	177.05	210.78	119.87
SEm ±	1.59	1.37	3.85	5.96	3.56
SEd±	2.25	1.93	5.44	8.43	5.03
CD	NS	3.86	NS	NS	NS
Interaction of Variety					
Ranga (V-1)	34.67	76.76	177.26	204.81	114.03
Roma (V-2)	39.58	80.77	181.86	216.13	117.42
SEm ±	1.59	1.37	3.85	5.96	3.56
SEd±	2.25	1.93	5.44	8.43	5.03
CD	4.50	3.86	NS	NS	NS
Interaction of Spacing					
50x50(S-1)	36.63	76.22	174.59	204.08	114.33
50x30(S-2)	37.99	81.11	180.41	214.03	122.92
40x30(S-3)	36.76	78.97	183.67	213.29	109.92
SEm ±	1.95	1.67	4.71	7.30	4.36
SEd±	2.76	2.37	6.66	10.32	6.16
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety					
Cs-1 x V1	32.96	74.50	177.76	202.85	110.07
Cs-1 x V2	37.37	78.08	186.37	217.46	113.08
Cs-2 x V1	36.38	79.03	176.75	206.77	117.99
Cs-2 x V2	41.78	83.46	177.34	214.80	121.75
SEm ±	2.25	1.93	5.44	8.43	5.03
SEd±	3.18	2.73	7.69	11.92	7.11
CD	NS	NS	NS	NS	NS

Table - 4.4 (B): Length of leaves in Turmeric crop under Bamboo Based AFS during July 2017 to March 2018

Treatments	Length of leaves				
	30DAS	60DAS	90DAS	120DAS	150DAS
Interaction of Cropping system x Spacing					
Cs-1 x S1	33.31	70.50	178.32	204.71	111.71
Cs-1 x S2	37.31	80.50	182.52	215.10	120.79
Cs-1 x S3	34.88	77.88	185.36	210.67	102.24
Cs-2 x S1	39.94	81.94	170.86	203.46	116.96
Cs-2 x S2	38.66	81.72	178.29	212.97	125.04
Cs-2 x S3	38.64	80.07	181.99	215.92	117.61
SEm ±	2.76	2.37	6.66	10.32	6.16
SEd±	3.90	3.35	9.42	14.60	8.71
CD	NS	NS	NS	NS	NS
Interaction of Variety x Spacing					
V-1 x S-1	32.18	72.45	170.64	210.94	112.44
V-1 x S-2	35.24	81.83	173.57	207.68	120.64
V-1 x S-3	36.58	76.01	187.56	195.81	109.01
V-2 x S-1	41.07	80.00	178.54	197.22	116.22
V-2 x S-2	40.74	80.39	187.24	220.39	125.19
V-2x S-3	36.93	81.93	179.79	230.78	110.83
SEm ±	2.76	2.37	6.66	10.32	6.16
SEd±	3.90	3.35	9.42	14.60	8.71
CD	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety x Spacing					
Cs-1 x V-1 x S-1	27.94	66.01	173.97	211.19	106.69
Cs-1 x V-1 x S-2	33.93	83.75	173.29	202.31	117.89
Cs-1 x V-1 x S-3	37.00	73.75	186.03	195.06	105.64
Cs-1 x V-2 x S-1	38.68	75.00	182.67	198.22	116.72
Cs-1 x V-2 x S-2	40.70	77.25	191.76	227.89	123.69
Cs-1 x V-2 x S-3	32.75	82.00	184.68	226.28	98.83
Cs-2 x V-1 x S-1	36.42	78.89	167.31	210.69	118.19
Cs-2 x V-1 x S-2	36.55	79.92	173.86	213.06	123.39
Cs-2 x V-1 x S-3	36.17	78.28	189.08	196.56	112.39
Cs-2 x V-2 x S-1	43.47	85.00	174.42	196.22	115.72
Cs-2 x V-2 x S-2	40.78	83.53	182.72	212.89	126.69
Cs-2 x V-2 x S-3	41.11	81.86	174.89	235.28	122.83
SEm ±	3.90	3.35	9.42	14.60	8.71
SEd±	5.51	4.73	13.32	20.64	12.32
CD	NS	NS	NS	NS	NS

DAS- Days after sowing the crop.

4.2 Yield Parameters of Turmeric in bamboo based agroforestry systems

Length of mother rhizome

The length of mother rhizome of turmeric was observed by graduated scale for cropping system, varieties, spacing's, and there interactions.

- a. **Effect of cropping system:** Effect of cropping system on length of mother rhizome showed statistically non-significant ($P < 0.05$), where the maximum length of mother rhizome was observed 4.63 cm in AFS (CS-2) and 4.10 cm open field (CS-1).
- b. **Effect of variety:** Effect of variety on length of mother rhizome showed statistically non-significant ($P < 0.05$) where the maximum length of mother rhizome of was observed 4.52 cm in Ranga (V-1) and 4.20 cm Roma (V-2) .
- c. **Effect of crop spacing:** Effect of crop spacing of turmeric crop for length of mother rhizome was found statistically non-significant ($P < 0.05$). The maximum average length of mother rhizome of was observed 4.66 cm in S-1 followed by 4.29 and 4.14cm in S-2 and S-3 respectively.
- d. **Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was also found statistically non-significant, where the average length of mother rhizome was recorded highest for CS-2 x V2 4.75cm followed by (4.54cm) for CS-1 x V1 with lowest length of 3.66cm for CS-1 x V2 interaction.
- e. **Effect of interaction of cropping system x crop spacing:** The effect of interaction of cropping system and spacing was found statistically non-significant and the average length of mother rhizome was recorded highest for CS-2 x S1 (5.00cm) followed by 4.75cm, 4.33cm and 4.15cm for CS-2 x S2, CS-1 x S-1 and CS-1 x S-3 respectively and the lowest length 3.83cm was observed for CS-1 x S2 interaction.
- f. **Effect of interaction of variety x crop spacing:** The interaction of variety and spacing was showed statistically non-significant results. The length of mother rhizome was recorded (5.45cm) for V-1 x S1 followed by 4.70cm and 4.54cm

for V-2 x S3 and V-1 x S-2 respectively while lowest length was recorded 3.58cm for V-1 x S3 interaction.

g. Effect of interaction of cropping system x variety x crop spacing: The interaction of variety and spacing was found statistically non-significant. The length of mother rhizome was recorded maximum for CS-1 x V-1 x S-1 (5.65cm) followed by 4.75cm for CS-2 x V-1 x S-2 and CS-2 x V-2 x S-1|S-2|S-3 with lowest 3.00cm for CS-1 x V-2 x S-1 interaction. Overall most of the interactions showed length of mother rhizome 4.8 ± 0.5 cm.

Width of mother rhizome

The width of mother rhizome at middle part were measured by using digital calipers and data is prepared in table- for cropping system, variety, crop spacing's and there interactions.

- a. Effect of cropping system:** Effect of cropping system on width of mother rhizome showed statistically significant ($P < 0.05$) variation. The width of mother rhizome was observed 9.58 cm in open field (CS-1) and 3.96 cm AFS (CS-2).
- b. Effect of variety:** Effect of variety on width of mother rhizome showed statistically significant ($P < 0.05$) variation. The width of mother rhizome was observed 7.13 cm in Ranga (V-1) and 6.42 cm Roma (V-2).
- c. Effect of crop spacing:** Effect of crop spacing of turmeric crop on width of mother rhizome was found statistically non-significant ($P < 0.05$). The maximum average width of mother rhizome was observed 7.31 cm in S-2 followed by 6.63cm and 6.38cm in S-1 and S-3 respectively.
- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically significant. The width of mother rhizome was recorded maximum for CS-1 x V1 (10.33cm) followed by 8.83cm for CS-1 x V2 with lowest width 3.92cm for CS-2 x V1 interaction. Overall CS x V interaction showed before results in cropping system (CS-1) for both the variations.
- e. Effect of interaction of cropping system x crop spacing:** The effect of interaction of cropping system and spacing was showed statistically non-

significant results. The width of mother rhizome was recorded 10.3cm for CS-1 x S2 followed by 9.38cm and 9.00cm for CS-1 x S1 and CS-1 x S-2 respectively where lowest width was observed for CS-2 x S3 interaction 3.75cm. Overall CS x S interaction showed better results for all spacings for CS-1(open).

f. Effect of interaction of variety x crop spacing: The effect of interaction of variety and spacing was also found statistically non-significant. The width of mother rhizome was recorded highest for V-1 x S2 (8.25cm) followed by 6.63cm for V-1 x S1 with lowest width at 6.25cm for V-2 x S2 interaction.

g. Effect of interaction of cropping system x variety x crop spacing: The interaction of variety and spacing was also showed statistically non-significant results. The width of mother rhizome was recorded higher side in CS-1 for at the spacings and variety where it was maximum for CS-1 x V-1 x S-2 (12.00cm) followed by CS-1 x V-1 x S-1 10.00cm, CS-1 x V-1 & V-2 x S-3 (9.00cm) and CS-1 x V-2 x S-1 & S-2(8.75cm) of tern and dropped between 4.50 to 3.25cm in crop of turmeric under AFS(CS-2) with lowest for CS-2 x V-1 x S-1 interaction.

Number of finger per plant

The formation of new fingers in mother rhizomes were counted at the time of harvesting the turmeric crop and the results are presented in (Table)

a. Effect of cropping system: Effect of cropping system on number of fingers showed statistically significant ($P < 0.05$). The maximum number of fingers in turmeric crop was observed 4.88 plant⁻¹ in open field (CS-1) and 4.33 plant⁻¹ AFS (CS-2).

b. Effect of variety: Effect of variety on number of finger showed statistically non-significant ($P < 0.05$) variation. The maximum number of fingers in turmeric crop was observed 4.75 plant⁻¹ in Roma (V-2) and 4.46 pp Ranga (V-1). Over all number of finger of turmeric crop was recorded % more Roma (V-2) as compare to Ranga (V-1).

- c. Effect of crop spacing:** Effect of crop spacing of turmeric crop for number of finger was found statistically non-significant ($P < 0.05$). The maximum number of fingers in turmeric crop was observed 4.69 plant^{-1} in S-3 followed by 4.63 plant^{-1} and 4.50 plant^{-1} in S-1 and S-2 respectively. The number of finger of turmeric crop was found little high in spacing S-3 compared to S-2 and S-1.
- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant for number of fingers. The number of fingers in turmeric crop was recorded highest for CS-1 x V2 (5.08 plant^{-1}) followed by 4.67 plant^{-1} for CS-1 x V1 while lowest number of finger was 4.25 plant^{-1} for CS-2 x V1 interaction.
- e. Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacing was also found statistically non-significant for numbers of ginger in turmeric crop. The number of fingers in turmeric crop was recorded highest for CS-1 x S3 (5.00 plant^{-1}) followed by 4.88 plant^{-1} for CS-1 x S1 with lowest number of fingers for CS-2 x S3 interaction (4.25 plant^{-1}).
- f. Effect of interaction of variety x crop spacing:** The interaction of variety and spacing was also found statistically non-significant for numbers of ginger in turmeric crop. The number of fingers in turmeric crop was recorded highest for V-2 x S3 4.88 plant^{-1} followed by 4.75 plant^{-1} for V-2 x S2 with lowest of 4.25 plant^{-1} for V-1 x S1 interaction.
- g. Effect of interaction of cropping system x variety x crop spacing:** The interaction of variety and spacing showed statistically non-significant results for numbers of finger in turmeric crop. The number of fingers in turmeric crop was recorded highest for CS-1 x V-2 x S-3 (5.25 plant^{-1}) followed by 5.00 plant^{-1} for CS-1 x V-2 x S-1 & S-2 # with lowest number of fingers for CS-2 x V-1 x S-2 interaction (4.00 plant^{-1}). Overall number of fingers was recorded higher in open cropping system (CS-1) as compared to (CS-2).

Length of finger per plant

The length of fingers from mother rhizome was measured by graduate scale in cm and results are presented in (Table) of statistical analysis

- a. **Effect of cropping system:** Effect of cropping system on length of finger showed statistically significant ($P < 0.05$). The maximum length of finger in rhizome of turmeric crop was observed 4.90 cm in open field (CS-1) and 4.35 cm AFS (CS-2).
- b. **Effect of variety:** Effect of variety on length of finger in rhizome showed statistically non-significant ($P < 0.05$). The maximum length of finger in rhizome of turmeric crop was observed 4.63 cm in both Roma (V-2) and Ranga (V-1).
- c. **Effect of crop spacing:** Effect of crop spacing of turmeric crop for length of finger was found statistically non-significant ($P < 0.05$). The maximum length of finger in rhizome of turmeric crop was observed 4.67 cm in S-2 followed by 4.62cm and 4.60cm in S-1 and S-3 respectively with very narrows variations.
- d. **Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was also found statistically non-significant for length of fingers. The length of fingers in turmeric crop was recorded highest for CS-1 x V1 & V2 (4.90cm) followed by 4.36cm for CS-2 x V2 and it was marginally lowest for CS-2 x V1 (4.35cm) crop growth in open field (CS-1) showed better results as compared to CS-2.
- e. **Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacing was also found statistically non-significant length of fingers. The length of finger of turmeric crop was recorded highest for CS-1 x S2 (5.02cm) followed by (4.78cm) for CS-1 x S1 with lowest length of finger (4.30cm) for CS-2 x S3 interaction. Overall crop growth in CS-1 showed better elongation in fingers as compared to growth in CS-2.
- f. **Effect of interaction of variety x crop spacing:** The interaction of variety and spacing was also found statistically non-significant for length of fingers (Table). The length of finger in turmeric crop was recorded highest for V-1 x S1 (4.73cm) followed by 4.70cm and 4.69cm for V-2 x S3 & S2 with lowest length 4.50cm for V-2 x S2 interaction.

g. Effect of interaction of cropping system x variety x crop spacing: The interactions of cropping system, variety and spacing were also found statistically non-significant for length of finger (Table). The length of finger in turmeric crop was recorded highest for CS-1 x V-1 x S-2 (5.21cm) followed by for CS-1 x V-1 x S-1(5.00cm) CS-1 x V-2 x S-3 and CS-2 x V-1 x S-1 (4.85cm) and the lowest length of finger was recorded 4.08cm for CS-2 x V-1 x S-2 interaction. Overall it was found good length in crop of open field (CS-1) as compared to (CS-2).

Length of root per plant

Root length of each plant measured in centimeter by scale and data are presented in table after statistical analysis root are major component of a plant and it elongation in the soil assured the mobilization water and nutrients to the plants.

- a. Effect of cropping system:** Effect of cropping system on length of root showed statistically significant ($P < 0.05$) for cropping system, where the maximum length of root in turmeric crop was observed 14.93 cm in AFS (CS-2) and 11.60 cm open field (CS-1).
- b. Effect of variety:** Effect of variety on length of root showed statistically non-significant ($P < 0.05$) results. The maximum length of root in turmeric crop was observed 14.05 cm in Roma (V-2) and 12.48 cm Ranga (V-1).
- c. Effect of crop spacings:** Effect of crop spacings on length of root of turmeric crop was found statistically non-significant ($P < 0.05$). The maximum length of root of turmeric crop was observed 14.31 cm in S-1 followed by 12.96cm and 12.53cm in S-2 and S-3 respectively.
- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant, for growth and length of root in turmeric crop and it was recorded highest for CS-2 x V2 (16.30cm) followed by 13.55cm for CS-2 x V1 and 11.79cm for CS -1 x V-2 with lowest 11.42cm for CS-1 x V1 interaction. Overall crop in open field (CS-1) showed higher value compare to (CS-2) among two varieties.

- e. Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacings was also found statistically non-significant. The length of root in turmeric crop was recorded highest for CS-1 x S3 (17.24cm) followed by 14.11cm and 13.43cm for CS-2 x S2 and CS-2 x S3 respectively afterword it draped between 11.81 to 11.38cm in open field crop (CS-1) with lowest of (11.38cm) for CS-1 x S1 interaction.
- f. Effect of interaction of variety x crop spacing:** The interaction of variety and spacings was also found statistically non-significant. The length of root in turmeric crop was recorded highest for V-2 x S1 (16.24cm) followed by 13.14cm and 12.79cm for V-2 x S2 , V-1 x S2 respectively and it was recorded lowest of 12.38cm for V-1 x S1 interaction.
- g. Effect of interaction of cropping system x variety x crop spacing:** The interaction of variety and spacing was also found statistically non-significant. The length of root in turmeric crop was recorded highest for CS-2 x V-2 x S-3 (20.85cm) followed by 14.20cm and 14.00cm for CS-2 x V-1 x S-2 & S-3 respectively. The lowest length of root was recorded 11.13cm for CS-1 x V-1 x S-1 interaction. Overall growth in root of turmeric crop was recorded poor in open field crop (CS-1) as compared to CS-2.

Fresh weight of rhizome (g plant⁻¹)

Rhizomes were carefully cleaned in water tank to remove soil particles and followed by air dry to evaporate water. The roots and stem parts were removed by using setter then washed for fresh weight. The data of fresh weight rhizome per plant was evolved statistically and presented in table

- a. Effect of cropping system:** Effect of cropping system on fresh weight of rhizome showed statistically non-significant ($P < 0.05$). The maximum per plant fresh weight of rhizome in turmeric crop was observed 69.30 gm/plant in open field (CS-1) and 60.72 gm/plant AFS (CS-2).
- b. Effect of variety:** Effect of variety on fresh weight of rhizome showed statistically non-significant ($P < 0.05$), where the maximum per plant fresh weight of rhizome in turmeric crop was observed 67.61 gm/plant in Roma (V-2) and 62.41 gm/plant Ranga (V-1).

- c. *Effect of crop spacing:*** Effect of crop spacing cm per plant fresh weight in rhizome was found statistically non-significant ($P < 0.05$). The maximum per plant fresh weight of rhizome in turmeric crop was observed 69.46 gm/plant in S-2 followed by 63.91 gm/plant and 61.67 gm/plant in S-3 and S-1 respectively
- d. *Effect of interaction of cropping system x variety:*** The interaction of cropping system and variety was found statistically non-significant. The per plant fresh weight of rhizome in turmeric crop was recorded highest for CS-1 x V2 (71.75 gm/plant) followed by (66.85 gm/plant) for CS-1 x V1 with lowest fresh weight of rhizome (57.96 gm/plant) for CS-2 x V1 interaction. Overall CS-1 and V-2 gave in either combination .
- e. *Effect of interaction of cropping system x crop spacing:*** The interaction of cropping system and spacing was also found statistically non-significant. The per plant fresh weight of rhizome in turmeric crop was recorded highest for CS-1 x S2 (71.26 gm/plant) followed by 68.98 gm/plant for CS-1 x S3 with lowest of 55.68 gm/plant for CS-2 x S1. Overall CS-1 gave higher yield of rhizome as compared to CS-2 for each spacing.
- f. *Effect of interaction of variety x crop spacing:*** The interaction of variety and spacing was also found statistically non-significant. The per plant fresh weight yield of rhizome in turmeric crop was recorded highest for V-2 x S2 (70.59 gm/plant) followed by 69.76 and 68.32 gm/plant for V-2 x S3 and V-1 x S-2 respectively. The lowest fresh weight of rhizome was recorded 58.06 gm/plant for V-1 x S3 interaction. Overall 50 x 30 cm spacing (S-2) gave better results for both the varieties.
- g. *Effect of interaction of cropping system x variety x crop spacing:*** The interaction of variety and spacing was showed statistically non-significant results for per plant fresh weight yield of rhizome. The per plant fresh weight of rhizome in turmeric crop was recorded highest for CS-1 x V-2 x S-3 (75.10 gm/plant) followed by 71.83 gm/plant and 70.70gm/plant for CS-1 x V-2 x S-2 and CS-1 x V-1 x S-2 respectively. In lowest range (56.67 to 53.26 gm/plant) fresh weight of rhizome was recorded in CS-2 x V-2 x S-1, CS-2 x V-1 x S-1,

and CS-2 x V-1 x S-3 interaction and respectively. Overall CS-1 with either combination gave higher value compare to CS-2 interaction.

Oven dry weight of rhizome (g plant⁻¹)

After weighing of fresh weight of rhizome (g plant⁻¹) samples were first dry in sun and kept in hot oven at 80 °C till get total dry moisture less material. The data of total dry weight of rhizome were evolved statistically to test significant level. (Table)

- a. Effect of cropping system:** Effect of cropping system on oven dry weight gm/plant of rhizome showed statistically significant ($P < 0.05$), the maximum oven dry weight of rhizome was observed 18.84 gm/plant in open field (CS-1) and 15.15 gm/plant AFS (CS-2).
- b. Effect of variety:** Effect of variety on oven dry weight gm/plant of rhizome showed statistically non-significant ($P < 0.05$) where the maximum oven dry weight of rhizome was observed 17.12 gm/plant in Roma (V-2) and 16.87 gm/plant Ranga (V-1), and showed very narrow variations .
- c. Effect of crop spacing:** Effect of crop spacing of turmeric crop for oven dry weight gm/plant rhizome was found statistically non-significant ($P < 0.05$) where the maximum oven dry weight of rhizome in turmeric crop was observed 17.31 gm/plant in S-2 followed by 17.03 gm/plant and 16.65 gm/plant in S-1 and S-3 respectively.
- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety was found statistically non-significant for oven dry weight of rhizome in turmeric crop and it was recorded highest for CS-1 x V2 (19.31 gm/plant) followed by 18.37 gm/plant for CS-1 x V1 with lowest of 14.93 gm/plant for CS-2 x V2 interaction. Overall CS-1 higher value as compared to CS-2 for both the varieties gave.
- e. Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacing was also found statistically non-significant for oven dry weight of rhizome in turmeric crop and it was recorded highest for CS-1 x S2 (19.83 gm/plant) followed by 19.10 gm/plant and 17.58 gm/plant for CS-1 x S1 and CS-1 x S-3 respectively where the lowest oven dry weight of

rhizome was recorded 14.78 gm/plant for CS-2 x S2 which was 1.04 and 0.1 gm/plant from CS-2 x S-3 and CS-2 x S-1 respectively. The less interaction of spacing with CS-1 gave higher value compared to CS-2.

- f. ***Effect of interaction of variety x crop spacing:*** The interaction of variety and spacing was also found statistically non-significant for oven dry weight gm/plant of rhizome in turmeric crop and it was recorded highest for V-1 x S2 (19.42 gm/plant) followed by 19.11 gm/plant for V-2 x S3 and V-2 x S-2, V1 x S-1(17. gm/plant) afterword it dropped to 15.2 gm/plant and 14.19 gm/plant at least position.
- g. ***Effect of interaction of cropping system x variety x crop spacing:*** The interactions of cropping system, variety and spacings were also found statistically non-significant. The per plant oven dry weight of rhizome of was recorded above the 19.27 gm/plant in CS-1 x V-1 x S-1|S-2,CS-1 x V-2 x S-1|S-2|S-3,CS-2 x V-1 x S-2 and CS-2 x V-2 x S-3 with maximum 19.93gm/plant (CS-1 x V-2 x S-2) and minimum 18.93 gm/plant (CS-1 x V-2 x S-1). Afterword et dropped to 16.10 gm/plant(CS-1 x V-1 x S-3) with lowest of 10.47 gm/plant(CS-2 x V-2 x S-2).

Table –4.5 A: Yield parameters of rhizome in Turmeric crop under Bamboo based AFS

Treatments	Mother rhizome		Finger growth in Root gm/plant			Fresh Wt	Oven Dry gm/plant
	Length (cm)	Width (cm)	No. (plant ⁻¹)	Length (cm)	Length (cm)		
Effect of Cropping system							
Open (Cs-1)	4.10	9.58	4.88	4.90	11.60	69.30	18.84
AFS (Cs-2)	4.63	3.96	4.33	4.35	14.93	60.72	15.15
SEm ±	0.29	0.26	0.20	0.20	1.20	4.40	1.21
SEd±	0.41	0.37	0.29	0.28	1.70	6.22	1.71
CD	NS	0.75	0.57	0.56	3.41	NS	3.42
Effect of Variety							
Ranga (V-1)	4.52	7.13	4.46	4.63	12.48	62.41	16.87
Roma (V-2)	4.20	6.42	4.75	4.63	14.05	67.61	17.12
SEm ±	0.29	0.26	0.20	0.20	1.20	4.40	1.21
SEd±	0.41	0.37	0.29	0.28	1.70	6.22	1.71
CD	NS	0.75	NS	NS	NS	NS	NS
Effect of Spacing							
50x50(S-1)	4.66	6.63	4.63	4.62	14.31	61.67	17.03
50x30(S-2)	4.29	7.31	4.50	4.67	12.96	69.46	17.31
40x30(S-3)	4.14	6.38	4.69	4.60	12.53	63.91	16.65
SEm ±	0.36	0.32	0.25	0.24	1.48	5.39	1.48
SEd±	0.50	0.46	0.35	0.34	2.09	7.62	2.09
CD	NS	NS	NS	NS	NS	NS	NS

Table –4.5 B: Yield parameters of rhizome in Turmeric crop under Bamboo based AFS

Treatments	Interaction of Cropping system x Variety						Fresh Wt	Oven Dry
	Mother rhizome		Finger growth in Root gm/plant					
	Length (cm)	Width (cm)	No. (plant ⁻¹)	Length (cm)	Length of root (cm)			
Cs-1 x V1	4.54	10.33	4.67	4.90	11.42	66.85	18.37	
Cs-1 x V2	3.66	8.83	5.08	4.90	11.79	71.75	19.31	
Cs-2 x V1	4.50	3.92	4.25	4.35	13.55	57.96	15.37	
Cs-2 x V2	4.75	4.00	4.42	4.36	16.30	63.48	14.93	
SEm ±	0.41	0.37	0.29	0.28	1.70	6.22	1.71	
SEd±	0.58	0.53	0.41	0.40	2.41	8.79	2.42	
CD	NS	1.05	NS	NS	NS	NS	NS	
Interaction of Cropping system x Spacing								
Cs-1 x S1	4.33	9.38	4.88	4.78	11.38	67.66	19.10	
Cs-1 x S2	3.83	10.38	4.75	5.02	11.81	71.26	19.83	
Cs-1 x S3	4.15	9.00	5.00	4.90	11.63	68.98	17.58	
Cs-2 x S1	5.00	3.88	4.38	4.45	17.24	55.68	14.96	
Cs-2 x S2	4.75	4.25	4.25	4.31	14.11	67.65	14.78	
Cs-2 x S3	4.13	3.75	4.38	4.30	13.43	58.84	15.72	
SEm ±	0.50	0.46	0.35	0.34	2.09	7.62	2.09	
SEd±	0.71	0.65	0.50	0.49	2.95	10.77	2.96	
CD	NS	NS	NS	NS	NS	NS	NS	

Table –4.5 C: Yield parameters of rhizome in Turmeric crop under Bamboo based AFS

Interaction of Variety x Spacing							
	Mother rhizome			Finger growth in		Root gm/plant	
	Length (cm)	Width (cm)	No. (plant⁻¹)	Length (cm)	Length of root (cm)	Fresh Wt	Oven Dry
V-1 x S-1	5.45	6.63	4.63	4.73	12.38	60.85	17.00
V-1 x S-2	4.54	8.25	4.25	4.64	12.79	68.32	19.42
V-1 x S-3	3.58	6.50	4.50	4.51	12.29	58.06	14.19
V-2 x S-1	3.88	6.63	4.63	4.50	16.24	62.50	17.06
V-2 x S-2	4.04	6.38	4.75	4.69	13.14	70.59	15.20
V-2x S-3	4.70	6.25	4.88	4.70	12.76	69.76	19.11
SEm ±	0.50	0.46	0.35	0.34	2.09	7.62	2.09
SEd±	0.71	0.65	0.50	0.49	2.95	10.77	2.96
CD	NS	NS	NS	NS	NS	NS	NS
Interaction of Cropping system x Variety x Spacing							
Cs-1 x V-1 x S-1	5.65	10.00	4.75	4.61	11.13	67.00	19.27
Cs-1 x V-1 x S-2	4.33	12.00	4.50	5.21	11.38	70.70	19.73
Cs-1 x V-1 x S-3	3.65	9.00	4.75	4.89	11.75	62.86	16.10
Cs-1 x V-2 x S-1	3.00	8.75	5.00	4.96	11.63	68.33	18.93
Cs-1 x V-2 x S-2	3.33	8.75	5.00	4.84	12.25	71.83	19.93
Cs-1 x V-2 x S-3	4.65	9.00	5.25	4.92	11.50	75.10	19.07
Cs-2 x V-1 x S-1	5.25	3.25	4.50	4.85	13.63	54.69	14.73
Cs-2 x V-1 x S-2	4.75	4.50	4.00	4.08	14.20	65.94	19.10
Cs-2 x V-1 x S-3	3.50	4.00	4.25	4.13	12.83	53.26	12.28
Cs-2 x V-2 x S-1	4.75	4.50	4.25	4.05	20.85	56.67	15.18
Cs-2 x V-2 x S-2	4.75	4.00	4.50	4.55	14.03	69.36	10.47
Cs-2 x V-2 x S-3	4.75	3.50	4.50	4.48	14.03	64.41	19.15
SEm ±	0.71	0.65	0.50	0.49	2.95	10.77	2.96
SEd±	1.01	0.91	0.70	0.69	4.17	15.23	4.19
CD	NS	NS	NS	NS	NS	NS	NS

Rhizome yield - Fresh and dry weight ($q\ ha^{-1}$)

The per unit area fresh and dry weight of turmeric was estimated after harvesting of turmeric crop from each plots of various treatments and results are presented after statistical analysis in table-8 for the role of cropping system, variety, crop spacing and their interactions.

1. Fresh weight of rhizome: Harvested rhizomes were cleaned from shoot and root residues and soil particles then weighed for yield of fresh rhizome and data are presented in table2.

a. Effect of cropping system: The fresh yield of rhizome showed (statistically significant) variation ($P < 0.05$), where the yield of fresh weight of rhizome was recorded $225.79\ qha^{-1}$ open condition (CS-1) and $161.46\ qha^{-1}$ under AFS respectively.

b. Effect of variety: Effect of variety on fresh yield showed (statistically non-significant) variation ($P < 0.05$) for variety. The yield of fresh weight of rhizome was recorded $206.71\ qha^{-1}$ in variety Ranga (V-1) and $180.55\ qha^{-1}$ in variety Roma (V-2) respectively.

c. Effect of crop spacing: The role of crop spacing on yield of fresh weight of rhizome of turmeric crop showed statistically non significant results ($P < 0.05$). The rhizome yield was recorded highest $209.44\ qha^{-1}$ in S-1 (50 x 50) spacing followed by $194.16\ qha^{-1}$ in S-3 (40 x 30) and lowest $177.29\ qha^{-1}$ S-2(50 x 30) spacing respectively.

d. Effect of interaction of cropping system x variety: The interaction of cropping system and variety on fresh weight yield also showed statistically significant results where highest yield of rhizome was observed $245.67\ qha^{-1}$ in CS-1 x V1 followed by $205.92\ qha^{-1}$ for CS-2 x V2, and $167.75\ qha^{-1}$ for CS-2 x V1 respectively, while minimum yield was recorded in $155.18\ qha^{-1}$ in CS-2 x V2 interaction.

e. Effect of interaction of cropping system x crop spacing: The interaction of cropping system and spacing on fresh weight yield also showed statistically significant variations where highest yield of rhizome was observed $246.31\ qha^{-1}$ in (CS-1 x S1) followed by $215.67\ qha^{-1}$ CS-1 x S3, $215.40\ qha^{-1}$ CS-1 x

S2, 172.65 qha⁻¹ (CS-2 x S3), and 172.57 qha⁻¹ (CS-2 x S1) respectively, while minimum yield was recorded in 139.18 qha⁻¹ for CS-2 x S2.

f. Effect of interaction of variety x crop spacing: The interaction of variety and spacing fresh on weight yield showed statistically significant relations, where highest yield of rhizome was observed 221.00 qha⁻¹ in S-1 x V1 followed by 206.73 qha⁻¹ (S-3 x V1), 197.88 qha⁻¹ (S-1 x V2), 192.40 qha⁻¹ (S-2 x V1), and 181.60 qha⁻¹ (S-3 x V2) respectively, while minimum yield was recorded in 162.17 qha⁻¹ for S-2 x V2.

g. Effect of interaction of cropping system x variety x crop spacing: The interaction of cropping system, variety and spacing on fresh weight yield showed statistically significant relations where highest yield of rhizome was observed 252.08 qha⁻¹ in CS-1 x V1 x S1 followed by 243.00 qha⁻¹ (CS-1 x V1 x S3), 241.02 qha⁻¹ (S-1 x V1 x S2), 239.09 qha⁻¹ (CS-1 x V2 x S1), afterward it dropped to 189.58 to 188.30 qha⁻¹ in CS-1 x V2 x S2, (CS-2 x V1 x S1), CS-1 x V2 x S3 interactions with insignificant variations. The lowest yield was ranged 155.89 to 134.77 qha⁻¹ in CS-2 x V2 x S1, and CS-2 x V1 x S2 and (S-2 x V2 x S2) Respectively.

2. Oven dry weight of rhizome: The oven dry weight of rhizome was estimated by sub-samples of each treatment where they were kept at 75° C in hot air oven till dry up of rhizome and thus oven dry yield of ginger was estimated.

a. Effect of cropping system: The oven dry yield of rhizome showed statistically significant variation (P<0.05), where the yield of oven dry weight of rhizome was recorded 61.04 qha⁻¹ for open crop (CS-1) and 42.53 qha⁻¹ under AFS respectively.

b. Effect of variety: Effect of variety on oven dry yield showed statistically non-significant variation (P<0.05) for variety. The yield of oven dry weight of rhizome was recorded 55.70 qha⁻¹ for variety Ranga (V-1) and 47.87 qha⁻¹ for variety Roma (V-2) respectively.

c. Effect of crop spacing: The role of crop spacing on yield of oven dry of rhizome of turmeric crop showed statistically non-significant variation (P<0.05). The oven dry yield was recorded highest 58.39 qha⁻¹ in S-1 (50cm x

50cm) spacing followed by 49.93 qha⁻¹ and 47.03 qha⁻¹ for S-3 (40cm x 30cm) and S-2(50cm x 30cm) spacing respectively.

- d. Effect of interaction of cropping system x variety:** The interaction of cropping system and variety on oven dry yield showed statistically significant results, where highest yield of rhizome was observed 66.69 qha⁻¹ in CS-1 x V1 followed by 55.40 and 44.71 qha⁻¹ CS-1 x V2, and CS-2 x V1 respectively, while minimum yield was recorded in 40.34 qha⁻¹ for CS-2 x V2 interaction
- e. Effect of interaction of cropping system x crop spacing:** The interaction of cropping system and spacing on oven dry yield also showed statistically significant variation, where highest yield of rhizome was observed 69.38 qha⁻¹ in CS-1 x S1 followed by 59.99 qha⁻¹ (CS-1 x S2), 53.76 qha⁻¹ (CS-1 x S3), 47.40 qha⁻¹ (CS-2 x S1), and 46.10 qha⁻¹ (CS-2 x S3) respectively, while minimum yield was recorded in 34.07 qha⁻¹ for CS-2 x S2.
- f. Effect of interaction of variety x crop spacing:** The interaction of variety and spacing on oven dry yield showed statistically significant relations, where yield of rhizome was observed 61.80 qha⁻¹ in S-1 x V1 followed by 54.99 qha⁻¹ (S-1 x V2), 54.59 qha⁻¹ (S-2 x V1), 50.71 qha⁻¹ (S-3 x V1), and 49.15 qha⁻¹ (S-3 x V2) respectively, while minimum yield was recorded in 39.47 qha⁻¹ for S-2 x V2.
- g. Effect of interaction of cropping system x variety x crop spacing:** The interaction of cropping system, variety and spacing on oven dry yield also showed statistically significant relations, where highest yield was observed 71.09 qha⁻¹ in CS-1 x V1 x S1 followed by 67.03 qha⁻¹ (CS-1 x V1 x S2), 66.09 qha⁻¹ (CS-1 x V2 x S1), 60.08 qha⁻¹ (CS-1 x V1 x S3), afterword it dropped to S-1 to S-2 qha⁻¹ CS-1 x V2 x S2, CS-2 x V1 x S1, CS-2 x V2 x S3, and then between 40 to 46.07 qha⁻¹ in A (CS-1 x V2 x S3)B (CS-2 x V2 x S1), C (CS-2 x V1 x S2), D (CS-2 x V1 x S3) respectively, while minimum yield was recorded in 26.03 qha⁻¹ in S-2 x V2 x S2.

Table 4.6 A: yield (qha⁻¹) of Turmeric crop under bamboo based AFS

Attributes	Fresh (qha ⁻¹)	Oven dry (qha ⁻¹)
Effect of Cropping System		
Cs-1 (Open)	225.79	61.04
Cs2(AFS)	161.46	42.53
SEm ±	11.48	3.76
SEd ±	16.24	5.31
CD (5%)	32.47	10.63
Effect of Variety		
V1 (Ranga)	206.71	55.70
V2 (Roma)	180.55	47.87
SEm ±	11.48	3.76
SEd ±	16.24	5.31
CD (5%)	NS	NS
Effect of Spacing		
S1 (50 x 50cm)	209.44	58.39
S2 (50 x 30cm)	177.29	47.03
S3 (40 x 300cm)	194.16	49.93
SEm ±	14.06	4.60
SEd ±	19.89	6.51
CD (5%)	NS	NS

Table –4.6 B: yield of Turmeric crop under bamboo based AFS

Attributes	Fresh(qha ⁻¹)	Oven dry(qha ⁻¹)
Effect of Cropping system x Variety		
CS-1 x V1	245.67	66.69
CS-1 x V2	205.92	55.40
CS-2 x V1	167.75	44.71
CS-2 x V2	155.18	40.34
SEm ±	16.24	5.31
SEd ±	22.96	7.51
CD (5%)	NS	NS
Interaction of Cropping system x Spacing		
CS-1 x S1	246.31	69.38
CS-1 x S2	215.40	59.99
CS-1 x S3	215.67	53.76
CS-2x S1	172.57	47.40
CS-2 x S2	139.18	34.07
CS-2 x S3	172.65	46.10
SEm ±	19.89	6.51
SEd ±	28.12	9.20
CD (5%)	NS	NS
Interaction of Variety x Spacing		
S1 x V1	221.00	61.80
S2 xV1	192.40	54.59
S3 xV1	206.73	50.71
S1 x V2	197.88	54.99
S2 xV2	162.17	39.47
S3 xV2	181.60	49.15
SEm ±	19.89	6.51
SEd ±	28.12	9.20
CD (5%)	NS	NS
Interaction of Cropping system x Variety x Spacing		
Cs1 x V1 x S1	252.76	71.90
Cs1 x V1 x S2	241.22	67.31
Cs1 x V1 x S3	243.05	60.85
Cs1 x V2 x S1	239.87	66.87
Cs1 x V2 x S2	189.58	52.67
Cs1 x V2 x S3	188.30	46.67
Cs2 x V1 x S1	189.24	51.70
Cs2x V1 x S2	143.59	41.86
Cs2 x V1 x S3	170.41	40.58
Cs2 x V2 x S1	155.89	43.11
Cs2 x V2 x S2	134.77	26.28
Cs2 x V2 x S3	174.89	51.63
SEm ±	28.13	9.20
SEd ±	39.77	13.02
CD (5%)	NS	NS

4.3 Growth behavior of bamboo species

The growth behavior of bamboo plantation *vizi*; population of culm clump⁻¹, clump diameter, height of culm, and diameter of culm at 3rd internodes and yield of culm kg⁻¹ were observed during the course of study *i.e.* from July 2017 to March 2019 and data are presented in table 4.9

Population of clums

The population of clums of bamboo in clump was observed 44.92 clump⁻¹ in July 2017 where share of matured clums was (28.57%) followed by young clums (60.30%), and dead clums (11.13%) respectively, while after 8 month of growth *i.e.* in March 2018 the population of clums was observed 57.00 clump⁻¹ where the contribution of matured, young and dead clums in clump was 24.85, 50.88, and 9.94% respectively and during these 8 month the 8.17 new clums clump⁻¹ was regenerated with share of 14.33% (Table).

Clump diameter

Clump diameter was observed 4.04m in July 2017 which increased to 4.88m in 8 month of growth *i.e.* after the harvesting of turmeric crop in March 2018, and during this period the increment in diameter was observed by 20.79%.

Height of culm

The average height of matured culm was observed 7.77m and 8.98m in July 2017 and March 2018 respectively, and between this periods the average culm height was increased by 1.21m (15.57%).

Diameter of culm at 3rd internodes (cm)

The average diameter of culm at 3rd internodes was observed 3.64cm and 3.87cm in July 2017 and March 2018 respectively, and the increment of culm was found 0.23cm (6.31%).

Yield of culm

Matured clums were harvested in summer *i.e.* before showings of turmeric crop in 2017 and total fresh biomass of bamboo culm was observed 12.39±2.66 kg culm⁻¹ which was shared by maximum by culm (7.30kg) followed by branches (3.44kg) and leaves (1.66kg) respectively. the sub-samples of each component were dried in oven at 75° C for 24 hours and dry weight of biomass of bamboo was

estimated there biomass of culm was found 5.00 kg culm⁻¹ which was shared maximum by culm (3.94kg) followed by branches (0.97kg) and leaves (0.09kg) respectively.

Table – 4.7 Growth and yield of bamboo during 2017-18

Parameters	Jul-17	Mar-18
A. Population of culm (n clump⁻¹)	44.92 ±20.83	57.00±23.50
i. Matured	12.83 ±8.42 (28.57%)	14.17±8.73 (24.85%)
ii. Young	27.08±10.54 (60.30)	29.00±10.53 (50.88)
iii. Dead	5±2.76 (11.13%)	5.67±2.81 (9.94)
iv. New	-	8.17±2.79 (14.33%)
B. growth parameters		
i. Clump diameter (m)	4.04±0.89	4.88±0.96
ii. Height of culm (m)	7.77±1.31	8.98±1.44
iii. Diameter of culm at 3rd internodes (cm)	3.64±1.32	3.87±1.16
C. Yield (kg/culm)	fresh weight	Dry weight
i. Culm	7.30±0.79	3.94
ii. Branch	3.44±0.91	0.97
iii. Leaves	1.66±0.31	0.09
Total weight	12.39±2.66	5.00±2.02

4.5 Microclimatic Observations

Around the turmeric crop microclimatic characteristics *vizi*; photo-synthetically active radiation (PAR), temperature and relative humidity was measured by using LICOR Quantum photo-meter, Digital Thermometer and Digital Hygrometer respectively in three different times in Morning, Noon and Evening in both open field and Agroforestry system at every 15 days intervals during crop period *i.e.* Sept. 2017 to Dec. 2017. The data were compiled and presented in tables and figures.

A .Photo synthetically Active Radiation (μ mol/cm²/s)

The result of Photo synthetically Active Radiation (PAR) in AFS and open field showed that average PAR during crop period was ranged 43.7 to 58.85 and 183.1 to 481.1 in open field (CS-1) and AFS (CS-2) respectively. The crop of open field (CS-1) 497.28, 498.41, 496.22, and 598.47 μ mol cm⁻² s⁻¹ during , September, October, November , December respectively. While in case of AFS

(CS-2) the average PAR received in a day was 481.05, 352.31, 389.94, and 351.41 $\mu\text{mol cm}^{-2} \text{s}^{-1}$ during September October, November and December respectively. The maximum PAR recorded in open area as compare to AFS as bamboo canopy intercept the sunlight. In season September to October High PAR recorded as compare to November and December.

B. Temperature ($^{\circ}\text{C}$)

The air temperature ($^{\circ}\text{C}$) was recorded around turmeric crop in AFS and open field are presented in table and figure. The temperature was recorded by Digital Thermometer at 15 days was interval during the crop growing period in open field (CS-1) and AFS (CS-2). The crop of open field (CS-1) average temperature received in a day was 30.09°C , 30.58°C , 22.53°C and 30.08°C during September, October November, December respectively and in case of AFS (CS-2) 32.67°C , 31.83°C , 26.87°C and 30.86 during September, October, November and December to respectively. The average temperature was recorded in more or less same in open and AFS in crop growing period as wider row to row spacing (cm) provide space for management of air north south direction.

C. Relative Humidity (%)

The result of relative humidity available to turmeric crop in AFS and open field are presented in table and figure. The relative humidity was recorded by Digital hygrometer at 15 days was interval during crop growing period i.e. September to December. The average relative humidity available to the crop of open field (CS-1) was of 66.63%, 67.19% 46.07% and 45.74% during July to August, September, October, November and December respectively & however in case of AFS (CS-2) it was recorded 73.04%, 59.02% ,50.81% and 36.31% during September, October, November and December respectively. The average relative humidity was recorded in more or less same in open and AFS in crop growing period become of bamboo plantation was at north – south row with 8 m wider spacing between row to row.

Table 4.8 (A) – Availability of PAR ($\mu \text{ mol S}^{-1} \text{ m}^{-2}$) for turmeric crop during July 2017 to March 2018

Photo synthetically active radiation ($\mu \text{ mol S}^{-1} \text{ m}^{-2}$)								
Date	OPEN field (CS-1)				Bamboo based AFS (CS-2)			
	Morning	Noon	Evening	AV	Morning	Noon	Evening	AV
16 Sept 17	399.3	791.3	301.2	497.28	200.22	761.88	38.43	481.05
	± 172.23	± 139.47	± 90.59	± 259.34	± 93.00	± 507.46	± 14.29	± 250.03
01 Oct 18	304.8	1044.4	262.3	537.16	265.00	101.22	46.16	183.11
	± 42.78	± 500.58	± 60.01	± 439.79	± 137.36	± 34.98	± 21.96	± 77.91
16 Oct 17	301.07	899.11	295.06	498.41	257.89	446.72	43.80	352.31
	± 242.12	125.64	51.60	347.03	218.91	387.69	15.75	230.79
01 Nov 17	187.50	868.83	304.61	453.65	167.61	367.00	44.39	267.31
	± 44.74	± 204.22	± 62.57	± 364.30	± 183.39	± 470.89	± 15.11	± 280.23
16 Nov 17	313.11	750.89	424.67	496.22	178.39	601.50	721.72	389.94
	± 90.13	± 93.04	± 107.35	± 227.49	± 126.37	± 1005.88	± 1922.19	± 558.49
01 Dec 17	304.22	780.89	382.72	489.28	119.00	297.22	67.00	208.11
	± 51.05	± 83.01	± 57.03	± 255.57	± 20.29	± 195.40	± 12.62	± 99.30
16 Dec 17	315.29	849.72	600.39	588.47	155.54	547.28	423.89	351.41
	± 46.47	± 53.06	± 69.01	± 267.41	± 22.35	± 175.68	± 129.31	± 88.20

Table -: 4.9 Temperature ($^{\circ}\text{C}$) available to turmeric crop of open field and Agroforestry system during July 2017 to March 2018

Temperature ($^{\circ}\text{C}$)								
Date	OPEN field (CS-1)				AFS (CS-2)			
	Morning	Noon	evening	AV	Morning	Noon	Evening	AV
16 Sept 17	28.6	31.5	30.2	30.09	32.17	35.37	30.47	32.67
SD	± 0.23	± 0.05	± 0.05	± 1.41	± 1.72	± 0.15	± 0.08	± 0.55
01 Oct 18	29.5	31.5	30.1	30.35	30.02	31.16	29.20	30.13
SD	± 0.05	± 0.05	± 0.05	± 1.02	± 0.24	± 0.33	± 0.26	± 0.12
16 Oct 17	28.16	32.45	31.13	30.58	28.97	35.72	30.79	31.83
SD	± 0.05	± 0.05	± 0.05	± 2.20	± 0.31	± 0.33	± 0.29	± 0.11
01 Nov 17	20.55	28.26	24.15	24.32	39.87	31.31	28.79	33.32
SD	± 0.05	± 0.05	± 0.05	± 3.86	± 55.94	± 0.24	± 0.02	± 18.61
16 Nov 17	20.55	24.85	22.19	22.53	26.36	28.26	26.00	26.87
SD	± 0.05	± 0.05	± 0.10	± 2.17	± 0.80	± 1.21	± 0.43	± 0.47
01 Dec 17	19.50	25.48	22.46	22.48	24.76	26.34	24.23	25.11
SD	± 0.10	± 0.09	± 0.05	± 2.99	± 0.69	± 0.05	± 0.63	± 0.38
16 Dec 17	26.54	33.54	30.16	30.08	25.96	34.51	31.69	30.86
SD	± 0.05	± 0.05	± 0.05	± 3.50	± 0.53	± 2.35	± 0.66	± 1.06

Table 4.10 -: Relative humidity (%) available to Turmeric crop of open field and Agroforestry system during July 2017 to March 2018

Relative humidity (%)								
Date	OPEN field (CS-1)				AFS (CS-2)			
	Morning	Noon	evening	AV	Morning	Noon	evening	AV
16 Sept 17	70.2	66.1	63.6	66.63	79.61	60.33	79.17	73.04
SD	±3.46	±3.08	±21.42	±3.34	±5.09	±0.84	±1.04	±1.66
01 Oct 18	77.0	71.1	71.2	73.07	78.83	72.11	80.28	77.07
SD	±0.84	±2.24	±3.07	±3.40	±0.79	±1.78	±3.58	±1.22
16 Oct 17	74.78	55.39	71.39	67.19	85.50	51.44	40.11	59.02
SD	±2.71	±4.22	±1.54	±10.36	±1.47	±1.95	±5.32	±2.04
01 Nov 17	59.72	48.33	45.89	51.31	60.39	42.00	45.50	49.30
SD	±1.53	±4.00	±0.76	±7.38	±0.61	±0.00	±0.51	±0.16
16 Nov 17	48.44	44.50	45.28	46.07	62.33	46.28	43.83	50.81
SD	±0.51	±0.79	±0.83	±2.09	±2.47	±1.67	±1.04	±0.50
01 Dec 17	44.67	43.67	44.44	44.26	47.67	45.06	44.72	45.81
SD	±0.91	±0.97	±0.78	±0.53	±0.77	±0.73	±0.75	±0.43
16 Dec 17	44.78	30.44	32.00	35.74	47.00	32.22	29.72	36.31
SD	±0.43	±0.70	±0.00	±7.86	±0.00	±4.35	±4.81	±2.94

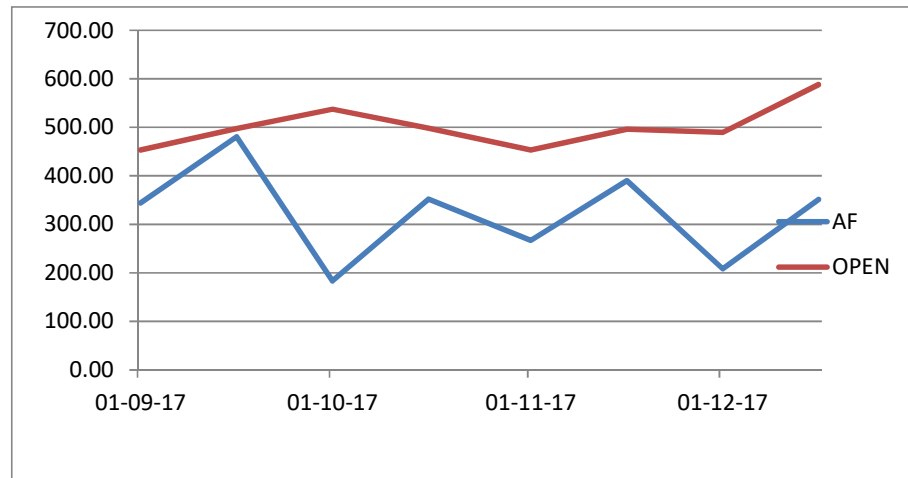


Figure- 4.1 (a) Micro-climatic feature PAR in AFS and open field

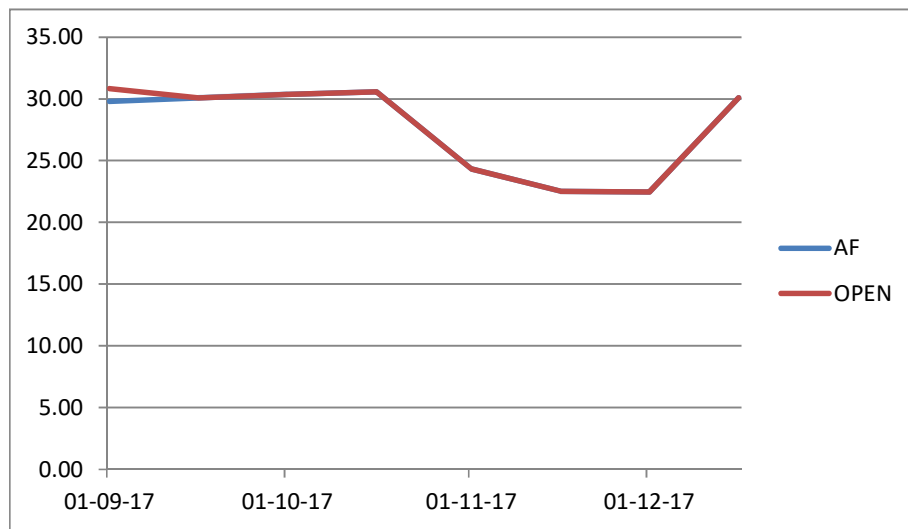


Figure-4.1 (b) Micro-climatic feature temperature in AFS and open field

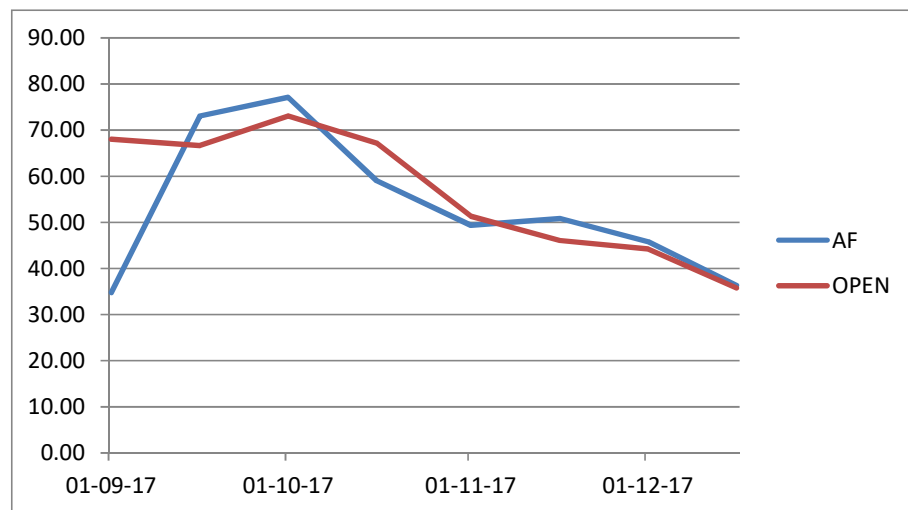


Figure-4.1 (c) Micro-climatic feature RH in AFS and open field

4.6 DISCUSSION

Bamboo are comparatively very fast growing giant woody grass species and its canopy proliferation create much shade which certainly influenced the growth performance of under storey vegetation but the management of bamboo plantation can create space around its to cultivate shade loving crops. Here in wider spacing plantation of *Dendrocalamus strictus*, turmeric crop was cultivated at various crop spacing and variety compare with open field crop.

The growth in height of turmeric plants was found fluctuating either with narrow variations or insignificant results for cropping system, varieties, crop spacings and their interactions and at 150 DAS it was highest in AFS as compare to open field crop (73.38cm), variety Roma (74.75cm) and 50 x 50cm wider spacing (76.75cm). This might be due to shade loving nature of species and higher nutrients availability in the soil at wider spacing. The growth in shade loving plant the performance was always found to be positively correlated to soil moisture content in a significant manner. Bhuiyan *et al.* (2012) reported the similar results for growth height of plant when were highest for turmeric and ginger, when grown under severe shade conditions. Chandra (2014) also observed maximum height of turmeric when intercropped under *Psidium guajava*. Kittur *et al.*, (2015) observed similar results higher plant height under 50 per cent shade of bamboo plantation; Das *et al.* (2011) cultivated turmeric under the 6year old *Emblia officinalis* orchard with better performance of the turmeric.

Overall number of tiller was found higher under AFS, where during peak growth period (90DAS) it was recorded maximum in varieties Roma (V₂) with higher tiller formation in S-3 spacing (3 tillers plant⁻¹). The formation of tillers was found consistently higher in AFS, variety Roma and spacing 40 x 30cm with significant variation, and there interactions also gave significant results.

The count of number of tillers was highest in crop under AFS (CS-2) as compare to crop of open (CS-1), this might be due to available at optimum level of sun light, moisture, and temperature. The quantity of tillers was found to be positively correlated to soil moisture and nutrient in a significant manner, under 11 year old guava Chandra (2014) Vikram and Hegde (2014) reported the performance of turmeric under cashew plantation where intercropping produced

significant number of tillers per clump (6.86) than sole crop in open field, similarly the number of tiller also were higher significantly ($p < 0.05$) under bamboo than control plot Kittur *et al.* (2015).

Shape, size and number of leaves in a plant regulate the over all performance and yield as the major source of food synthetisation, thus it an important component of any crop. Here in case of turmeric the number of leaves was more in AFS as compare to open field, because of the shade loving plant, presence of rich nutrients in soil, available at sunlight and temperature

Role of nutrients was reported by better growth of leaves under 25-30 % shade Bhuiyan *et al.* (2012), Patil *et al.* (2004) analyzed the organic carbon and organic matter of these soils which was under trees as compared open field increased from Das *et al.* (2011) observed that aonla-based agri-horticultural systems improvement in the soil properties organic carbon, available nitrogen and phosphorus, played important role for growth and yield of crops. Similarly, Kittur *et al.* (2015), found good performance of turmeric under bamboo with higher organic carbon N, P and K .

In present case the growth in rhizome of tuber crop depends on performance of above ground parts of plant and resource availability, where bamboo grown at wider spacing of 8 m on bunds stretched South- North directions, with very narrow variations in micro-climatic conditions from open field crop.

The formation and elongation new rhizome along with sub-fingers showed more or less similar trend in both cropping system with very narrow differences as resulted for width of rhizomes and its numbers while length rhizomes and its fingers and sub-fingers showed significant variation which good to variation in yield of turmeric.

In case of varieties of Ranga (V1) and Roma, the similar results were observed in both cropping system. The impact of crop spacing also revealed the insignificant out put in growth behaviour of rhizomes for numbers, length, and width for prime and sub-fingers for both varieties. In case of crop spacing S-3 (40 x 30 cm) gave better results than narrow (S-1) and wider (S-2) spacing for all the parameters. Similar results were observed Kittur *et al.*, (2015) of Bhuiyan *et al.* (2012) and Das *et al.* (2011) for spacing of the turmeric crop.

Turmeric prefers warm and humid climate and it grows well in medium light intensity; with optimum day length Das *et al.* (2011) and its yield was increased by 7.5 to 12.0 % under AFS. (Kumar *et al.*, 2003), Chandra (2014) get turmeric yield 150.48 q ha⁻¹. Mishra *et al.* (2000) reported that conservation of moisture level under tree crop increased the yield of turmeric by 12 per cent.

Interaction of cropping system and crop spacing showed variable results for rhizomes formation with its shape and size but over all the results were found insignificant statistically, because of 8 m wider plantation strip and it further had 6 m spacing of Bamboo clump and yearly harvested mature culms provides more or less similar PAR, Temperature and Relative humidity. In case of interaction of cropping system and variety (CS x V) showed variable results where the performance of Ranga variety was found better than Roma.

The yield of turmeric fresh weight was highest in open field (CS-1) significantly while the role of variety of turmeric (Ranga & Roma) and crop spacing did not show the insignificant results for yield of turmeric crop i.e. rhizomes, and these two major factors ultimately resulted the overall insignificant at some of various interactions of cropping system x variety, cropping system x spacing, variety x spacing and cropping system x variety x spacings. Performance of yield of turmeric crop under tree depends upon availability of proper moisture, maximum soil nutrients and light resource sharing between crops and trees. Similar oven dry weight yield of turmeric. Similar results was reported in Aiyadurai (1986) studied yield of turmeric crops was higher under partial shade under rainfed conditions and for better results, similar observations was made by Bisht *et al.* (2000) turmeric crops under *Quercus leucotrichophora*. In case of varieties Ranga (V1) and Roma (V2) of turmeric, the higher yield recorded highest in Ranga (V1) under bamboo based Agroforestry system where bamboo spacing 8 x 6m.

Overall the Ranga variety of turmeric found better for cultivation under Agroforestry system as it gave better yield under bamboo based Agroforestry system, similarly crop spacing S-1 (252.89qha⁻¹) followed by S-2 (241.39 qha⁻¹). The yield of turmeric variety Ranga was found better in open it their spacing but it

was good enough at spacing 50 x 50cm (S-1) under bamboo based AFS (189.2qha¹)

Bamboo belong to family of Poaceae, and it required extensive management in man made ecosystem as plantations (Chandrashekara, 1996) in agro-forestry and hedgerows on farm boundaries etc., (Divakara *et al.*, 2001; Kummar, 1997). The dense crown of clump increases the competition for more sunlight and for resource utilization, thus the harvesting of mature culms from clumps open the space at ground and canopy level. The growth performance of bamboo stands were observed for clump diameter (cm), population, culm height (m) and diameter of 3rd internodes of culms for morphology features while the yield of fresh and oven dry weight of culms, branches and leaves were observed by harvesting of mature culms. Performance of *Dendrocalamus strictus* under Agroforestry system was studied by Dindekar (2012) while wheat crop, Harne (2013) with rice crop, jeven (2019) with ginger and reported more or less similar results and they found the g/ha clums which was approximately 5.03 kg/ clums. The cultivation of bamboo on farmlands generated regular yearly income after 3-4 years of plantation (Naugraiya and Puri 1997), Balaji (1991). Wagh and rajput (1991) ranked the beneficial role of various tress intercropped with crops and they kept bamboo first than cashew, mango and jackfruit, rubber etc, then AFS with bamboo was reported an extremely versatile plant capable of providing ecological, economic and livelihood security to the people Banerjee, *et al*, (2009).

The microclimatic features *viz*; PAR ($\mu\text{mol s}^{-1} \text{m}^{-2}$), temperature ($^{\circ}\text{C}$) and relative humidity (%) available around the turmeric crop either grown under bamboo or in open field was ultimately reflected in performance of growing crops. Here the PAR was recorded in maximum in open field as compare to agroforestry system. The temperature around crops of open field and Agroforestry system showed more or less similar pattern of fluctuation and availability during crop growth period. In case of relative humidity, which was always associated with availability of sun light and existing air temperature found little higher in Agroforestry system. Similar result of micro-climatic characteristics were recorded by Dindekar (2012), Harne (2013) and Naugraiya (2003-2013) during cultivation of various Rabi and kharif crop under bamboo.

**SUMMARY, CONCLUSIONS AND SUGGETIONS FOR
FUTURE WORK**

6.1 SUMMARY

The present investigations entitled “Performance of Turmeric (*Curcuma longa* Rosc.) under Bamboo (*Dendrocalamus strictus* (Roxb.) Nees based Agroforestry System in Chhattisgarh.” was carried out at Forestry Research Farm, Indira Gandhi Krishi Vishwavidyaiaya, and Raipur (C.G.). The objectives of the study were to access the performance of Turmeric (*Curcuma longa*) crop under Bamboo (*Dendrocalamus strictus*) based agro-forestry system as compare to open field crop.

Turmeric (*Curcuma longa*) was grown as intercrop with Bamboo in agro-forestry system, and crop spacing treatments which influenced the growth parameters of turmeric crop *viz*; plant height of crop, numbers of tillers, number of leaves, length of leaves, of turmeric crops. All observations were recorded at 30 days interval from the days after sowing (DAS). Around the crop of turmeric the microclimatic parameters *viz*; photo synthetically active radiation (PAR), temperature and relative humidity were also recorded at 15 days interval from July 2017 to January 2018.

After harvesting of the turmeric crop, yield parameters, *viz*.; length and width of rhizome and mother rhizome, Number of Finger number and rhizome root length were recorded. Yield of rhizome as fresh weight was recorded while yield as oven dry weight was estimated by drying at 75 °C till complete dry of turmeric rhizome of each treatment. In the Bamboo crop, the population of culm (matured, young, dead and new) per clump, clump diameter, height of culm, diameter of culm at 3rd internode, fresh and oven dry weight of the culm, branches and leaves were measured after harvesting of selected mature culms in the month of march 2018.

Plant height

- Plant height was 83.67cm in Open (CS-1) and 77.88cm AFS (CS-2) at 120 DAS with statistically significant difference, in case variety 80.79cm in Ranga (V-1) and 80.75cm in Roma(V-2), in case spacing of crop it was found in order of S-2>S-3>S-1 in range of 83.13cm to 78.81cm with insignificant variation, though the interaction of cropping system x variety highest 84.08cm for CS-1 x V2 followed by 83.25cm for CS-1 x V1, while lowest height was recorded 77.42cm for CS-2 x V2, cropping system x spacing highest 84.63cm for CS-1 x S2 followed by 84.38cm for CS-1 x S3 with lowest height 75.63cm for CS-2 x S1, variety x spacing highest 86.13cm for V-2 x S2 followed by 81.75cm for V-1 x S1 with lowest height 75.88cm for V-2 x S1, cropping system x variety x spacing noted highest (89.0cm) for CS-1 x V-2 x S-2 followed by (84.8cm) for CS-1 x V-1 x S-3 with lowest height (72.5cm) for CS-2 x V-2 x S-1.

Number of tillers

- Numbers of tillers plant⁻¹ was 2.38 in open (CS-1) and 3.08 in AFS (CS-2) at 120 DAS with statistically significant variation, in case variety 2.58 in Ranga (V-1) and 2.88 in Roma (V-1), in case spacing of crop it was found in order of S-3>S-1>S-2 in range of 2.82 to 2.59 with insignificant variation, though the interaction of cropping system x variety higher 3.17plant⁻¹for CS-2 x V2 followed by 3.00plant⁻¹for CS-2 x V1 with lowest of 2.17plant⁻¹ for CS-1 x V1 respectively, cropping system x spacing showed highest 3.30 plant⁻¹ in CS-2 x S-1 followed by 3.14 plant⁻¹ and 2.81 plant⁻¹ in CS-2 x S-3 and CS-2 x S-2 respectively with minimum of 2.25 plant⁻¹ in CS-1 x S-1 interaction, variety x spacing highest (3.09plant⁻¹) for V-2 x S-3 followed by 2.85plant⁻¹ for V-1 x S1 with lowest number of tiller for V-1 x S-2 (2.35plant⁻¹), cropping system x variety x spacing higher for CS-2 x V-1 x S-1(3.05plant⁻¹) and the lowest number of tillers per plant was recorded for CS-1 x V-1 x S-2 (2.0plant⁻¹).

Number of leaves

- Number of leaves plant⁻¹ was 20.50 in open (CS-1) and 20.79 in AFS (CS-2) at 120 DAS with statistically significant result, in case of variety 20.29 plant⁻¹ in Ranga(V-1) and 21.00 plant⁻¹ in Roma (V-1), in case of spacing it was found in

order of S-1>S-2>S-3 in range of 21.56 plant⁻¹ to 19.75 plant⁻¹ with insignificant variation, though the interaction of cropping system x variety highest 21.42 plant⁻¹ for CS-1 x V2 followed by 21.00 plant⁻¹ for CS-2 x V1 while lowest 19.58 plant⁻¹ leaves was counted for CS-1 x V1 with significant variation, cropping system x spacing showed highest 21.63 plant⁻¹ in CS-2 x S-1 followed by 21.50 plant⁻¹ and 20.75 plant⁻¹ in CS-1 x S-1 and CS-1 x S-2 respectively with minimum of 19.25 plant⁻¹ in CS-1 x S-3 interaction, variety x spacing highest (21.63 plant⁻¹) for V-2 x S-1 followed by 21.50 plant⁻¹ for V-1 x S1 with lowest number of leaves for V-1 x S-3 (18.88 plant⁻¹), cropping system x variety x spacing highest (22.3 plant⁻¹) for CS-2 x V-1 x S-1 followed by (21.3 plant⁻¹) for CS-1 x V-2 x S-2 with lowest of 17.8 plant⁻¹ for CS-1 x V-1 x S-2.

Length of leaves

- Leaves length was 210.16 cm in open (CS-1) and 210.78cm in AFS (CS-2) at 120 DAS with statistically insignificant, in case of variety 204.81cm in Ranga (V-1) and 216.13cm in Roma (V-2), in case of spacing it was found in order of S-2>S-3>S-1 in range of 214.03 cm to 204.08 cm with insignificant variation, though the interaction of cropping system x variety highest 217.4cm for CS-1 x V2 followed by 214.8cm for CS-2 x V2 with lowest number of leaves for CS-1 x V1(202.85cm), cropping system x spacing highest 215.92cm for CS-2 x S3 followed by 215.10cm for CS-1 x S2 with lowest size of leaves for CS-2 x S1(203.46cm), variety x spacing maximum 230.78cm for V-2 x S-3 followed by 220.39cm for V-2 x S2 with lowest of 195.81cm for V-1 x S-3, cropping system x variety x spacing maximum 235.3cm for CS-2 x V-2 x S-3 followed by 227.9cm for CS-1 x V-2 x S-2 with lowest of 195.1cm for CS-1 x V-1 x S-3.

Rhizome length

- Rhizome length was 4.10 cm in open (CS-1) and 4.63 cm in AFS (CS-2) with statistically insignificant variation, with non-significant difference in case of variety 4.52cm in Ranga (V-1) and 4.20cm in Roma (V-2), in case of spacing it was found in order of S-1>S-2>S-3 in range of 4.66 cm to 4.14cm with insignificant variation, though the interaction of cropping system x variety showed highest 4.75cm in CS-2 x V2 followed by 4.54cm and 4.50 cm in CS-1 x V1 and

CS-2 x V1 respectively with minimum length of 3.66cm in CS-1 x V2 interaction, cropping system x spacing showed highest 5.00cm in CS-2 x S-1 followed by 4.75cm and 4.33cm in CS-2 x S-2 and CS-1 x S-1 respectively with minimum of 3.83cm in CS-1 x S-2 interaction, though the interaction variety x spacing recorded 5.45cm V-1 x S1 followed by 4.70cm and 4.54cm in V-2 x S3 and V-1 x S-2 respectively with lowest length was recorded 3.58cm in V-1 x S3 interaction, cropping system x variety x spacing maximum 5.7cm in CS-1 x V-1 x S-1 followed by 4.8cm for CS-2 x V-1 x S-2 and CS-2 x V-2 x S-1|S-2|S-3 with lowest 3.0cm in CS-1 x V-2 x S-1 interaction.

Rhizome width

Rhizome width was 9.58 cm in open (CS-1) and 3.96 cm in AFS (CS-2) with statistically significant differences, in case of variety 7.13cm in Ranga (V-1) and 6.42cm in Roma (V-2) with significant variation, in case of spacing it was found in order of S-2>S-1>S-3 in range of 7.31 cm to 6.38 cm with insignificant variation, though the interaction of cropping system x variety showed maximum 10.33cm in CS-1 x V1 followed by 8.83cm and 4.00cm in CS-1 x V2 and CS-2 x V2 respectively with lowest width 3.92cm in CS-2 x V1 interaction, cropping system x spacing showed highest 10.38 cm in CS-1 x S2 followed by 9.38cm and 9.00cm for CS-1 x S1 and CS-1 x S-3 respectively with lowest width was showed 3.75cm in CS-2 x S3 interaction, variety x spacing was showed highest 8.25cm in V-1 x S2 followed by 6.63cm in V-1 x S1 and V2 x S-1 with lowest width at 6.25cm in V-2 x S2 interaction, cropping system x variety x spacing was showed and 9.0cm maximum 12.0cm in CS-1 x V-1 x S-2 followed by 10.0cm in CS-1 x V-1 x S-1,C and S-1 x V-1 & V-2 x S-3 respectively (9.00cm) with minimum of 3.3cm in CS-2 x V-1 x S-1 interaction.

Number of Fingers

- Number of fingers was 4.88 plant⁻¹ in open (CS-1) and 4.33 plant⁻¹ in AFS (CS-2) in statistically significant results, in case of variety 4.46 plant⁻¹ in Ranga (V-1) and 4.75 plant⁻¹ in Roma (V-2) with statistically non significant variation, in case of spacing it was found in order of S-3>S-1>S-2 in range of 4.69 plant⁻¹ to 4.50 plant⁻¹ with insignificant variation, though the interaction of cropping system x

variety showed highest 5.08 plant⁻¹ in CS-1 x V2 followed by 4.67 plant⁻¹ and 4.42 plant⁻¹ in CS-1 x V1 with lowest number of finger was 4.25 plant⁻¹ in CS-2 x V1 interaction, cropping system x spacing showed highest 5.00 plant⁻¹ in CS-1 x S3 followed by 4.88 plant⁻¹ and 4.75 plant⁻¹ in CS-1 x S1 and CS-1 x S-2 respectively with lowest number of fingers in 4.25 plant⁻¹ CS-2 x S3 interaction variety x spacing highest 4.88 plant⁻¹ in V-2 x S3 followed by 4.75 plant⁻¹ and 4.63 plant⁻¹ in V-2 x S2 and V1 x S-1 & V2 x S2 with lowest of 4.25 plant⁻¹ in V-1 x S1 interaction, cropping system x variety x spacing highest 5.03 plant⁻¹ in CS-1 x V-2 x S-3 followed by 5.0 plant⁻¹ for CS-1 x V-2 x S-1 & S-2 with lowest number of fingers 4.0 plant⁻¹.in CS-2 x V-1 x S-2 interaction.

Fingers length

- Fingers length was 4.90 cm in open (CS-1) and 4.35 cm in AFS (CS-2) and has statistically significant results, in case of variety 4.63cm in Ranga (V-1) and 4.63cm (V-2), in case of spacing it was found in order of S-2>S-1>S-3 in range of 4.67 cm to 4.60 cm with insignificant variation, though the interaction of cropping system x variety highest for CS-1 x V1& V2 (4.90cm) followed by 4.36cm for CS-2 x V2 and it was marginally lowest for CS-2 x V1 (4.35cm), cropping system x spacing showed highest for CS-1 x S2 (5.02cm) followed by (4.78cm) for CS-1 x S1 with lowest length of finger (4.30cm) for CS-2 x S3 interaction, variety x spacing highest for V-1 x S1 (4.73cm) followed by 4.70cm and 4.69cm for V-2 x S3 & S2 with lowest length 4.50cm for V-2 x S2 interaction, cropping system x variety x spacing highest for CS-1 x V-1 x S-2 (5.2cm) followed by for CS-1 x V-1 x S-1(5.0cm) CS-1 x V-2 x S-3 and CS-2 x V-1 x S-1 (4.9cm) and the lowest length of finger was recorded 4.1cm for CS-2 x V-1 x S-2 interaction.

Rhizome root length

- The rhizome root length was 11.60cm in open (CS-1) and 14.93cm in AFS (CS-2) with statistically significant variations, in case of variety 12.48cm in Ranga (V-1) and 14.05cm in Roma (V-2), in case of spacing it was found in order of S-1>S-2>S-3 in range of 14.31cm to 12.53cm with insignificant variation, though the interaction of cropping system x variety highest for CS-2 x V2 (16.30cm) followed by 13.55cm for CS-2 x V1 and 11.79cm for CS -1 x V-2 with lowest

11.42cm for CS-1 x V1 interaction, cropping system x spacing showed highest for CS-1 x S3 (17.24cm) followed by 14.11cm and 13.43cm for CS-2 x S2 and CS-2 x S3 respectively afterword it draped between 11.81 to 11.38cm in open field crop (CS-1) with lowest of (11.38cm) for CS-1 x S1 interaction, variety x spacing highest for V-2 x S1 (16.24cm) followed by 13.14cm and 12.79cm for V-2 x S2 , V-1 x S2 respectively and it was recorded lowest of 12.38cm for V-1 x S1 interaction, cropping system x variety x spacing recorded highest for CS-2 x V-2 x S-3 (20.9cm) followed by 14.2cm and 14.00cm for CS-2 x V-1 x S-2 & S-3 respectively. The lowest length of root was recorded 11.1cm for CS-1 x V-1 x S-1 interaction.

Fresh weight of rhizome (gm/plant)

- The fresh weight yield of turmeric was 69.30 gm/plant in open field (CS-1) and 60.72 gm/plant in AFS (CS-2) with statistically insignificant differences, in case of variety 62.41 gm/plant in Ranga (V-1) and 67.61 gm/plant in Roma (V-2), with statistically non- significant variation in case of spacing it was found in order of S-2>S-3>S-1 in range of 69.46 gm/plant to 61.67 gm/plant with insignificant variation, though the interaction of cropping system x variety recorded highest (71.75 gm/plant) in CS-1 x V2 followed by (66.85 gm/plant) and CS-1 x V1 and 63.48gm/plant in CS-2 x V2 respectively with lowest fresh weight of rhizome (57.96 gm/plant) in CS-2 x V1 interaction, cropping system x spacing showed highest (71.26 gm/plant) in CS-1 x S2 followed by 68.98 gm/plant and 67.66gm/plant in CS-1 x S-3 and CS-1 x S-1 respectively with lowest of 55.68 gm/plant in CS-2 x S1 interaction, variety x spacing observed highest (70.59 gm/plant) in V-2 x S2 followed by 69.76gm plant⁻¹ and 68.32 gm/plant for V-2 x S3 and V-1 x S-2 respectively, with lowest fresh weight of rhizome was showed 58.06 gm/plant for V-1 x S3 interaction. Cropping system x variety x spacing observed highest (75.1 gm/plant) in CS-1 x V-2 x S-3 followed by 71.8 gm/plant and 70.7 gm/plant for CS-1 x V-2 x S-2 and CS-1 x V-1 x S-2 respectively, with minimum of 53.3gm plant⁻¹ in CS-2 x V-1 x S-3 interaction.

Oven Dry weight of rhizome gm/plant

- The oven dry weight yield of turmeric was 18.84 gm/plant in open field (CS-1) and 15.5 gm/plant in AFS (CS-2) with statistically insignificant differences, in case of variety 16.87 gm/plant in Ranga (V-1) and 17.12 gm/plant in Roma (V-2), in case of spacing it was found in order of S-2>S-1>S-3 in range of 17.31 gm/plant to 16.65 gm/plant with insignificant variation, though the interaction of cropping system x variety recorded highest for CS-1 x V2 (19.31 gm/plant) followed by 18.37 gm/plant for CS-1 x V1 with lowest of 14.93 gm/plant for CS-2 x V2 interaction. cropping system x spacing recorded highest for CS-1 x S2 (19.83 gm/plant) followed by 19.10 gm/plant and 17.58 gm/plant for CS-1 x S1 and CS-1 x S-3 respectively where the lowest oven dry weight of rhizome was recorded 14.78 gm/plant for CS-2 x S2 which was 1.04 and 0.1 gm/plant from CS-2 x S-3 and CS-2 x S-1 respectively, variety x spacing observed highest for V-1 x S2 (19.42 gm/plant) followed by 19.11 gm/plant for V-2 x S3 and V-2 x S-2, V1 x S-1(17. gm/plant) afterword it dropped to 15.2 gm/plant and 14.19 gm/plant at least position, cropping system x variety x spacing observed above the 19 gm/plant in CS-1 x V-1 x S-1|S-2,CS-1 x V-2 x S-1|S-2|S-3,CS-2 x V-1 x S-2 and CS-2 x V-2 x S-3 with maximum 19.9 gm/plant (CS-1 x V-2 x S-2) and minimum 18.9 gm/plant (CS-1 x V-2 x S-1).

Yield in fresh weight of turmeric (qha⁻¹)

- The fresh weight yield of turmeric was 225.79 q ha⁻¹ in open field (CS-1) and 161.46 q ha⁻¹ in AFS (CS-2) with statistically significant differences, in case of variety 206.71 q ha⁻¹ in Ranga (V-1) and 180.55 q ha⁻¹ in Roma (V-2), with statistically non- significant variation, in case of spacing it was found in order of S-1>S-3>S-2 in range of 209.44 q ha⁻¹ to 177.29 q ha⁻¹ with insignificant variation, though the interaction of cropping system x variety was showed 245.67 qha⁻¹ in CS-1 x V1 followed by 205.92 qha⁻¹&167.75 qha⁻¹ in CS-1 x V2, and in CS-2 x V1 respectively, with minimum yield was recorded in 155.18 qha⁻¹ in CS-2 x V2 interaction, cropping system x spacing was showed highest 246.31 qha⁻¹ in CS-1 x S1 followed by 215.67 qha⁻¹ and 215.40 qha⁻¹ in CS-1 x S3, and CS-1 x S2, respectively with minimum yield was showed in 139.18 qha⁻¹ in CS-2 x S2,

interaction, variety x spacing observed 221.00 qha⁻¹ in S-1 x V1 followed by 206.73 qha⁻¹ and 197.88 qha⁻¹ in S-3 x V1, and (S-1 x V2), respectively with minimum yield was showed in 162.17 qha⁻¹ in S-2 x V2, interaction cropping system x variety x spacing was observed 252.08 qha⁻¹ in CS-1 x V1 x S1 followed by 243.00 qha⁻¹ and 241.02 qha⁻¹ in (CS-1 x V1 x S3), and (S-1 x V1 x S2), respectively, with minimum of 134.8qha⁻¹ in CS-2 x V-2 x S-2 interaction.

Yield in oven dry weight of turmeric (qha⁻¹)

- The oven dry weight yield of turmeric was 61.04 q ha⁻¹ in open field (CS-1) and 42.53 q ha⁻¹ in AFS (CS-2) with statistically significant results, in case of variety 55.70 q ha⁻¹ in Ranga (v-1) and 47.87 q ha⁻¹ in Roma (v-2), in case of spacing it was found in order of S-1>S-3>S-2 in range of 58.39 q ha⁻¹ to 47.03q ha⁻¹ with insignificant variation, though the interaction of cropping system x variety observed 66.69 qha⁻¹ in CS-1 x V1 followed by 55.40 and 44.71 qha⁻¹ CS-1 x V2, and CS-2 x V1 respectively, while minimum yield was recorded in 40.34 qha⁻¹ for CS-2 x V2 interaction, cropping system x spacing observed 69.38 qha⁻¹ in CS-1 x S1 followed by 59.99 qha⁻¹ (CS-1 x S2), 53.76 qha⁻¹ (CS-1 x S3), 47.40 qha⁻¹ (CS-2 x S1), and 46.10 qha⁻¹ (CS-2 x S3) respectively, while minimum yield was recorded in 34.07 qha⁻¹ for CS-2 x S2, variety x spacing observed 61.80 qha⁻¹ in S-1 x V1 followed by 54.99 qha⁻¹ (S-1 x V2), 54.59 qha⁻¹ (S-2 x V1), 50.71 qha⁻¹ (S-3 x V1), and 49.15 qha⁻¹ (S-3 x V2) respectively, while minimum yield was recorded in 39.47 qha⁻¹ for S-2 x V2, cropping system x variety x spacing observed 71.09 qha⁻¹ in CS-1 x V1 x S1 followed by 67.03 qha⁻¹ (CS-1 x V1 x S2), 66.09 qha⁻¹ (CS-1 x V2 x S1), 60.08 qha⁻¹ (CS-1 x V1 x S3), afterword it dropped to S-1 to S-2 qha⁻¹ CS-1 x V2 x S2, CS-2 x V1 x S1, CS-2 x V2 x S3, and then between 40 to 46.07 qha⁻¹ in A (CS-1 x V2 x S3) B (CS-2 x V2 x S1), C (CS-2 x V1 x S2), D (CS-2 x V1 x S3) respectively, while minimum yield was recorded in 26.03 qha⁻¹ in S-2 x V2 x S2.

Bamboo growth and yield

- Population of culm clump⁻¹ was 44.9 in July 2017 and increased to 57.0 with share of matured (24.8%), young (50.8%), dead (9.9%) and new culm (14.3%) after 8 month in the growth period of crop.

- Diameter of clumps was recorded 4.04m in July 2017 and it increased to 4.88m after 8 month of growth.
- Height of culm recorded was 7.77m in July 2017 and after 8 month it was 8.98m which was 15.5% more.
- Diameter of 3rd internodes of bamboo culms 3.64 cm in July 2017 and after 8 month it was 3.87cm.
- The total biomass in above ground part of a culm was 12.39±2.6 kg/culm which was shared by 7.30±0.79, 3.4±0.9 and 1.6±0.3 by clean bole of culm, branches and leaves respectively.

Microclimatic parameters

- Microclimatic feature *viz*; photo synthetically active radiation (PAR) was consistently recorded higher in open field as compare to AFS due to absence of trees canopy though temperature (°C) and relative humidity (%) were observed more or less in similar pattern.

6.2 CONCLUSION

The following conclusion are drawn from the study conducted, which had aimed to assess the performance of turmeric (*Curcuma longa*) crop under Bamboo (*Dendrocalamus strictus*) based agro-forestry system.

- As cover crop of turmeric under Bamboo plantation at wider spacing, the yield of fresh ginger was 225.79 q ha⁻¹ in open field as compare to AFS in 161.46 q ha⁻¹ with significant variation of 28.49 %.
- Yield of turmeric was found higher at variety Ranga (V-1) in 206.71 q ha⁻¹ as compare to Roma (V-2) in 180.55 q ha⁻¹, and Ranga variety is more suitable for cultivation. Yield of turmeric was found higher at spacing S-1 (50 x 50cm) in 209.44 q ha⁻¹ with insignificant variation to S-3 (40 x 30cm) but significantly much higher from S-2 (177.29 q ha⁻¹) hence spacing S-1 was more suitable for cultivation of turmeric.
- Interaction of cropping system x variety in yield of turmeric was found highest CS-1 x V-1 in 245.67 q ha⁻¹ and lowest CS-2 x V-2 in 155.18 q ha⁻¹ cropping

system x spacing in yield of turmeric was found insignificant statistically, it was found in higher at S-1 followed by S-2 CS-1 x S-1 (246.31 q ha⁻¹) in interaction. Spacing in both cropping system in order of CS-1>CS-2 in range of 246.31 to 139.18 q ha⁻¹, where yield in wider spacing (S-1) was 246.31 and 172.57 q ha⁻¹ for CS-1 and CS-2 respectively thus turmeric can cultivated, interaction of variety x spacing higher 221.00 q ha⁻¹ in S-1 x V-1 and lowest is 162.17 q ha⁻¹ in S-2 x V-2 as compared S-1 and V-1 is better of the bamboo based AFS, interaction of cropping system x variety x spacing highest is 252.8 q ha⁻¹ in CS-1 x V-1 x S-1 and lowest is 134.8 q ha⁻¹ in CS-2 x V-2 x S-2.

Agroforestry system known for improve multi level of production, here in bamboo based Agroforestry system can be adoptable because yearly production of bamboo plantation after 3 years with yield of cover crop with minimum input and management.

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Dear Author(s),

It is pleasure to inform you that your manuscript No. 202004384 -IJCMAS entitled "**Performance of Turmeric (*Curcuma longa*) under Bamboo (*Dendrocalamus strictus*) based Agroforestry System in Chhattisgarh**" has been accepted for publication in International Journal of Current Microbiology and Applied Sciences and published in the Vol 9 (04) to be released in April-2020.

Thank you

With Regards

Dr.M.Prakash
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