COMPARATIVE STUDY ON CULTIVATION OF MEDICINAL MUSHROOM (*Ganoderma lucidum)* IN DIFFERENT TREE SPECIES OF GARHWAL HIMALAYA, INDIA

Thesis

By

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Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF SCIENCE IN FORESTRY (FOREST PRODUCTS AND UTILIZATION)

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College of Forestry, Ranichauri

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2021

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CERTIFICATE- I

This is to certify that the thesis entitled **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Forestry** in the discipline of **Forest Products and Utilization** of VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand is a bonafide research work carried out by **Mr. Maneesh Kumar**, **I.D. No. 19366** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

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ACKNOWLEDGEMENT

Praise to the Almighty God for the life, energy, wisdom and determination he has given me during the process of compiling this piece of research work. I thank my dearest parents; ***Mr. Sundar Lal*** *and* ***Mrs. Ekadashi Devi*** *plus my grandmother, brother and sisters for their nurturing, loving and inspiration they have rendered to me. Finally endless appreciation goes to my uncle* ***Mr. Mohan Singh*** *for giving me the opportunity, financial support and meaning of education.*

At the outset, it gives me immense pleasure to express my sincere regard and deep sense of gratitude to my esteemed Major Advisor, ***Dr. Arvind Bijalwan****, Head, Department of Agroforestry for his benevolent sustained guidance, sound suggestions, continuous encouragement and empathy which inspired me to work sincerely.*

I am equally obliged to the members of my Advisory committee ***Dr. Amol Vasishth****, Head of Department, Department of Forest products and Utilization;* ***Dr. R. K. Prasad,*** *Assistant Professor, Department of Basic Science;* ***Mr. Pankaj Lal*** *Assistant Professor, Department of Forest products and Utilization for their interest, valuable suggestions and constructive criticism during the course of the present investigation. I am also thankful to* ***Dr. M. K. Riyal,*** *Assistant Professor, Department of Basic Science for his valuable inputs in the analysis of this research.*

I also express my ecstatic thank to all the teachers of the College of Forestry, Ranichauri for their kind co-operation and impeccable guidance during the course of study. I am highly thankful to ***Prof. V. P. Khanduri****, Dean College of Forestry, Ranichauri Campus for his close supervision and providing essential facilities to conduct the proposed investigations.*

I am highly grateful to ***National Mission on Himalayan Studies (NMHS)****,* ***GB Pant National Institute of Himalayan Environment, Almora, Uttarakhand (MoEFCC, Govt. of India)*** *for funding this research under the project "Adoption of Medicinal and*

Edible Mushroom Integrated with Climate Resilient Interventions for Upscaling Livelihood in Garhwal Himalaya" implemented in College of Forestry, VCSG UUHF Ranichauri, Tehri Garhwal, Uttarakhand, India.

Special thanks go to ***Mrs. Kalpana Bahuguna Uniyal****, Senior Research Fellow, Department of Agroforestry for her selfless support and guidance during the course of writing this thesis manuscript.*

No words can appreciate the all-round help rendered to me by my colleagues, ***Mohit, Abhishek Bisht, Vivek Rawat, Abhishek Thakur, Gaurav Kumar, Ahish, Shubham, Chandra Mohan, Naresh Singh,*** *all my classmates and other friends.*

Last but not least I am thankful to all those who have helped me directly or indirectly and whose names, I forgot to mention in the endeavour.

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ABSTRACT

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Title: Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India.

Ganoderma lucidum is a well-known medicinal mushroom having a long history of its medicinal uses across the globe. It grows saprophytically or parasitically on the large variety of dead or dying broad-leaf trees species throughout the world. The present study titled "Comparative study on cultivation of medicinal mushroom (*Ganoderma lucidum*) in different tree species of Garhwal Himalaya, India" is aimed to the cultivation of *Ganoderma lucidum* mushroom on different tree species; Peach (*Prunus persica*), Plum (*Prunus domestica*), Apricot (*Prunus armeniaca*), Oak (*Quercus leucotrichophora*), Bhimal (*Grewia optiva*) and Poplar (*Populus deltoides*) billets/logs with different diameters; D-1 (4-5cm), D-2 (5-6cm) and D-3 (6-7cm). The investigation consisted of eighteen treatments comprising above described six wood species with three diameters of each species in two factorial completely randomized designs with three replications of each treatment. Different growth performance parameters (mycelial colonization, pinhead formation, cap formation, fruiting body formation and harvesting) were studied and the minimum time for harvesting was observed in wood billets of Bhimal and Apricot species. Physical properties parameters (pinhead length, number of pinheads, cap diameter, stipe length, fruiting body diameter and physical appearance of fruiting bodies) were also observed with the highest fruiting body diameter in wood billets of Oak and Bhimal species. Yield parameters (fresh weight, dry weight, biological efficiency and number of fruiting bodies obtained) were recorded with the wood billets of Oak and Bhimal species having maximum fresh and dry weight of fruiting bodies while the highest biological efficiency was obtained in wood billets of Poplar and oak species. The overall findings of present study suggested that *Ganoderma lucidum* mushroom grow well on Oak, Bhimal and Poplar wood billets as compared to Apricot, Plum and Peach wood billets.

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नाम – मनीष कुमार
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(वन उत्पाद एवं उपयोगिता)
सलाहकार –डॉ० अरविन्द बिजल्वाण
(सह–प्रध्यापक)

परिचय संख्या0– यूयूएचएफ / 19366
विभाग – वन उत्पाद एवं उपयोगिता
महाविद्यालय – वानिकी महाविद्यालय,रानीचौरी,
वी०च०सिं0ग0 उत्तराखण्ड औद्यानिकी एवं
वानिकी विश्वविद्यालय भरसार, पौड़ी गढ़वाल,
उत्तराखण्ड, भारत।

शीर्षक – गढ़वाल हिमालय, भारत की विभिन्न वृक्ष प्रजातियों में औषधीय मशरूम (*गैनोडर्मा ल्यूसिडम*) की खेती का तुलनात्मक अध्ययन।

गैनोडर्मा ल्यूसिडम एक अत्यन्त महत्वपूर्ण औषधीय मशरूम है जिसके औषधीय उपयोगों का विश्वभर में एक लम्बा इतिहास है। यह मृतजीवी या परजीवी के रूप में विभिन्न प्रकार की मृत या मृतप्रायः चौड़ी पत्ती वाली वृक्ष प्रजातियों में उगता है। वर्तमान अध्ययन जिसका शीर्षक **"गढ़वाल हिमालय, भारत की विभिन्न वृक्ष प्रजातियों में औषधीय मशरूम (गैनोडर्मा ल्यूसिडम) की खेती का तुलनात्मक अध्ययन"** है, जिसका उद्देश्य विभिन्न वृक्ष प्रजातियों– आड़ू (*प्रूनस पर्सिका*), प्लम (*प्रूनस डोमेस्टिका*), खुबानी (*प्रूनस अर्मेनियाका*), ओक (*क्वेरकस ल्यूकोट्राईकोफोरा*), भीमल (*ग्रेविया ऑप्टिवा*) और पॉपलर (*पॉपुलस डेल्टोइड्स*) की बिलेट्स / लॉगस को विभिन्न मोटाईयों– डी–1 (4–5 सेमी), डी–2 (5–6 सेमी) और डी–3 (6–7 सेमी) में गैनोडर्मा ल्यूसिडम की खेती करना है। जाँच मे अठारह ट्रिटमेंट शामिल थे। जिसमे ऊपर वर्णित छः लकड़ी की प्रजातियों की तुलना प्रत्येक प्रजाति की तीन मोटाइयों के साथ टू फैक्टोरियल कम्पलीट रैंडामाइज्ड डिजाइन में प्रत्येक ट्रिटमेंट की तीन प्रतिकृति के साथ की गई थी। विभिन्न विकास प्रदर्शन मानकों (कवकजाल कोलोनाइजेशन, पिनहेड गठन, कैप गठन, फ्रूटिंग बॉडी गठन और तुड़ाई) का अध्ययन किया गया, जिसमें तुड़ाई के लिये न्यूनतम समय भीमल एवं खुबानी प्रजातियों की बिलेट्स में देखा गया। ओक और भीमल प्रजातियों की बिलेट्स में फ्रूटिंग बॉडी अधिकतम चौड़ाई के साथ भौतिक गुण मानकों (पिन हेड की लम्बाई, पिन हेडो की संख्या, कैप की चौड़ाई, स्टाईप की लम्बाई, फ्रूटिंग बॉडी की चौड़ाई और फ्रूटिंग बॉडी की भौतिक बनावट) को भी देखा गया। उपज मानकों (ताजा वजन, सूखा वजन, जैविक दक्षता और फ्रूटिंग बॉडी की संख्या) को भी दर्ज किया गया, जिसमें ओक एवं भीमल प्रजाति में अधिकतम ताजा वजन एवं सूखा वजन प्राप्त हुआ, जबकि अधिकतम जैविक दक्षता पॉपलर एवं ओक प्रजाति की बिलेट्स में प्राप्त हुई। वर्तमान अध्ययन के सम्रग निष्कर्षो का यह सुझाव है कि *गैनोडर्मा ल्यूसिडम* मशरूम खुबानी, प्लम और आड़ू की बिलेट्स की तुलना में ओक, भीमल और पॉपलर की बिलेट्स में अच्छी तरह से विकसित होता है।

डॉ अरविन्द बिजल्वाण
(सलाहकार)

मनीष कुमार
(लेखक)

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ABBREVIATIONS

%	Percent
et al.	Etalia (co-worker)
cm	Centimetre
CD	Critical difference
ºC	Degree Celsius
km^2	Kilo meter square
masl	Mean above sea level
mm	Mili meter
sp.	species
MT	Metric tones
µm	Micro meter
@	At the rate
lux	Luminous intensity
BE	Biological efficiency
kg	Kilo gram
g	Gram
GL	*Ganoderma lucidum*
T	Treatments
RH	Relative humidity
PDA	Potato dextrose agar
ANOVA	Analysis of variance
Nos.	Number
i.e.,	That is
etc.	Et cetera
viz.	Videlicet
DF	Degree of freedom

CHAPTER-1 INTRODUCTION

Uttarakhand state is situated in the west region of the central Himalayas. It extends from 28°43" N to 31°28" N latitude and 77°34" E to 81°03" E longitude on India's political map. The regions total geographical area is 53,483 km^2 accounting for about 15.5% of the western Himalayas total geographical area and 1.63 % of India's total land area (Kumari & Tiwari 2009; Joshi *et al*., 2012). The documented forest area of the state is approximately 24,303.04 km^2 accounting for 45.44% of the area of state (FSI, 2019). The Garhwal Himalaya lies in the northern part of India between the latitudes 30°18" to 30°19" N and longitudes 78°24" to 78°24" E. This region has a sub-tropical to temperate climatic conditions (1000 to 2500 masl). The mean annual temperature ranges from 8°C to 35°C with an average annual rainfall of 1200 mm (Bijalwan, 2014).

The six major forest types described in Uttarakhand are tropical wet deciduous forest, tropical dry deciduous forest, subtropical pine forest, Himalayan moist temperate forest, Himalayan dry temperate forest and subalpine/alpine forest (Champion & Seth, 1968). The majority of the forests in Uttarakhand Himalaya range from 250 to 3500 metres with *Quercus, Rhododendron, Pinus, Cedrus, Cupressus, Abies, Picea, Shorea* and *Betula* species dominating. The variety of vegetation in these forests as well as the favourable environmental conditions help fleshy macro fungi to grow and develop (Joshi *et al.,* 2012). The rich diversity of flora grows and exists in Garhwal Himalayan forests. Mushrooms are common in this region, because of climatic conditions, plant distributions and field features of Garhwal Himalaya is favourable for the growth of mushrooms and various kinds of medicinal mushrooms grow in this region (Vishwakarma *et al.,* 2011).

Ganoderma lucidum (W. Curtis Fr.) P. Karsten is a well-known medicinal mushroom that has a long history of use and cultivation particularly in China, Japan and other Asian countries and it is a member of fungal group Basidiomycetes which belongs to Polyporaceae (*Ganoderma*ceae) family (Moncalvo, 2000). *Ganoderma lucidum* is also known as (Lingzhi in Chinese; Reishi, mannentake or Sachitake in Japanese; and Youngzi

in Korian) is a Basidiomycetes (*Ganoderma*ceae) fungal species (Chang and Miles, 2004). This mushroom is known in India as "jarhphorh" and in Haryana as "Satpatra" and "Hirdo" (Rawat, 2018). The Greek words Ganos which means "shining" and Derma which means "skin" are combined to from the name "*Ganoderma*" (Liddell *et al.,* 1980). The genus *Ganoderma* was established by Karsten (1881) with *Ganoderma lucidum* (Cur.) P. Kar. as the type species (Moncalvo and Ryvarden, 1997). This mushroom is also known as the "Mushroom of Immortality," "God of herbs," "Herb of Spiritual Potency" and "Celestial Herb" in Chinese ancient scripts due to its medicinal properties and presence of several medicinal compounds. The name lingzhi represents success, well-being, divine power and longevity (Wasser, 2005; Lin, 2009; De Silva *et al.*, 2012; Al-Obaidi *et al.*,2016). *Ganoderma* has a wide host range of species with more than 44 species of 34 genera identified as potential hosts (Bijalwan et al., 2020). The genus *Ganoderma* has 219 species with *Ganoderma lucidum* (W. Curt.: Fr.) P. Karsten serving as the type species (Moncalvo, 2000).

The body of the *Ganoderma lucidum* mushroom is divided into three main parts: a kidney-shaped cap, the mushroom's steam or shaft and spores. They feature yellow and brown decorated inner layers on their double-walled truncate spores (Babu *et al*., 2008). *Ganoderma lucidum* is polypore basidiomycetes fungi with double-walled basidiocarps (Donk, 1964). The existence of double-walled basidiospores characterizes *Ganoderma lucidum* from other polypore and this mushroom is also known as shelf mushrooms or bracket fungi (Adaskaveg and Gilbertson, 1988). *Ganoderma lucidum* species have the characteristics such as basidiomycetes are annual stipitate to sessile, pileus surface thick, dull cuticle or shiny and laccate with a thin cuticle of clavate end cells, context cream colored to dark purplish brown, soft and spongy to firm-fibrous, pore surface cream colored, bruising brown, stipe present central or lateral and hyphal system dimitic (Ryvarden, 2004). *Ganoderma* species has been found globally in different types of fruit body shape and colors like black, white, yellow, red, blue-green and purple (Zhao and Zhang, 1994; Woo *et al.*, 1999; Upton, 2000).

Ganoderma is a wild species found in tropical and temperate region throughout Africa, America, Europe and Asia (Wang *et al.,* 2012). *Ganoderma* species survive in hot, moist conditions and they are native to tropical regions (Pilotti *et al.,* 2004). *Ganoderma lucidum* produces fruiting bodies on both alive and dead trunks, trees and branches. They grow as saprobes, alternative parasites that can survive on decomposing wood (Turner, 1981). *Ganoderma lucidum* is a wood-decaying pathogenic fungus associated with broad-leaf tree root and butt rot (Bijalwan *et al.,* 2020). This mushroom can be found on a large variety of trees throughout the world. *Ganoderma lucidum* is frequently found alone in deciduous, coniferous or mixed forests in dead trunks, fallen lumber, rotten wood, rotten roots and stumps. *Ganoderma lucidum* grow on most of the tree species such as *Alnus sp., Betula sp., Castanea sp., Castanopsis sp., Cyclobalanopsis sp., Populus sp., Salix sp., Quercus sp. and Ulmus sp.* (Du *et al.,* 2019). *Ganoderma lucidum* is mainly grown on deciduous trees (dead or dying trees) in various parts of the Himalayas, particularly oak, pyrus, maple, quercus, elm, willow, sweet gum, magnolia, locust, acer, alnus, betula, tilia, Castanea, coryolus, fagus, fraxinus, populus, plums and less commonly on coniferous trees, i.e., larix, picea and pinus (Wasser, 2005; Jiang, 2015).

White rot fungi such as *Ganoderma lucidum*, play a significant role in the ecological and industrial breakdown of woody plants to collect nutrients. They hold effective lignocellulose degrading enzyme processes that can be used for bio pulping, bioremediation and bioenergy production (Hepting, 1971; Adaskaveg *et al.,* 1991; Coetzee *et al.,* 2015; Kues *et al.,* 2015). It has been recognized and used extensively in Chinese and Japanese culture for about 2000 years (Sliva, 2006).

Ganoderma lucidum is a key source of medicines that has been used around the world for over 2000 years (Wasser, 2005). Wild-grown high-quality *Ganoderma lucidum* fruiting bodies are rare in nature they have historically been expensive for their therapeutic benefits (Zhu *et al.,* 2015). Various biochemical such as triterpenoids, polysaccharides and peptidoglycans (Roy *et al*., 2015) are present in this mushroom which exert its activity

against various diseases like diabetes, heart disease, cancer, gout etc. (Lin, 2009; De Silva *et al.,* 2012). There are various scientific studies and evidence which prove the benefits of *Ganoderma lucidum* mushroom such as boosting the immune system, anti-cancer properties, fighting fatigue and depression, good for heart health, good for blood sugar control and antioxidant properties (Sliva *et al.,* 2003; Lin, 2005).

Traditional remedies for health improvement use all parts of the *Ganoderma lucidum* mushroom including the fruiting body, spores and mycelia (Smith *et al.,* 2002). *Ganoderma lucidum* as a possible pharmacological macro fungus that plays an essential role in disease prevention and therapy in traditional medicine (Sanodiya *et al.,* 2009). Pharmacotherapeutic experiments have confirmed several of *Ganoderma lucidum* actions and properties such as immunomodulation, antioxidant activity, anticancer activity and induction of cytokine production etc. (Wasser, 2002; Gao *et al.,* 2004; Hong *et al.,* 2004; Zhou *et al.,* 2007; Mahajna *et al.,* 2009). *Ganoderma lucidum* products are currently available in a variety of forms including dietary supplements, powdered form and tea, all of which are manufactured from multiple parts of the fruiting body (Liu *et al.,* 2010).

In an artificial medium containing wood, *Ganoderma lucidum* can grow fruiting bodies. Even though the first artificial medium cultivation of *Ganoderma lucidum* was carried out in 1937, experts from the Chinese Academy of Science in Beijing carried out the first successful cultivation of *Ganoderma lucidum* in 1969 (Yu and Shen, 2003). This fungus can be grown in a wood-containing substrate such as sawdust or a log of wood (Chen, 1999). *Ganoderma lucidum* is cultivated on two types of wood logs such as natural wood-log and sterilization wood-log. Sterilization wood logs have various advantages for *Ganoderma lucidum* cultivation such as: short growth cycle, high biological efficiency and high economic benefits (Lin and Zhou, 1999). Most of the broad-leaf tree species are suitable for cultivating *Ganoderma lucidum*. Trees with a thick bast, hard substance, less heartwood, developed wood ray, no aromatic saliva and a large duct branch are better for cultivation (Hapurachchi *et al.,* 2018; Wang *et al.,* 2014).

Tea waste was used as a supplement for substrate preparation for *Ganoderma lucidum* cultivation investigated by (Peksen and Yakupoglu, 2009). *Ganoderma lucidum* has been grown on a various type of substrates with constant growth conditions such as relative humidity, water content, light intensity, air pH and temperature (Chang and Miles, 2004). Because of its pharmaceutical importance and presence of numerous biochemical substances as well as contributions from developing countries like China, India, Poland, Hungary and Vietnam, worldwide production of *Ganoderma lucidum* mushrooms has been steadily increasing (Chang, 2007).

In 2002, the worldwide production of this mushroom was around 4900-5000 tones, with China contributing 3800 tones (Stamets, 2005). In 2000-2001, the medicinal mushrooms *Ganoderma lucidum* were imported from Malaysia and the market for *Ganoderma lucidum* based nutraceuticals was estimated to be worth around US $20.00 million (Thakur, 2005; Veena *et al.*,2012). In 2011, the global market for *Ganoderma lucidum* mushroom products was estimated to be worth $150 million with 175,000 distributors (www.google.com/organo gold review, 2012). The global production of *Ganoderma lucidum* is approximated to be around 6000 tons with China contribute for half of that (Verma and Prasad, 2010). *Ganoderma lucidum* mushrooms have a global market worth around 1.5 billion dollars while the Indian market is worth around Rs.120 crore per year (Geetha *et al.,* 2012).

Because of its medicinal properties, *Ganoderma lucidum* mushroom was the first medicinal mushroom to attain widespread popularity in India. *Ganoderma lucidum* has been successfully grown on sawdust and wheat straw with rice and wheat bran by a number of Indian researchers (Mishra and Singh, 2006; Rai, 2003; Veena and Pandey, 2004; 2012). Harsh (1993) first studied the ethno-medicinal value of *Ganoderma lucidum* mushroom in India. In India, the market for *Ganoderma lucidum* based nutraceuticals is quickly growing, with annual imports from Malaysia and China reaching Rs 100 crore (Rai, 2008; Mishra *et al.*,2014).

The *Ganoderma lucidum* mushroom is widely studied due to its great medical value, since it includes a variety of chemical compounds with nutritional and therapeutic potential (Hapuarachchi *et al.*, 2016). The demand for large quantities of its fruiting bodies can be supplied by improving traditional cultivation methods with a shorter production period as well as refining traditional cultivation methods with the goal of improving the quality and quantity of *Ganoderma lucidum* fruiting bodies. The pattern of cultivation was improved on shorter wood logs (Chen, 1996) as well as sawdust from various hardwood tree species and straw from various agricultural crops (Mishra and Singh, 2006).

Keeping importance of the above topic in mind the present investigation carried out **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** has been proposed with the following objective:

1. To cultivate the medicinal mushroom *Ganoderma lucidum* on different wooden billets and compere the growth performance.

2. To compare the physical properties at different growth stages of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

3. To compare the production potential/biological efficiency of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

CHAPTER-2 REVIEW OF LITRATURE

The review of literature on research is an essential part of any kind of scientific research. The review of literature here is based on the objective of the study, which gives an idea about the work done in past and provide the basis for interpretation and discussion of new findings. The available literature on different species sawdust substrate and wood logs to the present investigation is reviewed under the title **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** which is described as below with proper headings:

2.1 *Ganoderma lucidum*: Importance and Uses

2.2 Physical properties of *Ganoderma lucidum* fruiting body

2.3 Physiological factors

- Temperature
- Humidity
- pH

2.4 Cultivation technology

- Billets / logs preparation
- Spawn preparation
- Inoculation and Spawning
- Pinhead formation
- Cap formation
- Fruiting body formation
- Harvesting

2.5 Yield potential / biological efficiency

2.1 *Ganoderma lucidum*: Importance and Uses

The medicinal mushroom *Ganoderma lucidum* has a long list of health benefits. It is the oldest mushroom known to man, having been used as medicine in Japan and China for

about 2,000 years. It revitalises the body and mind, slows the ageing process and extends life expectancy **(Liu *et al.*, 1979).**

Stamet and Yao (1999) reported that therapeutic benefits of *Ganoderma lucidum* have long been recognised in countries such as China, Korea and Japan and there has been a big improvement in recent years in activities related to the use of *Ganoderma* products for medicinal purposes.

Polysaccharides, proteins (peptidoglycans) and triterpenoids are the three major physiologically active constituents in *Ganoderma lucidum* **(Boh *et al.*, 2007; Zhou *et al.*, 2007).**

Chang and Buswell (1999) reported that *Ganoderma lucidum* has been used to treat hepatitis, chronic hepatitis, nephritis, hypertension, arthritis, neurasthenia, insomnia, bronchitis, asthma and gastric ulcers in traditional Chinese and Japanese medicine.

Zang (1999) reported that *Ganoderma lucidum* has been used to treat HIV, cancer, low blood pressure, high blood pressure, diabetes, rheumatism, heart issues, paralysis, ulcers, asthma, exhaustion, hepatitis A, Band C, insomnia, sterility, psoriasis, mumps, epilepsy and alcoholism.

Ganoderma lucidum have various medicinal properties like anti-inflammatory reported by **(Patocka, 1991),** antitumor **(Kishida *et al.*, 1988 and Zhang *et al.*, 2000)** and antiviral **(Kim *et al.*, 1994).**

Wang *et al.* (1995) reported that a number of polysaccharides from the basidiomycetes, *Ganoderma lucidum* have been shown to produce antitumor effects, thus being potentially useful in cancer therapy.

Harsh *et al.* (1993) reported that tribals in India have been used the extract of *Ganoderma lucidum* to treatment of joint pain.

Kim *et al.* (1994) reported that *Ganoderma lucidum* showed promising antiviral action against HIV and **Mizuno (1996**) also reported that it helps to keep one's mental health.

Teow (1997) reported that after two months of treatment, the extract of *Ganoderma lucidum* was found beneficial in lowering blood glucose levels in diabetic patients.

Morigawa *et al.* (1986) reported that Ganoderic acid extracted from *Ganoderma lucidum* has anti-coagulating effects on the blood and decreases the cholesterol levels.

Ganoderma lucidum possess antitumor and antioxidant properties as well as a sedative effect on the nervous system and the capacity to promote cardio-cerebral circulation **(Liu 1999; Ooi and Liu 1999; Jones and Sanardhanan 2000; Reshetnikov *et al.*, 2001).**

Wasser (2002) reported that polysaccharides and triterpenoids are the two main components in *Ganoderma lucidum* fruit body that are possessed to have therapeutic properties. *Ganoderma lucidum* has the unique property of enhancing the immune system in addition to promoting longevity.

Polysaccharides present in *Ganoderma lucidum* have possess immunomodulatory and antitumor properties **(Zhu and Lin, 2005 and Zhu and Lin, 2006).**

Liu (1996) and Su, *et al.* (1997) reported that more than 100 different types of polysaccharides have been extracted from *Ganoderma lucidum* fruiting body and mycelia.

Polysaccharides from *Ganoderma lucidum* are the major 12 components responsible for immunomodulating effects **(Usui *et al.*,1983; Mizuno *et al.*, 1986; Wasser and Weis, 1999).**

Kim and Kim (1999) reported that Some triterpenoids from *Ganoderma lucidum* have exhibited biological activities such as antitumor, immunomodulating, hepatoprotective, antiviral and anti-oxidative effects and currently 119 triterpenoids have been extracted from the fruiting body and mycelia of *Ganoderma lucidum*, which include highly oxidized lanostane-type triterpenoids such as ganoderic and lucidenic acids, ganodermic acids, ganoderemic acids, lucidone, ganoderal and ganoderols.

Wang *et al.* (1997); Wasser and Weis (1999) reported that *Ganoderma lucidum* products have been shown to immunomodulation, chemo and radio-prevention, anti-aging,

hepatoprotection, nucleic acid synthesis stimulation, antitumor activity and antibacterial activity.

Ganoderma lucidum contains small amounts of polyphenols, steroids, lignin, ganomycins, vitamins, lectin, nucleosides, nucleotides, alkaloids, amino acids and organic germanium **(Chai *et al.*, 1997; Rosecke and Konig, 2000).**

Jiang (2015) reported that *Ganoderma lucidum* is a part of a variety of cosmetics products mostly in China, Korea, United States and a few other Asian and European countries, many being used for skin lightening.

Hyde *et al.* (2010) reported that various cosmetics facial mask on the market contain *Ganoderma lucidum* extracts which help to whiten the skin.

Meehan (2015) reported that *Ganoderma lucidum* was combined with three additional herbs and zinc to stimulate hair growth in human males by lowering dihydrotestosterone or prostatic hyperplasia levels.

Dong and Han (2015) reported that *Ganoderma lucidum* is used for functional foods in daily life such as soups, tea, wine and yoghurt. *Ganoderma lucidum* alone or in combined with other herbs like Chinese yam (*Dioscorea opposite*), magnolia berry (*Schisandra chinensis*) and desert-broomrape (*Cistanche deserticola*) can be used in herbal wine for balance the body and slow down the ageing process. *Ganoderma lucidum* is used to make tea, which can be consumed alone or in combination with other plants such as Japanese honeysuckle (*Lonicera japonica*), Chinese hawberry (*Crataegus pinnatifida*) and wolfberry (*Lycium barbarum*). *Ganoderma lucidum* combined with Panax ginseng (*Panax ginseng*) to make soups these soups are helping to calm tensions, relieve asthma and enhance the immune system.

Zhao (2015) reported that *Ganoderma lucidum* is mixed with sanqi (*Panax nostoginseng*) to make herbal Sanqi wine, which leads to increasing blood circulation and soothe nerves.

Ganoderma lucidum products are divided into three types; developmental products based on fruiting bodies **(Wasser, 2011),** mycelia **(He, 2000)** and spore powder **(Xie *et al.*, 2002).**

Perumal (2009) reported that the United States is the largest market for *Ganoderma lucidum* and related products.

Lai *et al.* (2004) and Li *et al.* (2016) reported that China is the largest producer and exporter with a capacity of over 1,10,000 MT/year of fruiting bodies, slices and spore powders as the most popular products among consumers. There are more than 100 research institutes dealing with the study of *Ganoderma lucidum* and more than 200 factories involved in the production of drugs and nutraceuticals**.** *Ganoderma lucidum* is varies from drugs, health liquor and dietary supplements to cosmetology products. These products are sold as prescription drugs in some Asian countries and mostly are advertised as dietary supplements in globally and the various types of *Ganoderma lucidum* products have been commercialised in globally with at least 100 brands and over 780 products available on global markets.

2.2 Physical properties of *Ganoderma lucidum* fruiting body

Ganoderma lucidum is a medicinal mushroom which has been collected in different shape, size and forms from around the world. *Ganoderma lucidum* fruiting body is composed of context, cutis and tube, which come in a various of colors and shapes such as; brown, yellowish-brown, dark brown, reddish-brown, puce light brown, and black as well as reniform, suborbicular, cochlear, hippocrepiform, flabelliform and other irregular shapes **(Du *et al.*, 2004).**

Veena and Pandey (2011) studied the morphological characteristics of *Ganoderma lucidum* fruiting body and observed that the pileal width (73-93 mm), pileal thickness (6.9-8.1 mm), stalk length (58-74 mm) and stalk thickness (5.8–7.3 mm) were not affected by the substrate formulation.

Roy *et al.* (2015) concluded that the fruiting body growth of *Ganoderma lucidum*, substrate Mahogani reached up to 14 cm in rice bran and wheat bran in 9 and 6 days after

primordial initiation respectively. After 18 days of primordial initiation, the total mycelial growth of Gerjan substrate was 13.5 cm with rice bran and 13 cm with wheat bran.

Gonzalez *et al.* (2015) studied that the *Ganoderma lucidum* mushroom morphology in two strains which was strain CP-145 (average pileus length 31-38 mm and width 45-65 mm) and strain CP-405 (average pileus length 27-55 mm and width 47-78 mm).

Kapoor and Sharma (2014) reported that the fruiting body of *Ganoderma lucidum* was usually large, stipitate, dimidiate, rarely suborbicular, reddish brown and their lateral and upper surface coated with a hard, shiny substance resembling sealing wax with the width of Pileus, length of the stem and thickness being 2.0-5.0 cm, 1.5-4.5 cm and 0.5- 2.0 cm respectively. Basidiospores are brown, ovate, with rounded base, truncate to a narrowly rounded apex and 10-12 x 6.5-8.0 µm in size.

Babu and Subhasree (2008) reported that *Ganoderma lucidum* mushroom's fruiting body is composed of three parts: a kidney-shaped cap, the mushroom's steam and spores**.**

Rawat (2018) reported that the fruiting bodies of *Ganoderma lucidum* are irregular in shape, kidney-shaped, copper red, brown-golden, brown, dark brown in color with Basidiospores size 6-9.08 µm×9.11-12 µm.

Du *et al.* (2004) reported that the pileus of *Ganoderma lucidum* is composed of context, cutis and tube, which come in a variety of colors and shapes, including light brown, yellowish-brown, brown, reddish-brown, dark brown, puce and black, as well as flabelliform, suborbicular, cochlear, reniform, hippocrepiform and other irregular shapes. Pileus has radial furrows of sizes, such as laccate or nonlaccate. The stipe is formed of hyphae and is classified as sessile, substipitate, or stipitate depending on whether the stipe is present or not. The stipe on pileus has a variety of attachment types, ranging from lateral to nearly central. The basidiospores have two walls, one that is colorless on the outside and dark brown on the inside. Basidiospores range in shape from ovoid to rectangular, with a truncate or untruncate apex.

Siwulski *et al.* (2015) reported that *Ganoderma lucidum* produces a fruiting body with a cap diameter ranging from (3-25 cm). The cap is lustrous, crimson, cherry-red, reddish-brown, or reddish-black in color and is flat, rounded, or kidney-shaped. The juvenile fruiting bodies are yellow-brown or yellow-red in color, but as they mature, they become darker. The stipe is lustrous and unevenly twisted, measuring 50-120 x 10-20 mm in size and taking on the same or darker color as the cap. Trimitic, spongy or corky, powdery, pale, beige, or brown in color, the hymenophore is trimitic. *Ganoderma lucidum* spores are ellipsoid or oval, with two covering layers: an external, colorless, smooth layer and an inside, yellowish-brown, lumpy layer, with a size range of 6-11 µm.

Bhatt *et al.* (2018) reported that the pileus of *Ganoderma lucidum* as 25-120 mm wide, elongated when young, more or less fan-shaped with maturity, surface smooth, glossy, shining, concentrically sulcate, yellowish brown to reddish brown in color. Tubes of *Ganoderma lucidum* whitish to brown, up to 10 mm deep, pore surface white to yellowish white, light brown to brown when bruised or on maturity, pore rounded to ovate, 5-7 per mm, pore surface white to yellowish white, light brown to brown when bruised or on maturity and stipe 35-110 x 10-25 mm, subcylindrical, concolorous with pileus to purplish brown, central to eccentric.

Stamets (1993) reported that the woody textured mushroom, which is 5-20 cm in diameter and has a shiny surface that seems lacquered when wet, has a conk-like or kidney-like shape. The color of the cap ranges from a dull red to a reddish brown and it can even be practically black. New growth is pale in color, changing to yellow brown and then reddish brown as it matures. When dry, the spores of *Ganoderma lucidum* have a powdery brown appearance and the spores size ranged between 13-17 µm in length and 7.5-10 µm in breadth **(**

Palanna *et al.* (2020) reported that the stems is white to yellow in color, gradually turning brown or black, eccentrically or laterally linked to the cap, usually sinuous and up to 10 cm long and 5 cm thick. The fruiting body of *Ganoderma lucidum* mushroom is

stipitate, dimidiate, or reniform and occasionally suborbicular, thick, corky, yellowish in margins that turn brownish with shiny laccate on the surface and basidiospores of *Ganoderma lucidum* are brown in color, oblong in shape with a rounded base and a truncate to narrowly rounded tip.

Kumar (2021) reported that the cap of *Ganoderma lucidum* is rounded to crescent, flat, rounded, fan or kidney formed, 2-20 cm in diameter, 4-8 cm thick, superior smooth surface, irregularly knobby or concentric waves, corky, rough, with or without stained emergence, shiny, red, cherry-red, reddish-brown or reddish-black in color, dark red to reddish brown or reddish black in middle. *Ganoderma lucidum* fruiting bodies have pores 2–20 mm long, pores minute, thick 4–7 μm, whitish while crisp, ripening or wounded, earthy color, surface yellowish cream, pore 6 mm for each, unpredictable, tuberous 3–5 mm long, unstratified, whitish brown. *Ganoderma lucidum* stipes are 3-14 cm long, 0.5-4 cm thick, turned, magnified at the base and have a similar shade or look to the cap surface. *Ganoderma lucidum* powder is light to dark brown, lenient, flexible, or gristly, with bits of cap plectenchyma, dark brown tube sections and basidiospores.

Seephueak *et al.* (2019) concluded that rubber sawdust supplemented with 15% palm oil sludge produced the largest pileus diameter (5.84 cm) followed by 5% rice bran in sawdust substrate (5.03 cm) and non-supplemented sawdust (1.34 cm).

Bijalwan *et al.* (2021) cultivated *Ganoderma lucidum* mushroom on *Populus deltoids* billets with an average stipe length of 2.29 cm and a fruiting body diameter of 3.7 cm in district Tehri Garhwal, Uttarakhand and an average stipe length of 2.42 cm and a fruiting body diameter of 4.28 cm in district Dehradun, Uttarakhand.

2.3 PHYSIOLOGICAL FACTORS

2.3.1 Temperature

Chen (1996) reported that *Ganoderma lucidum* species have been found in both subtropical and temperate region. A temperature of around 30°C allows rapid mycelium growth and reduces the time for fruiting body development.

Ganoderma lucidum fruiting bodies can grow at a temperature of 5-35°C. The ideal temperature for the growth of *Ganoderma lucidum* fruiting bodies in the matrix is 25–30°C, while the ideal temperature for basidiospore germination is 24–26°C. The fruiting bodies of *Ganoderma lucidum* grow normally at a temperature range 25–30°C and pileus deformity can be caused by extreme temperature changes **(Du *et al.*, 2019).**

Kapoor *et al.* (2014) examined the impact of temperature on mycelial growth of *Ganoderma lucidum* and they concluded that the temperature range 25-35°C was optimal for the most of *Ganoderma lucidum* strains mycelial development.

Singh *et al.* (2007) has recorded the natural growth of *Ganoderma lucidum* fruiting bodies in temperature range 25-30°C on the stumps of oak and some broad-leaved tree species.

Ralte *et al.* (2020) reported that the temperature range 26±2ºC for spawn run, 27±2°C for primordia initiation and stalk development, 25°C for cap differentiation and 27±2°C for maturation with light exposure lasting 10-12 hours was sufficient of *Ganoderma lucidum* growth.

Nayak *et al.* (2018) concluded that the temperature range 30-35°C was ideal for the fruiting body formation of *Ganoderma lucidum*.

Rawat (2018) recorded the maximum mycelial growth (8.72cm) at 25°C followed by 20°C (7.34cm) and 35°C (3.58cm) respectively. The optimal temperature range for mycelial growth was found to be between 20-25°C.

Zhou *et al.* (2012) reported that the temperature range 18-25°C for primordia initiation, 24-28°C for fruiting body development is suitable. The fruiting body of *Ganoderma lucidum* grows generally in temperature ranges 15-35°C and when the temperature drops below 20°C, the fruit body turns yellow and stops growing and **t**he temperature range 25-30°C ideal for fruiting body development.

Bijalwan *et al.* (2021) in his experiment, cultivated *Ganoderma lucidum* mushroom on *Populus deltoids* billets in two sites- Village Sherpur and Manjgaun, Uttarakhand with average temperature being 32°C and 28°C, respectively. They observed the shorter

cropping cycle with better yield of *Ganoderma lucidum* in Sherpur village.

Veena and Pandey (2012) reported that the optimal temperature range (21-27°C) was sufficient for *Ganoderma lucidum* growth.

2.3.2 Humidity

Du *et al.* (2019) reported that *Ganoderma lucidum* mushroom grows in moist environment and during the hyphae growth 65-70% relative humidity and 85-90% relative humidity for further growth of *Ganoderma lucidum* fruiting body was sufficient.

Chen (1996) reported that 90-95% relative humidity was ideal for the vegetative growth of *Ganoderma lucidum*.

Rani *et al.* (2015) concluded that after primordia formation, 85% relative humidity was ideal for fruiting body formation.

Gurung *et al.* (2012) concluded that for the fruiting body development of *Ganoderma lucidum,* 80-90% relative humidity was sufficient.

Gonzalez *et al.* (2015) reported that when the primordia formation stages begin, 70% relative humidity is ideal for cropping room.

Zhou *et al.* (2012) reported that *Ganoderma lucidum* is an annual fungus that can be found on a wide range of dead and decaying trees the best relative humidity is 60-70% for mycelium running, 85-90% for primordial initiation and 85-95% for fruiting body development.

Li *et al.* (2016) reported that the last step of the *Ganoderma lucidum* mushroom fruiting body formation process is a crucial component for fruiting body production and when the humidity level is high fruiting body developed properly.

Joshi and Sagar (2016) reported that 95% relative humidity was suitable for cropping chamber for better quality fruiting bodies production.

2.3.3 pH

Du *et al.* (2019) studied the ideal conditions for *Ganoderma lucidum* growth, in which they observed that the hyphae normally grow in pH ranges from 3-9 and the optimal

pH range for hyphae growth is 4.5-5.2. When the pH level is 8 hyphae will slow down and eventually stop developing and if the pH level is higher than 9 hyphae will stop growing. The pH range 5.0-5.5 is suitable for the *Ganoderma lucidum* mushroom mycelium running and primordia initiation (**Zhou and Lin, 1999; Hou and Liao, 2009; Zhou *et al.*, 2012**; **Kapoor *et al.*, 2014).**

Nayak *et al.* (2018) reported that *Ganoderma lucidum* requires a variety of conditions for development and cultivation a pH range 4.0-4.5 is ideal.

Joshi and Sagar (2016) concluded that the pH range 5.5-6.5 was found to be sufficient for mycelial growth.

Gurung *et al.* (2012) observed that the best growth of *Ganoderma lucidum* at the pH range of 5.5-6.5.

Lee *et al.* (2002) reported that the pH 4.2 is ideal for development of *Ganoderma lucidum* mushroom.

Singh *et al.* (2015) concluded that the pH value of 5.5 was most favorable for the growth of *Ganoderma lucidum* mycelium followed by 5.0, 6.0 and 4.5 respectively.

2.4 CULTIVATION TECHNOLOGY

In ancient times, *Ganoderma lucidum* was mainly collected from forests. However, in the past it was only cultivated in low quantities in the wild due to its high cost. Meanwhile in the late 1980s, small logs (15 cm or less) were introduced as a novel way of growth. Currently, this method has widely been used for *Ganoderma lucidum* production. Today, this technique is preferred by *Ganoderma* cultivators in China, Japan and Korea **(Kumar, 2021).**

In the past, *Ganoderma lucidum* was grown using 1m long natural wood logs that had not been sterilized. To harvest mature fruiting bodies on such substrates, a long incubation period of 2-3 years was required. Short logs have been used in developed new and improved techniques since the late 1980s. The time-saving short-log cultivation methods are now used practically by many *Ganoderma* natural-log producers (**Chen, 2002).**

2.4.1 Billets / logs preparation

Chen (1996) reported that the standard log size of 15 cm diameter and 15-24 cm long is commonly used in the cultivation of *Ganoderma lucidum* mushroom.

Mayzumi *et al.* (1997) reported that the natural wood log with a diameter of 15 cm and a length of 15 cm are used in Japan for *Ganoderma lucidum* cultivation.

Chen (1999) reported that in United States of America, 12.7 cm diameter and 20.3 cm long logs are used for *Ganoderma lucidum* cultivation.

Bijalwan *et al.* (2021) reported that the *Populus deltoids* billets with a length of 10-15 cm and a diameter of 4-5 cm was used for the production of *Ganoderma lucidum* fruiting bodies.

Huang (1997) reported that the natural logs with a dimension of 15 cm diameter and 18-24 cm length give better yield.

Chen and Chao (1997) reported that the natural wood logs with a diameter of 6-15 cm and a length of 15 cm are used for *Ganoderma lucidum* cultivation in China.

Singh *et al.* (2014) concluded that the billets of popular wood, 10-15 cm long and 4-5 cm diameter was suitable for cost effective cultivation of *Ganoderma lucidum.*

Du *et al.* (2019) observed that the wood logs with a diameter of 18-22 cm and a length of 15-28 cm are suitable for production of *Ganoderma lucidum* fruiting bodies.

Ke *et al.* (2019) obtained good results of *Ganoderma lucidum* fruiting bodies production from Linden wood logs about 30 cm long and 15–22 cm in diameter.

2.4.2 Spawn preparation

Joshi and Sagar (2016) studied the effect of various types of grain substrates on *Ganoderma lucidum* spawn development and spawn was prepared by a variety of cereal grains as substrates, including maize, barley, wheat, pearl millet and soybean. They concluded that the Barley grains was entirely covered by mycelium in the average spawn

production time (8 days) followed by pearl millet, wheat, maize and soybean respectively.

Rai (2003); Dadwal and Jamaluddin (2004) reported that wheat grains are the most common material for spawn production of *Ganoderma lucidum.*

Erkel (2009); Ralte *et al.* (2020) also reported that the wheat grains are suitable substrate for *Ganoderma lucidum* spawn preparation.

Nithya *et al.* (2014) concluded his experiment sorghum grains best material for mother spawn preparation.

2.4.3 Inoculation and spawning

Bijalwan *et al.* (2021) reported that the spawn @20 g/bag for the inoculation and a temperature 26±1°C and 60–70% relative humidity for incubation was found to be good for colonization of *Ganoderma lucidum* on *Populus deltoids* billets.

Thakur and Sharma (2015) reported that the substrate was inoculated with 15 g grain spawn and incubated at 28±2°C gives the complete colonization in 12 days.

Pauri (2011) reported that various doses of spawn @ 2,4,6,8and 10% of the weight of substrate was inoculated.

Gonzalez *et al.* (2015) reported that the substrate was inoculated @ of 200 g of each strain and five replicate bags were inoculated for each strain.

Erkel (2009) reported that the bags were incubated at 25±2°C without light exposure and the spawn run phase was completed in 12 days after inoculation.

Chen (1996) reported that 5-10 g *Ganoderma lucidum* spawn for each log is sufficient for spawning.

Veena and Pandey (2011) reported that substrate was inoculated @60 g/1kg and incubated in the dark at 30±2°C. The average spawn run time is between 18.8-22.8 days.

Siwulski *et al.* (2018) concluded that 10g of wheat grain spawn was sufficient for the spawning and substrate was incubated at a temperature of 25°C and 80–85% relative humidity.

Singh *et al.* (2014) concluded that after inoculation, the billets of poplar were completely colonized in 15-17 days.

2.4.4 Pinhead formation

Chen (1996) reported that *Ganoderma lucidum* primordia was appeared in 50-60 days after spawning in natural log cultivation and during primordia formation stage 100-200 lux light, 85-95% relative humidity and low oxygen levels was suitable.

Du *et al.* (2019) concluded that after inoculation of substrate the hyphae germinate in 2-3 days at a temperature of 20-22°C and temperature range 22–26°C suitable for hyphae growth.

Mehta *et al.* (2014) investigated that the mango sawdust produced the earliest primordia in (21±1 days) followed by Sheesham sawdust (24±0.58 days) and poplar sawdust (29±1 days) respectively.

Joshi and Sagar (2015) concluded that the pinhead initiation of *Ganoderma lucidum* was took 32.0-32.8 days after inoculation in pearl and barley millets respectively.

Roy *et al.* (2015) concluded that the substrate Mahogani and Gerjan took 33-35 and 36-40 days respectively for primordia formation with rice and wheat bran, whereas teak, beechwood and teak chambul sawdust had poor mycelial growth.

Gurung *et al.* (2012) studied about the sawdust of Sal and Sheesham with additives rice and wheat bran, corn flour and gram flour as a substrate for *Ganoderma lucidum* cultivation and they concluded that the *Alnus nepalensis* sawdust with additives took minimum time 43 days for primordia formation while *Shorea robusta* sawdust took maximum time 46 days for primordia formation.

Singh *et al.* (2014) concluded that the pinheads of *Ganoderma lucidum* mushroom was emerged in after 15-17 days of billet installation.

Bijalwan *et al.* (2021) found in his experiment, after colonizing the billets in soil the villages of Sherpur and Manjgaun, the pinheads began to emerge on 15-19 days and 19-22 days respectively.

Ralte *et al.* (2020) reported that during the pinning stage 27°C temperature, 75-85% relative humidity with light exposure 1100 lux for 10-12 hours was sufficient and they

concluded that the time taken for pinhead formation of *Ganoderma lucidum* in locally mixed sawdust + wheat bran 20% (21.8 d) followed by L.M.S. + R.B. 10% (26.4 d), L.M.S.+W.B. 10% (26.4 d), L.M.S.+ R.B. 20% (30.4 d) and L.M.S. without supplement (31.4 d) respectively.

Zohu *et al.* (2012) reported that *Ganoderma lucidum* is an annual fungus that grows in a broad range of non-living or living trees and during the pinning stage 18-25°C temperature, 85-90% relative humidity, 500-1000 lx light and adequate ventilation with low amount of oxygen are essential for pinhead initiation.

Gonzalez *et al.* (2015) concluded that after colonizing the substrate, *Ganoderma lucidum* primordia developed in 17-19 days and primordia appearance time was varies depending on the strain and substrate.

2.4.5 Cap formation

Ralte *et al.* (2020) reported that 25°C temperature and 75-85% relative humidity with a 1100 lux light for 10-12 hours are best for during the cap formation stage.

Rani *et al.* (2015) reported that 27°C temperature, 85% relative humidity and 800 lux lights with proper aeration are essential for during the cap formation stage.

Erkel (2009) concluded that during cap formation stage 30-32°C temperature, 85-90% relative humidity with a 10-hour light exposure were favorable and *Ganoderma lucidum* cap developed in 2-3 days, after opening the mouth of bags.

Veena and Pandey (2011) reported that during the cap formation stage 30±2°C temperature, 90–95% relative humidity with light and proper ventilation was sufficient for cropping chamber.

Bijalwan *et al.* (2021) concluded that after colonizing the billets in soil, village Sherpur took minimum time 43-47 and village Manjgaun took maximum time 47-51 days for cap formation.

Nithya *et al.* (2014) concluded that the cap stage of *Ganoderma lucidum* began in 4-5 days after pinhead initiation.

Joshi and Sagar (2015) also reported that the cap formation stage of *Ganoderma lucidum* began in 2-3 days, after pinhead initiation.

Thakur and Sharma (2015) observed that the cap of *Ganoderma lucidum* appears in 2-3 days, after opening the mouth of the bags and the temperature range 30-32°C, 85-90% relative humidity with a 10-hour light exposure is suitable for cap development.

Gurung *et al.* (2012) reported that 30-32°C temperature, 80-90% relative humidity and appropriate ventilation with light exposure was sufficient for cap development.

2.4.6 Fruiting body formation

Du *et al.* (2019) reported that during the pileus differentiation of *Ganoderma lucidum* required 26-28°C temperature, 90–95% relative humidity with proper ventilation and otherwise pileus differentiation would be slow down or the fruit body would be deformed. The fruiting body of *Ganoderma lucidum* develop early in a well-ventilated condition with a short stipe, thick pileus and high yield.

Bijalwan *et al.* (2021) concluded that the fruiting body of *Ganoderma lucidum* was completely formed in 60-65 days in the village Sherpur and 65-70 days in the village of Manjgaun.

Singh *et al.* (2014) concluded that after cap formation, the fruiting body of *Ganoderma lucidum* took 15-17 days for complete maturation and 55-60 days after spawning.

Li *et al.* (2016) reported that high relative humidity (85-95%) is essential for intact pileus development.

Rani *et al.* (2015) reported that 27°C temperature and 85% relative humidity with more than 800 lux light was sufficient for fruiting body formation and they observed that after 11^{th} days of primordia initiation the fruiting body of *Ganoderma lucidum* was formed.

Ralte *et al.* (2020) reported that during the fruiting body development and maturity stage, 27±2ºC temperature and 60-65% relative humidity with 10-12 hours light exposure

was suitable and they concluded that *Ganoderma lucidum* time taken for fruiting body development in various combinations of sawdust and supplements, after spawning in locally mixed sawdust + wheat bran 20% took (39.2 d) followed by L.M. S. + W.B. 10% (39.4 d), L.M.S.+ R.B. 10% (40.8 d), L.M.S.+ R.B. 20% (42.2 d) and L.M.S. without supplement (44.4 d) respectively.

Gonzalez *et al.* (2015) reported that for promoting the fruiting body growth of *Ganoderma lucidum,* the temperature range (25.3-27.8℃) and 70% relative humidity was suitable.

Zohu *et al.* (2012) reported that the optimum temperature range 24-28℃, 85-95% relative humidity, 15,000-50,000 lx. light level with proper ventilation is sufficient for fruiting body growth of *Ganoderma lucidum*.

Veena and Pandey (2011) reported that the temperature 30±2℃, 90–95 % relative humidity with 12 hours of light and 30 minutes appropriate ventilation is essential for fruiting body promotion of *Ganoderma lucidum*.

2.4.7 Harvesting

Singh *et al.* (2014) reported that the mature fruiting bodies of *Ganoderma lucidum* grew reddish brown from pale to golden in color are considered ready to harvest and they concluded that the fruiting bodies of *Ganoderma lucidum* took 70-80 days for harvesting in first crop from spawn run to fully development, while three flushes of *Ganoderma lucidum* took 130-140 days for harvesting.

Ralte *et al.* (2020) reported that during the maturity stage of *Ganoderma lucidum,* sporocarp produces spores and is visible around the fruiting bodies. When the fruiting bodies of *Ganoderma lucidum* was harvested the pileus was fully brownish-red and covered with spores.

Veena and Pandey (2011) reported that the average harvesting duration of *Ganoderma lucidum* fruiting bodies from three flushes was 90 days**.**

Roy *et al.* (2015) concluded that the first harvest days of *Ganoderma lucidum*

fruiting bodies for Mahogani and Gerjan with rice and wheat bran were 60-71 days and 66-90 days, respectively. After first harvest of *Ganoderma lucidum* fruiting bodies, the second, third and fourth harvests of *Ganoderma lucidum* fruiting bodies were harvested in every 18-20 days.

Nithya *et al.* (2014) reported that after 30 days of primordia initiation, the fruiting body of *Ganoderma lucidum* was harvested.

Zhou *et al.* (2012) reported that the complete growth cycle of *Ganoderma lucidum* mushrooms from spawning to fruiting body maturation is dependent on the cultivation method used and the fruiting bodies of *Ganoderma lucidum* usually took 90–150 days for harvesting.

Gonzalez *et al.* (2015) concluded on his experiment after spawning, the time taken for harvesting of *Ganoderma lucidum* mature basidiocarps in strains CP-145 (70 days) and CP-405 (72 days) respectively.

Chen (1996) reported that the fruiting body of *Ganoderma lucidum* took average 150-160 days in natural log cultivation for harvesting.

Gurung *et al.* (2012) concluded that the average initial harvest days for *Shorea robusta* and *Alnus nepalensis*, were 66 and 60 days respectively.

Du *et al.* (2004) reported that when the pileus stops developing, the color of the pileus is same as the stipe, the edge of the pileus has two or three layers of thickening line with brown basidiospore dispersal and the pore surface is brown to yellow, the fruiting body can be harvested.

Bijalwan *et al.* (2021) concluded that after installing the billets in soil, the fruiting bodies of *Ganoderma lucidum* in village Sherpur first crop were took 60-65 days and village Manjgaun took 65-70 days for harvesting while the average crop cycle of *Ganoderma lucidum* in village Sherpur 132–136 days with three flushes and village Manjgaun 141–145 days.

2.4.8 Yield potential / Biological efficiency

Ralte *et al.* (2020) reported that the total yield of *Ganoderma lucidum* fruiting bodies were calculated from two flushes in biological efficiency percentage (weight of fresh harvested mushroom/dry weight of the substrate) ×100 and on her experiment they concluded that fruiting bodies production of *Ganoderma lucidum* were locally mixed sawdust + wheat bran 20% (174.4 g/kg with BE 54.5%), followed by L.M.S.+W.B. 10% (171.7 g/kg with BE 53.5%), L.M.S.+R.B.% (163.5 g/kg with BE 51.9%), L.M.S.+R.B. 20% (145.5 g/kg with BE 46.8%)and L.M.S. without supplement (121.5 g/kg with BE 35%) respectively.

Veena and Pandey (2011) reported that the biological efficiency obtained ranged 25.7 % from (90% paddy straw and 10% rice bran) and 29.9% from (22.5% sawdust, 67.5% paddy straw and 10% rice bran) respectively. The dry recovery biological efficiency yield was found to be 24.1-29.8%.

Roy *et al.* (2015) concluded that the overall production from Mahogani and Gerjan supplemented with wheat bran was 235.2 g/kg and 210.9 g/kg, with biological efficiencies of 7.6% and 6.8% respectively. The overall production from Mahogani and Gerjan supplemented with straw bran was 132.9g/kg and 110.4g/kg, with biological efficiency of 4.3% and 3.6% respectively.

Nithya *et al.* (2014) reported that the yield of *Ganoderma lucidum* fruiting bodies was poor in wheat bran and teak sawdust combinations as compared to wheat straw and teak combinations, paddy straw and teak combinations produced the highest yield.

Joshi and Sagar (2015) concluded that the barley substrate was produced the maximum fruiting bodies yield of *Ganoderma lucidum* (65.24 g/kg).

Rani *et al.* (2015) said that the biological efficiency varies depending on the types of sawdust and bran used as well as their combinations and they concluded that the yield of *Ganoderma lucidum* fruiting bodies was obtained 42.06±2.14 g/packet with a biological efficiency of 8.41±0.48%.

Gonzalez *et al.* (2015) concluded that the fruiting bodies yield of *Ganoderma*

lucidum was obtained in two strains CP-405 (47.9g with BE 8.2%) and CP-145 (40.9g with BE 6.9%).

Seephueak *et al.* (2019) studied on the effects of palm oil sludge as a supplement with rubber sawdust for fruiting bodies production of *Ganoderma lucidum* and they obtained the maximum yield from rubber sawdust supplemented with 5% palm oil sludge (74.82 g/bag with BE 22.01 %) followed by 8% palm oil sludge (74.75 g/bag with BE 21.99 %), 10% palm oil sludge (71.88 g/bag with BE 21.14 %), 15% palm oil sludge (69.44 g/bag with BE 20.42 %) and 5% rice bran (66.31 g/bag with BE 19.50%), 20% palm oil sludge (65.06 g/bag with BE 19.14%) and control non-supplemented sawdust produced the lowest yield (33.37 g/bag with BE 9.81%) respectively.

Gurung *et al.* (2012) evaluated the impact of different types of sawdust supplement on yield of *Ganoderma lucidum* and they obtained the maximum yield from *Alnus nepalensis* sawdust (15.05 g/400 g with BE 15.69%) while *Shorea robusta* sawdust produced the lowest yield (1.5 g/400 g and BE 0.512%) and *Dalbergia sisoo* sawdust was not produce any yield.

Kaur *et al.* (2015) investigated the fruiting bodies yield of *Ganoderma lucidum* in three strains and they obtained the maximum yield in 5% level GL-2 with wheat bran supplement (91 g/bag with BE 13%) while strains GL-1 with wheat bran supplement produce minimum yield (72 g/bag with 10.3%) and strain GL-3 with wheat bran supplement did not produce any fruiting bodies yield.

Thakur and Sharma (2015) evaluated the optimal substrate for *Ganoderma lucidum* cultivation and they obtained the average highest yield from the 80% *Jacaranda mimosifolia* sawdust + 20% wheat bran (195 g/ kg with BE 27.9%) followed by 90% JMS+ 10% WB (174 g/kg with BE 24.9%) and 100% JMS produce lowest yield (99 g/kg with BE 14.2%) while average yield of JMS with various combinations of WB (156 g/kg with BE 22.33%). The average highest yield from 90% *Mangifera indica* sawdust+10% what bran

(176.5 g/kg with BE 25.2%) followed by 80% MIS+20% WB (151.8 g/kg with BE 21.7%) and 100% MIS produce lowest yield (88.2 g/kg with BE 12.6%) while average yield of MIS with various combinations of WB (138.83 g/kg with BE 19.83%). The average highest yield from 90% *Dalbergia Sissoo* sawdust +10% wheat bran (91.7 g/kg with BE 13.1%) followed by 100% DSS only (57.8 g/kg with BE 8.3%) and 80% DSS+20% WB produce lowest yield (49.4 g/kg with BE 7.1%) while average yield of DSS with various combinations of WB (66.3 g/kg with 9.50%) respectively.

Bijalwan *et al.* (2021) concluded that the fruiting bodies yield of *Ganoderma lucidum* in first crop from 50 billets was 160.1 g (dry weight) while the overall production of dried fruiting bodies from three flushes was 362.8 g and the average weight of the fruiting body was 3.02 g in village Sherpur. In village Manjgaun, the fruiting bodies yield of *Ganoderma lucidum* in first crop from 50 billets was 151.2 g (dry weight) while the overall production of dried fruiting bodies from three flushes was 316.5 g and the average weight of a fruiting body was 3.2 g.

Jeewanthi *et al.* (2017) concluded that the average yield of fruiting bodies in substrates Mango (100%), Rubber (100%), Rubber + Mango (50%:50%) and Rubber + Lunumidella (50%:50%) sawdust resulted in per bag (49.3 g, 42.5 g, 45.7 g and 43.7 g) with biological efficiency of (5.4%, 5.1%, 5.3%and 5.7%) respectively. The total highest yield of 3 months was resulted by 100% Mango sawdust (541.91 g/bag) followed by Rubber + Mango sawdust (502.37 g/bag), Rubber + Lunumidella sawdust (480.92 g/bag), Rubber (467.39 g/bag) and lowest yield Rubber + Jack sawdust mixture (289.08 g/bag) respectively.

Magday *et al.* (2014) concluded that the highest yield was obtained from 70% rice straw and 30% sawdust combinations (17.76 g) followed by 100% RS (17.40 g), 50% RS + 50% SD (16.14 g), 100% SD (14.64 g) and 30% RS + 70% SD (13.62 g) respectively.

Singh *et al.* (2014) reported that the total fruiting bodies yield of *Ganoderma lucidum* was obtained in BE 22%.

Mehta *et al.* (2014) reported that the Mango sawdust proved to be a superior substrate, yielding 1.5 times more than poplar sawdust which proved to be the least suited. Mango sawdust in combination with 20% wheat bran produces the highest yield with a biological efficiency of 58.57%.

Jo *et al.* (2013) investigated the effects of food waste compost on mycelial growth rate and fruiting body growth of *Ganoderma lucidum* and various FWC contents 0, 5, 10, 15, 20, 25, 30, 35and 40% were used. The FWC content 15% gave the highest FB yield (27.0±1.3 g/ bottles) and largest number of fruiting body yield, whereas the fruiting body yield in control FWC (20,25,30,35 and 40) was not better in the control FWC (5 or 10).

CHAPTER-3 MATERIALS AND METHODS

The present investigation entitled **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** was conducted at College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand. The details of the experimental materials and techniques employed during the investigation have been described in this chapter.

3.1 Experimental site

3.1.1 Study site

The present study was conducted at the College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India.

3.1.2 Cultivation site

3.1.2.1 Location

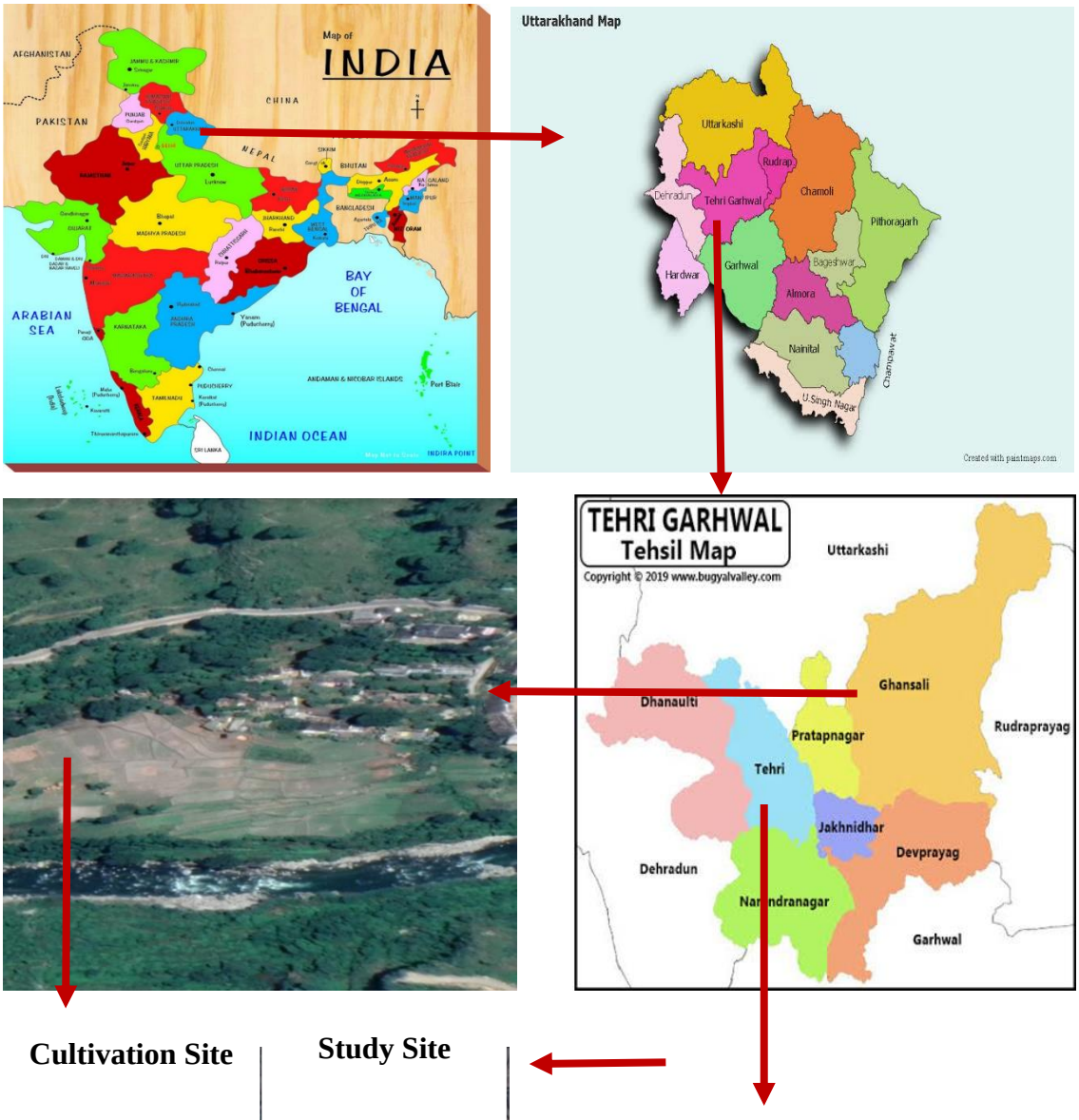
The cultivation site Silyara is situated at Bhilangna block, Tehri Garhwal, Uttarakhand. The cultivation site lies between 30°45 N latitude and 78°63 E longitudes in the mid-hill zones of Uttarakhand with the altitude of 965 masl.

3.1.2.2 Climate and Weather

The climate of the cultivation site is warm during the summer with average temperature (19-38°C) and cold in the winter with average temperature (6-22°C). The climatic conditions of the cultivation site were mildly hot during the months of June, July, August and September. The average daily temperature of the cultivation site was recorded (29±3°C).

3.2 Experimental materials and laboratory instruments

The following laboratory instruments and materials were used in this experiment: autoclave, laminar air flow, pH meter, sprit lamp, glassware, refrigerator, hygrometer, saw,



Source: Amazon.in

www.paintmap.com

www.bugyalvalley.com

Fig. 3.1 Location map of cultivation and study site

pruning saw, basula, sickle, measuring scale, butter paper, calcium carbonate, potassium D-chromate, sulfuric acid, formalin, ethyl alcohol, neem oil, cotton, rubber band, knife, tarpaulin sheet, wheat grains, electronic weighing balance and various sized polybags: (10cm width and 15cm height), (12×20 cm), (8×12 inch), (10×12 inch), (14×12 inch) and (18×12 inch).

Table-3.1 Tree species taken for *Ganoderma lucidum* cultivation

S. N.	Common name	Scientific name	Symbols
1	Peach	*Prunus persica*	S-1
2	Plum	*Prunus domestica*	S-2
3	Apricot	*Prunus armeniaca*	S-3
4	Oak	*Quercus leucotrichophora*	S-4
5	Bhimal / Beul	*Grewia optiva*	S-5
6	Poplar	*Populus deltoides*	S-6

Table-3.2 Wood billets / logs Size

S. N.	Length of Billets (cm)	Diameter of Billets (cm)	Symbols
1	16	4-5	D-1
2	16	5-6	D-2
3	16	6-7	D-3

Table-3.3 Treatments details

S. N.	Combinations	Combination details	Symbols
1	S-1×D-1	Peach billets size (4-5 cm)	T^1
2	S-1×D-2	Peach billets size (5-6 cm)	T^2
3	S-1×D-3	Peach billets size (6-7 cm)	T^3
4	S-2×D-1	Plum billets size (4-5 cm)	T^4
5	S-2×D-2	Plum billets size (5-6 cm)	T^5
6	S-2×D-3	Plum billets size (6-7 cm)	T^6
7	S-3×D-1	Apricot billets size (4-5 cm)	T^7
8	S-3×D-2	Apricot billets size (5-6 cm)	T^8
9	S-3×D-3	Apricot billets size (6-7 cm)	T^9
10	S-4×D-1	Oak billets size (4-5 cm)	T^{10}
11	S-4×D-2	Oak billets size (5-6 cm)	T^{11}
12	S-4×D3	Oak billets size (6-7 cm)	T^{12}
13	S-5×D-1	Bhimal billets size (4-5 cm)	T^{13}
14	S-5×D-2	Bhimal billets size (5-6 cm)	T^{14}
15	S-5×D-3	Bhimal billets size (6-7 cm)	T^{15}
16	S-6×D-1	Poplar billets size (4-5 cm)	T^{16}
17	S-6×D-2	Poplar billets size (5-6 cm)	T^{17}
18	S-6×D-3	Poplar billets size (6-7 cm)	T^{18}

3.3 Experimental methodology

3.3.1 Cleaning and Sterilization of Glassware

Neutral borosil glassware was used for laboratory work, which was cleaned with laboratory detergent and rinsed with tap water. Before usage, glassware was oven dried and dehydrated using dry heat at 180°C for 3 hours in a hot air oven after being wrapped in aluminium foil. The glassware was rinsed with distilled water after being washed with tap water. The glassware cleaning solution was made with the following components: 40 g of potassium D-chromate in 150 mL of water and then slowly add in the 230 ml of sulfuric acid.

3.3.2 Isolation and purification of Culture

Fresh basidiocarp was used to isolate the *Ganoderma lucidum* strain, which was then purified on potato dextrose agar media. The isolation experiment was carried out in a laminar air flow. To remove the dust and other undesired particles and then the fruiting body of *Ganoderma lucidum* was cleaned with cotton. It was then sliced into little pieces after being surface sterilised with 95% ethyl alcohol. A sterilised sharp blade was used to separate the fresh white border tissue from the basidiocarp. The size of the inoculums was fixed at approximately 3-5 mm^3. Small size bits were put aseptically into petri dishes containing 20 ml solidified PDA mixed with streptomycin sulphate to avoid the bacterial contamination. The petri dishes were incubated at a temperature 30°C until the mycelium had completely covered the plate. It was sub-cultured and then obtain a pure culture and stored in refrigerator on PDA slants for further study.

3.3.3 Spawn preparation

The mother spawn of *Ganoderma lucidum* was prepared by using wheat grains as per the procedure described by Singh *et al.* (2017). By sieving, winnowing, or hand plucking unwanted grains, the grains were cleaned to remove any broken, shrivelled grains. According to Borah *et al.* (2020) cleaning, rinsing and cooking the appropriate wheat grains takes around 30 minutes. After draining the excess water, 20g of calcium carbonate

(CaCO3) per kg of cooked cereal grain was added to speed up the growth of the spawn. The grains were than coated with CaCO3 to raise the pH above 7 and then fill the polypropylene bags with 200g/bag of processed substrate for spawn preparation. Cotton plugs were used to close the bags open ends, which was then covered with butter paper. The filled bags were then sterilised in an autoclave for 1-1.5 hours at 121°C (15 lb pressure/sq. inches). Thereafter, these bags were inoculated with an equal-sized mycelial bit of pure culture and incubated at 25±2°C until the mycelium covered the wheat grains.

3.3.4 Cultivation technology

3.3.4.1 Selection of tree species

Ganoderma lucidum is suitable for cultivating on most broadleaf trees. Trees with thick bast, hard material, less heartwood, developed wood rays, no aromatic sliva and rich duct branch are more suitable for cultivation of *Ganoderma lucidum* (Du *et al.*, 2004). In this experiment, six tree species; Peach, Palm, Apricot, Oak, Bhimal and Poplar were select for billet preparation.

3.3.4.2 Billets / Logs preparation

The length of billets was fixed at (16 cm) with three different diameters; (4-5 cm), (5-6 cm) and (6-7 cm) were used in this experiment for cultivation of *Ganoderma lucidum*. The branches of peach, palm, apricot, oak, bhimal and poplar were cut from trees with the help of a saw and pruning saw. After cutting the branches of these tree species, the wood was debarked with the help of a basula and a sickle. After that, fixed the length and diameter of the billets and cut the billets of these tree species. Then, debarked billets of the above species were submerged in a 1% malt solution for about 24 hours. Afterwards, the billets were removed from the malt solution and sun dried properly till the moisture content of the billets was approximately 35%–45%.

3.3.4.3 Bagging and sterilization

After drying the billets, the billets were tied according to diameter and put into polypropylene bags after ensuring the sections flat and tight. Wood billets of all six species

were filled into polypropylene bags and tied at the mouth of the bags with the help of rubber bands. After that, these billet packets were kept inside and autoclaved for sterilisation at 121°C temperature and 15 psi pressure for 2-3 hours (Bijalwan *et al.,* 2021). After sterilization, the billet packets were kept for cooling at room temperature.

3.3.4.4 Inoculation

After sterilisation and cooling of the wooden billets, inoculation was carried out in a clean and dry place to avoid uninvited contamination (Gimenez, 2017). The billets of Peach, Plum, Apricot, Oak, Bhimal and poplar species were inoculated with *Ganoderma lucidum* spawn inside the laminar air flow. The inoculation amount of spawn for each wood log is about 5-10 g, which is sufficient for mycelial colonization reported by (Du *et al.,* 2004). In this experiment, the spawn was inoculated at a rate of 30 g per packet.

3.3.4.5 Colonization

After inoculation, the mouth of the bags was plugged with non-absorbent cotton and tied airtight with the help of a rubber band. These bags were kept at a constant 28-32°C temperature to grow the mycelium for about 15 days (until the bags turn completely white). The key management for 15 days was mainly ventilation, lowering humidity and preventing the invasion of mixed microorganisms. The spawn run was carried out in darkness and less oxygen was provided. After about 15 days, mycelium run billets was ready for the cultivation of *Ganoderma lucidum*.

3.3.4.6 Preparation of soil

After spawning, garden soil was collected and filtered through metal wire mesh and then mixed with sand in the ratio of 4:1 (soil and sand). The sand was mixed into the soil to improve the drainage of the soil. Then, lime at the rate of 0.5% of soil weight was mixed for solarization. After mixing the lime into the soil, soil was covered with a tarpaulin sheet and exposed to sunlight for solarization for at least one day so that the harmful organisms present in the soil was destroyed.

3.3.4.7Installation of billets in soil

After preparing the soil, the soil was filed into polybags and the billets were then installed in these polybags. The billet installed polybags were transferred to the cultivation room under dark conditions and watered the next day of billet installation. Before transferring the polybags to the cultivation room, after cleaning the room, formalin was sprayed so that the room becomes clean without germs.

3.3.5 Management of cropping room for fruiting body development

Management of the cropping room was very important for the production of good quality fruiting bodies. Management was very important to control the temperature, humidity and ventilation of the cropping room so that a good quality fruit body can be produced. The temperature range 25-35°C, 60-90% air relative humidity and proper ventilation is essential for obtaining high quality fruiting bodies and a lower temperature reduces the quality of the fruiting body (Du *et al.*, 2004). Various growth stages of *Ganoderma lucidum* development are described as below:

3.3.5.1 Pinhead formation stage

After installation of *Ganoderma lucidum* mycelium run billets into the soil, the polypropylene bags were kept in a dark room with proper ventilation until the pinheads of the *Ganoderma lucidum* mushroom start to appear. After 8-12 days of billets installation, small pinheads (1-3 cm) white in colour was start to appear on the upper surface of the polypropylene bags.

3.3.5.2 Cap formation stage

After emergence of the pinheads, the upper part of pinheads was becoming grew round shaped like an umbrella with a flat upper surface and white in colour.

3.3.5.3 Fruiting body development stage

After 20-30 days of pinhead emergence, the upper surface of the cap was beginning to turn a dark red brown and shiny in colour. At this stage, the fruiting body of *Ganoderma lucidum* mushroom was completely developed.

3.3.5.4 Harvesting

After shedding the spore powder, the fruiting bodies of *Ganoderma lucidum* was ready for harvest. The fruiting bodies of *Ganoderma lucidum* were harvested with the help of a sterilised knife. The first crop of *Ganoderma lucidum* mushroom took about 40-50 days, second crop (60-70 days) and third crop (75-100 days) for harvesting, from the spawning.

3.3.6 Weighing of fruiting bodies

The freshly harvested fruiting body and after dried the fruiting body of *Ganoderma lucidum* were weighed with the help of electronic weighing machine with a sensitivity of (0.01 g).

3.3.7 Biological efficiency

The total fresh weight of all harvested fruiting bodies of *Ganoderma lucidum* from the three flushes was measured as the total yield of the mushroom. The following formula was used to calculate the biological efficiency (Ahmed *et al.*, 2008).

B. E. (%) = fresh weight of fruiting body/ dry weight of substrate×100

3.3.8 Storage and packaging

The harvested fruiting bodies of *Ganoderma lucidum* mushroom was properly dried for 2-3 days with the help of sunlight. After sun drying, the fruiting bodies of *Ganoderma lucidum* were packed into airtight polybags with the help of rubber bands and kept stored in a dry place.

3.4 Statistical analysis

The cropping room experiment data analysed according to the procedure of analysis of variance for two factorial completely randomized design (CRD) with three replications, six wood species and three type dimensions billets of each species. Data was recorded on different growth stages of *Ganoderma lucidum* was subjected to analysis using the statistical software (SAS-JMP trial version 16.1.0). The critical difference (5% level of

significance) was calculated to compare the mean. The analysis of variance (ANOVA) procedure was used to test for significant effect of treatments, species and interaction of species and diameter.

3.5 Observation recorded

3.5.1 Growth performance

The time taken by each fruiting body during the various growth stages of *Ganoderma lucidum* such as pinhead formation, cap formation, fruiting body development and harvesting stages were recorded.

3.5.2 Physical properties of *Ganoderma lucidum* fruiting bodies

3.5.2.1 Observe the physical appearance of *Ganoderma lucidum* fruiting bodies in different wood billets.

Physical appearance of fruiting bodies like colour, shape and texture were observed in all wood billets. Changes in colour and overall physical appearance were observed at each growth stage.

3.5.2.2 Pinhead length, Stipe length and diameter of the *Ganoderma lucidum* fruiting at different growth stages.

Pinhead length, cap diameter, stipe length and mature fruit body diameter of all wood species was measured in different *Ganoderma lucidum* growth stages.

3.5.3 Weight of fruiting bodies

After harvesting the fruit body, the fresh harvested fruit bodies and the dried fruit bodies were weighed with the help of an electric weighing balance with sensitivity (0.01g).

3.5.3.1 Total fresh yield of fruiting body from each billet of all wood species.

The fresh harvested fruiting bodies of *Ganoderma lucidum* was weighed from each billet of all wood species.

3.5.3.2 Total dry yield of fruiting bodies from each billet of all wood species.

The dried fruiting bodies of *Ganoderma lucidum* was weighed from each billet of all wood species.

3.5.4 The total number of pinheads emerged and obtained fruiting bodies counted.

The total number of pinheads emerged and fruiting bodies obtained from each billet of all wood species were counted.

CHAPTER-4 RESULTS AND DISCUSSION

The results of the study entitled **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** have been described and discussed in this chapter under different objectives as stated earlier.

4.1 To cultivate the medicinal mushroom *Ganoderma lucidum* on different wooden billets and compere the growth performance.

4.2 To compare the physical properties at different growth stages of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

4.3 To compare the production potential/biological efficiency of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

4.1 To cultivate the medicinal mushroom *Ganoderma lucidum* on different wooden billets and compere the growth performance.

4.1.1 Mycelial colonization

The time taken by billets inoculated with *Ganoderma lucidum* spawn for complete mycelial colonization in different wood species were studied and the observations are presented in table 4.1.

Table-4.1: Time period (days) for 50% and 100% mycelial colonization of *Ganoderma lucidum* in different wood billets

Species	S-1 (Peach)	S-2 (Plum)	S-3 (Apricot)	S-4 (Oak)	S-5 (Bhimal)	S-6 (Poplar)
Time period for 50% colonization (days)	8	7	5	8	6	7
Time period for 100% colonization (days)	15	12	11	14	13	14

The complete mycelial colonization of inoculated billets took place between 11 to 15 days on different wood species. Time taken for 50% and 100% colonization in different wood species was recorded. Earliest (50%) colonization was recorded in Apricot billets (5 days) followed by Bhimal billets (6 days), Plum and Poplar billets (7 days) and Peach and Oak billets (8 days). However, Apricot billets was the earliest to complete the colonization in 11 days followed by Plum billets (12 days), Bhimal billets (13 days), Oak and Poplar billets (14 days) and Peach billets (15 days).

Our investigations were having relevance to the studies being reported by **Singh *et al.* (2014)** who concluded that the billets of poplar were completely colonized in 15-17 days. Similar results for complete mycelial colonization of *Ganoderma lucidum* in different substrate were also reported by **Thakur and Sharma (2015)** wherein he recorded the complete mycelial colonization of *Ganoderma lucidum* in 12 days. **Erkel (2009)** also concluded the completion of spawn run phase in 12 days after inoculation. On other hand, **Veena and Pandey (2011)** concluded that the average spawn run time is between 18.8-22.8 days whilst the investigation carried out by **Ralte *et al.* (2020)** showed the complete span run in between 17.4-24 days. On the contrary, **Roy *et al.* (2015)** concluded that sawdust of *Michelia champaca, Tectona grandis* and *Dipterocarpus turbinatus* took 12, 15 and 18 days for complete mycelial colonization respectively.

4.1.2 Pinhead formation

The time taken by billets inoculated with *Ganoderma lucidum* spawn for pinhead formation in different wood species billets were studied and the observations of three crops are presented in table 4.2.

After installation of *Ganoderma lucidum* mycelium run billets into the soil, time period for pinhead formation in different wood species S-1 (Peach), S-2 (Plum), S-3 (Apricot), S-4 (Oak), S-5 (Bhimal) and S-6 (Poplar) billets with different diameter D-1 (4-5 cm), D-2 (5-6 cm) and D-3 (6-7 cm) were studied. The significance of time period for pinhead formation in different wood species, different type of diameter and interaction of

Table-4.2: Time taken by billets inoculated with *Ganoderma lucidum* spawn for pinhead formation in different wood species billets (days)

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	6.66	6.66	7.33	8.00	7.50	7.00	7.19
D-2	7.83	7.66	7.33	7.33	7.50	7.33	7.49
D-3	8.83	7.33	7.33	7.33	5.33	7.33	7.24
Mean species	7.77	7.21	7.33	7.55	6.77	7.22	7.31
CD values (at 5% levels): Species: NS; Diameter: NS; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	6.50	6.66	8.00	7.00	5.50	5.16	6.47
D-2	6.33	6.16	8.50	7.00	6.16	6.50	6.77
D-3	6.83	6.83	7.83	6.83	6.00	6.16	6.74
Mean species	6.55	6.55	8.11	6.94	5.88	5.94	6.66
CD values (at 5% levels): Species: 0.94; Diameter: NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	5.16	4.00	4.16	3.83	4.00	5.66	4.46
D-2	6.33	6.33	4.98	5.33	5.16	6.50	5.77
D-3	6.00	5.50	5.50	6.50	4.83	5.33	5.61
Mean species	5.83	5.27	4.88	5.22	4.66	5.83	5.28
CD values (at 5% levels): Species: NS; Diameter: NS; Species × Diameter: NS							

species and diameter were varied nonsignificant in first crop. Result presented in table 4.2 indicates that earliest pinhead formation was observed in Peach and Plum billets (6.66 days) with the Oak billets (8.0 days) being last in D-1 diameter. In D-2 diameter, Apricot, Oak and Poplar billets took minimum time (7.33 days) for pinhead formation while the Peach billets was the maximum (7.83 days). In D-3 diameter, initial pinhead formation was observed in Bhimal billets (5.33 days) and Peach billets (8.83 days) was the last. The

overall results indicates that Bhimal billets (6.77 days) was the earliest to attain the pinhead formation followed by Plum billets (7.21 days), Poplar billets (7.22 days), Apricot billets (7.33 days), Oak billets (7.55 days) and Peach billets (7.77 days). In different diameter, diameter D-1 billets (7.19 days) was the earliest to attain pinhead formation followed by diameter D-3 billets (7.24 days) and diameter D-2 billets (7.49 days).

The time taken for pinhead formation in different wood species was varied significant while different diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.2 indicates that Poplar billets took minimum time (5.16 days) for pinhead formation while the Apricot billets took maximum time (8 days) in D-1 diameter. In D-2 diameter, Plum and Bhimal billets (6.16 days) were the earliest to attain pinhead formation while the Apricot billets (8.5 days) were the last. In diameter D-3, first pinhead initiation was started in Bhimal billets (6.00 days) with Apricot billets (7.83 days) being last. Results indicates that different wood species varied significant in each other, Bhimal billets (5.88 days) were the quickest to reach for pinhead formation while the Apricot billets (8.11 days) were the last. However, Bhimal billets (5.88 days) were earliest to reach for pinhead formation followed by Poplar billets (5.94 days), Peach and Plum billets (6.55 days), Oak billets (6.94 days) and Apricot billets (8.11 days). In different diameter, diameter D-1 billets took minimum time (6.47 days) for pinhead formation followed by diameter D-3 billets (6.74 days) and diameter D-2 billets (6.77 days).

The significance of time taken to attain the pinhead formation stage in different wood species, different type of diameter and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.2 indicates that Oak billets (3.83 days) were first to reach the pinhead formation stage with Poplar billets (5.66 days) being last in D-1 diameter. In D-2 diameter, the earliest pinhead formation stage was observed in Apricot billets (4.98 days) and Poplar billets (6.50 days) were the last. In D-3 diameter, Bhimal billets (4.83 days) were earliest to reach the pinhead formation stage and Oak billets (6.50 days) were the last. Result indicates that, first pinhead formation stage was observed in Bhimal billets (4.66 days) while the Peach and Poplar billets (5.83 days) were

the last. However, Bhimal billets (4.66 days) were quickest to reach the pinhead formation stage followed by Apricot billets (4.88 days), Oak billets (5.22 days), Plum billets (5.27 days) and Peach and Poplar billets (5.83 days). In different diameter, diameter D-1 billets (4.46 days) were first to reach the pinhead formation stage followed by diameter D-3 billets (5.61 days) and diameter D-2 billets (5.77 days).

The primordia appearance time varies depending on the strains and substrates was reported by **Gonzalez *et al.*, (2015)** wherein they concluded that primordia of *Ganoderma lucidum* was developed in 17-19 days after colonizing the substrate**.** Our results are in line with **Singh *et al.* (2014)** who reported that the pinheads of *Ganoderma lucidum* was emerged in 15-17 days after billet installation, **Joshi and Sagar (2015)** also reported that after inoculation pinhead was initiated in 32.0-32.8 days. Similarly, **Bijalwan *et al.* (2021)** concluded that after installation of the billets into soil, pinheads of *Ganoderma lucidum* began to emerge on 15-22 days. On the country, **Roy *et al.* (2015)** concluded that after colonizing the substrate, Mahogani and Gerjan took 33-35 and 36-40 days for primordia formation respectively. On other hand, **Du *et al.* (2019)** reported that after inoculation, hyphae germinated in 2-3 days at a temperature of 20-22°C. **Mehta *et al.* (2014)** concluded that after inoculation, mango sawdust produced the earliest primordia in (21±1 days) followed by Sheesham sawdust (24±0.58 days) and poplar sawdust (29±1 days) respectively.

4.1.3 Cap formation

Pinheads of *Ganoderma lucidum* time taken for cap formation in different wood species billets were studied and the observations are presented in table 4.3.

After pinhead formation of *Ganoderma lucidum,* time taken for cap formation in different wood species was varied significant, different type of diameter and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.3 indicates that Poplar billets (6.16 days) were earliest to reach the cap formation stage and Oak billets (10.33 days) were the last in D-1 diameter. In D-2 diameter, first cap formation stage was observed in Bhimal billets (6.16 days) with the Apricot billets (9.33 days) being last.

Table-4.3: Time taken (days) for attaining cap formation stage in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	9.50	8.66	9.50	10.33	7.00	6.16	8.85
D-2	8.33	8.00	9.33	8.83	6.16	7.00	7.94
D-3	9.83	8.83	9.00	12.16	7.00	7.33	9.02
Mean species	9.22	8.49	9.27	10.44	6.72	7.49	8.60
CD values (at 5% levels): Species: 1.19*; Diameter: NS; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	8.70	7.66	8.66	8.50	7.50	7.16	8.03
D-2	8.83	7.50	8.33	9.33	7.16	7.16	8.05
D-3	10.0	8.50	9.16	9.66	7.50	7.33	8.69
Mean species	9.17	7.88	8.71	9.16	7.38	7.21	8.25
CD values (at 5% levels): Species: 1.17*; Diameter: 0.83*; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	8.16	4.00	4.50	4.83	4.33	6.83	5.44
D-2	6.83	7.16	6.67	8.16	6.83	6.66	7.05
D-3	8.00	7.16	7.50	8.16	6.00	7.50	7.38
Mean species	7.66	6.10	6.22	7.05	5.72	6.99	6.62
CD values (at 5% levels): Species: NS; Diameter: 1.59; Species × Diameter: NS							

In D-3 diameter, Bhimal billets took minimum time (7.0 days) for cap formation stage and Oak billets were the maximum (12.16 days). Result indicates that different wood species showed significant variation in each other, Bhimal billets (6.72 days) were earliest to reach the cap formation stage while Oak billets (10.44 days) were the last. However, first cap formation stage was observed in Bhimal billets (6.72 days) followed by Poplar billets (7.49 days), Plum billets (8.49 days), Peach billets (9.22 days), Apricot billets (9.27 days) and

Oak billets (10.44 days). In different diameter, diameter D-2 billets were earliest to reach the cap formation stage (7.94 days) followed by diameter D-1 billets (8.85 days) and diameter D-3 billets (9.02 days).

Pinheads of *Ganoderma lucidum* time taken for cap formation in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.3 indicates that firstly cap formation stage was observed in Poplar billets (7.16 days) and Peach billets (8.70 days) was the last in D-1 diameter. In D-2 diameter, Bhimal and Poplar billets (7.16 days) was earliest to reach the cap formation stage and Oak billets (9.33 days) was the last. In D-3 diameter Poplar billets took minimum time (7.33 days) for cap formation stage with the Peach billets being maximum (10.0 days). Result indicates that different wood species varied significant in each other, firstly cap formation stage was observed in Poplar billets (7.21 days) while the peach billets (9.17 days) was the last. However, Poplar billets (7.21 days) was earliest to reach the cap formation stage followed by Bhimal billets (7.38 days), Plum billets (7.88 days), Apricot billets (8.71 days), Oak billets (9.16 days) and peach billets (9.17 days) respectively. In different diameter, diameter D-1 billets were earliest to attain the cap formation stage (8.03 days) followed by D-2 (8.05 days) and diameter D-3 (8.69 days) respectively.

Pinheads of *Ganoderma lucidum* time taken for cap formation in different wood species, interaction of species and diameter was varied nonsignificant and different type of diameter was varied significant in third crop. Result presented in table 4.3 indicates that first cap formation stage was started in Plum billets (4.0 days) with the Peach billets (8.16 days) being last in D-1 diameter. In D-2 diameter, Poplar billets (6.66 days) were earliest to reach the cap formation stage and Oak billets (8.16 days) were the last. In D-3 diameter, Bhimal billets took minimum time (6.0 days) for cap formation stage and Oak billets were the maximum (8.16 days). Result indicates that Bhimal billets (5.72 days) were earliest to reach the cap formation stage while the Peach billets (7.66 days) were the last. However, first cap formation stage was started in Bhimal billets (5.72 days) followed by Plum billets (6.10 days), Apricot billets (6.22 days), Poplar billets (6.99 days), Oak billets (7.05) and

Peach billets (7.66 days). In different diameter, diameter D-1 billets was earliest to reach the cap formation stage (5.44 days) followed by diameter D-2 (7.05 days) and diameter D-3 (7.38 days).

The results were in accordance with the finding of **Nithya *et al.* (2014)** wherein they observed that the cap stage of *Ganoderma lucidum* began in 4-5 days after pinhead initiation. Cap development of *Ganoderma lucidum* began in 2-3 days, after pinhead initiation was also reported by **Joshi and Sagar (2015).** The results obtain in the present study are in line with **Erkel (2009)** who reported that after opening the mouth of bags, *Ganoderma lucidum* cap developed in 2-3 days. Similarly, **Thakur and Sharma (2015)** investigated that *Ganoderma lucidum* cap appeared in 2-3 days, after primordia initiation. On other hand, **Bijalwan *et al.* (2021)** concluded that after installation of the billets into soil, pinheads of *Ganoderma lucidum* took place between 43-51 days for cap formation and **Chen (1996)** also reported that the cap formation took 20-25 days, after primordia initiation in natural logs cultivation.

4.1.4 Fruiting body formation

Cap stage of *Ganoderma lucidum* time taken for formation of fruiting body in different wood species billets were studied and the observations are presented in table 4.4.

Cap stage of *Ganoderma lucidum* time taken for formation of fruiting body in different wood species was varied significant, different type of diameter and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.4 indicates that Plum billets took minimum time (8.50 days) for fruiting body formation and Oak billets were the maximum (11.83 days) in D-1 diameter. In D-2 diameter, earliest fruiting body formation was observed in Bhimal billets (7.83 days) and Poplar billets (10.50 days) were the last. In D-3 diameter, Bhimal billets (7.33 days) were earliest to reach the fruiting body formation stage with Oak billets (14.50 days) being last. Result indicates that different wood species showed significant variation in each other, Bhimal billets took minimum time (7.88 days) for fruiting body formation while the Oak billets being highest

Table-4.4: Cap stage of *Ganoderma lucidum* time taken (days) for formation of fruiting body in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	9.16	8.50	11.00	11.83	8.50	9.50	9.74
D-2	8.33	10.16	10.33	10.00	7.83	10.50	9.52
D-3	9.83	12.83	9.50	14.50	7.33	9.50	10.58
Mean species	9.10	10.49	10.27	12.11	7.88	9.83	9.95
CD values (at 5% levels): Species: 1.88*; Diameter: NS; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	10.00	11.00	8.33	9.83	8.16	8.16	9.24
D-2	8.66	8.33	8.16	8.83	8.33	9.83	8.69
D-3	8.83	10.00	8.66	10.50	8.16	9.50	9.07
Mean species	9.16	9.77	8.38	9.72	8.21	9.16	9.07
CD values (at 5% levels): Species: NS; Diameter: NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	8.83	7.00	4.50	6.50	4.50	8.50	6.63
D-2	8.66	9.33	7.16	9.50	8.66	8.33	8.60
D-3	9.00	9.83	9.00	10.00	8.16	8.66	9.10
Mean species	8.83	8.72	6.88	8.66	7.10	8.49	7.84
CD values (at 5% levels): Species: 2.60*; Diameter: 1.84*; Species × Diameter: NS							

(12.11 days). However, first fruiting body formation stage was observed in Bhimal billets (7.88 days) followed by Peach billets (9.10 days), Poplar billets (9.83 days), Apricot billets (10.27 days), Plum billets (10.49 days) and Oak billets (12.11 days). In different diameter, diameter D-2 billets took minimum time (9.52 days) for fruiting body formation followed by diameter D-1 (9.74 days) and diameter D-3 (10.58 days).

Cap stage of *Ganoderma lucidum* time taken for formation of fruiting body in different wood species, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.4 indicates that first fruiting body formation stage was observed in Bhimal and Poplar billets (8.16 days) and Plum billets (11.0 days) were the last in D-1 diameter. In D-2 diameter, Apricot billets (8.16 days) were earliest to reach the fruiting body formation with Poplar billets (9.83 days) being last. In D-3 diameter, Bhimal billets took minimum time (8.16 days) for fruiting body formation and Oak billets were the maximum (10.50 days). Result indicates that Bhimal billets (8.21 days) was earliest to reach the fruiting body formation stage while the Plum billets (9.77 days) was the last. However, firstly fruiting body formation stage was observed in Bhimal billets (8.21 days) followed by Apricot billets (8.38 days), peach and Poplar billets (9.16 days), Oak billets (9.72 days) and Plum billets (9.77 days). In different diameter, diameter D-2 billets took minimum time (8.69 days) for fruiting body formation followed by diameter D-3 billets (9.07 days) and diameter D-1 billets (9.24 days).

Cap stage of *Ganoderma lucidum* time taken for formation of fruiting body in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.4 indicates that Apricot and Bhimal billets took minimum time (4.50 days) for fruiting body formation and Peach billets were the maximum (8.83 days) in D-1 diameter. In D-2 diameter, first fruiting body formation stage was observed in Apricot billets (7.16 days) with Oak billets (9.50 days) being last. In D-3 diameter, Bhimal billets (8.16 days) were earliest to reach the fruiting body formation stage and Oak billets (10.0 days) were the last. Result indicates that different wood species and diameter showed significant variation in each other, Apricot billets (6.88 days) were earliest to reach the fruiting body formation stage while the Peach billets (8.83 days) being the last. However, first fruiting body formation stage was observed in Apricot billets (6.88 days) followed by Bhimal billets (7.10 days), Poplar billets (8.49 days), Oak billets (8.66 days), Plum billets (8.72 days) and Peach billets (8.83 days). In different diameter, diameter D-1 billets took minimum time

(6.63 days) for fruiting body formation followed by diameter D-2 billets (8.60 days) and diameter D-3 billets (9.10 days).

Our experimental results are in line with **Rani *et al.* (2015)** wherein they reported that the fruiting body of *Ganoderma lucidum* was formed on 11th days of after primordia initiation. Similarly, **Singh *et al*. (2014)** concluded that fruiting body of *Ganoderma lucidum* took 15-17 days for fruiting body development, after cap formation and 55-60 days, after spawning. On the country, **Bijalwan *et al.* (2021)** concluded that the fruiting body of *Ganoderma lucidum* was completely formed in average 60-70 days, after billets installation and **Chen (1996)** also reported that the fruiting body of *Ganoderma lucidum* took 25 days for pileus differentiation, after primodia initiation in natural logs cultivation. On other hand, **Ralte *et al.* (2020)** concluded that the fruiting body of *Ganoderma lucidum* took average (39.2-44.4 days) for fruiting body development in locally mixed sawdust with various doses of rice and wheat bran, after spawning.

4.1.5 Harvesting

Fruiting body of *Ganoderma lucidum* time taken for harvesting in different wood species billets were studied and the observations are presented in table 4.5.

Fruiting body of *Ganoderma lucidum* time taken for harvesting in different wood species, interaction of species and diameter was varied significant and different diameter was varied nonsignificant in first crop. Result presented in table 4.5 and figure 4.1 indicates that Bhimal billets (36.0 days) were earliest to reach the harvesting and Oak billets (43.6 days) were the last in D-1 diameter. In D-2 diameter, Bhimal billets (34.50 days) were first to reach the harvesting and Oak billets (39.16 days) were the last. In D-3 diameter, Bhimal billets took minimum time (32.66 days) for harvesting with Oak billets (47 days) being last. Result indicates that different wood species and interaction of species and diameter showed significant variation in each other, Bhimal billets (34.38 days) were earliest to reach the harvesting while the Oak billets (43.10 days) being last. However, Bhimal billets (34.38 days) were first to reach the harvesting followed by Apricot and Poplar billets (37.88 days), Plum billets (38.22 days), Peach billets (40.11 days) and oak billets (43.10

days). In different diameter, diameter D-2 billets took minimum time (37.80 days) for harvesting followed by diameter D-1 billets (38.30 days) and diameter D-3 billets (39.69 days).

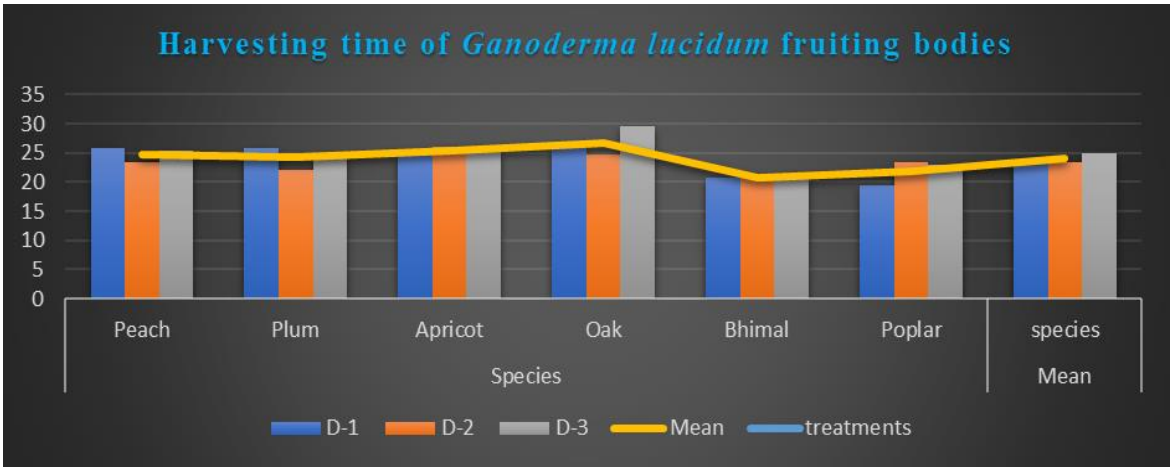


Fig. 4.1 Fruiting body of *Ganoderma lucidum* time taken for harvesting in first crop

Fruiting body of *Ganoderma lucidum* time taken for harvesting in different wood species was varied significant, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop.

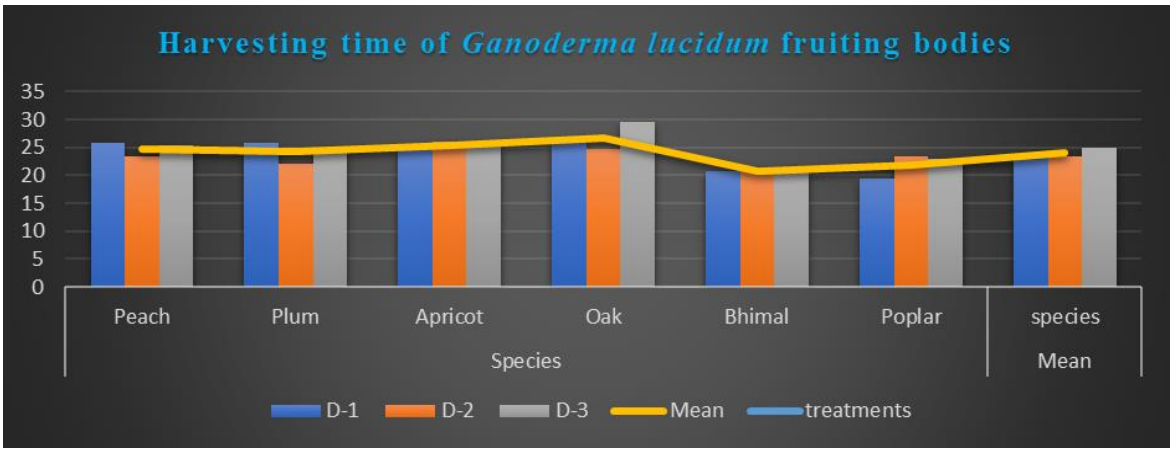


Fig. 4.2 Fruiting body of *Ganoderma lucidum* time taken for harvesting in second crop

Result presented in table 4.5 and figure 4.2 indicates that Poplar billets took minimum time (19.50 days) for harvesting and Oak billets were the maximum (26.0 days) in D-1 diameter. In D-2 diameter, Bhimal billets (20.66 days) were first to reach the harvesting with Apricot billets (26.16 days) being last. In D-3 diameter, Bhimal billets (21.16 days) were earliest to reach for harvesting and Oak billets (29.50 days) were the last. Result indicates that different wood species showed significant variation in each other, Bhimal billets (20.82 days) were earliest to reach the harvesting while the Oak billets (26.72 days) being last. However, Bhimal billets (20.82 days) was first to reach the harvesting followed by Poplar billets (21.94 days), Plum billets (24.22 days), Peach billets (24.83 days), Apricot billets (25.38 days) and Oak billets (26.72 days). In different diameter, diameter D-2 took minimum time (23.33 days) for harvesting followed by diameter D-1 (23.74 days) and diameter D-3 (24.88 days).

Fruiting body of *Ganoderma lucidum* time taken for harvesting in different wood species, interaction of species and diameter was varied nonsignificant and different type of diameter was varied significant in third crop. Result presented in table 4.5 and figure 4.3 indicates that Apricot billets (13.16 days) were quickest to reach the harvesting and Poplar billets (21.00 days) were the last in D-1 diameter. In D-2 diameter, Apricot billets (14.16 days) were earliest to reach the harvesting and Oak billets (23.0 days) were the last. In D-3 diameter, Bhimal billets took minimum time (19.0 days) for harvesting with Oak billets being the maximum (24.66 days). Result indicates that Apricot billets (16.58 days) were earliest to reach the harvesting with the Peach billets (22.33 days) being last. However, Apricot billets (16.58 days) were first to reach the harvesting followed by Bhimal billets (18.77 days), Plum billets (20.11 days), Oak billets (20.94 days), Poplar billets (21.33 days) and Peach billets (22.33 days). Different diameter showed significant variation with each other, diameter D-1 billets took minimum time (17.19 days) for harvesting followed by diameter D-2 (20.73 days) and diameter D-3 (22.11 days) respectively.

Table-4.5: Fruiting body of *Ganoderma lucidum* time taken (days) for harvesting in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	39.33	35.83	38.83	43.16	36.00	36.66	38.30
D-2	38.50	37.83	38.00	39.16	34.50	38.83	37.80
D-3	42.50	41.00	36.83	47.00	32.66	38.16	39.69
Mean species	40.11	38.22	37.88	43.10	34.38	37.88	38.59
CD values (at 5% levels): Species: 2.35*; Diameter: NS; Species × Diameter: 4.08							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	25.83	25.83	24.66	26.00	20.66	19.50	23.74
D-2	23.33	22.00	26.00	24.66	20.66	23.33	23.33
D-3	25.33	24.83	25.50	29.50	21.16	23.00	24.88
Mean species	24.83	24.22	25.38	26.72	20.82	21.94	23.98
CD values (at 5% levels): Species: 2.19*; Diameter: NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	22.16	15.00	13.16	15.16	16.66	21.00	17.19
D-2	21.83	22.83	14.16	23.00	20.66	21.50	20.73
D-3	23.00	22.50	22.00	24.66	19.00	21.50	22.11
Mean species	22.33	20.11	16.58	20.94	18.77	21.33	20.01
CD values (at 5% levels): Species: NS; Diameter: 4.42*; Species × Diameter: NS							

The fruiting bodies of *Ganoderma lucidum* usually take 90–150 days to fully develop and be harvested**.** The complete growth cycle of *Ganoderma lucidum* mushrooms, from spawning to fruiting body maturation, is dependent on the cultivation method used was reported by **Zhou *et al.* (2012).** The result of the present investigation is similar to the results reported by **Veena and Pandey (2011)** wherein she concluded that average harvesting duration of *Ganoderma lucidum* fruiting bodies from three flushes was 90 days.

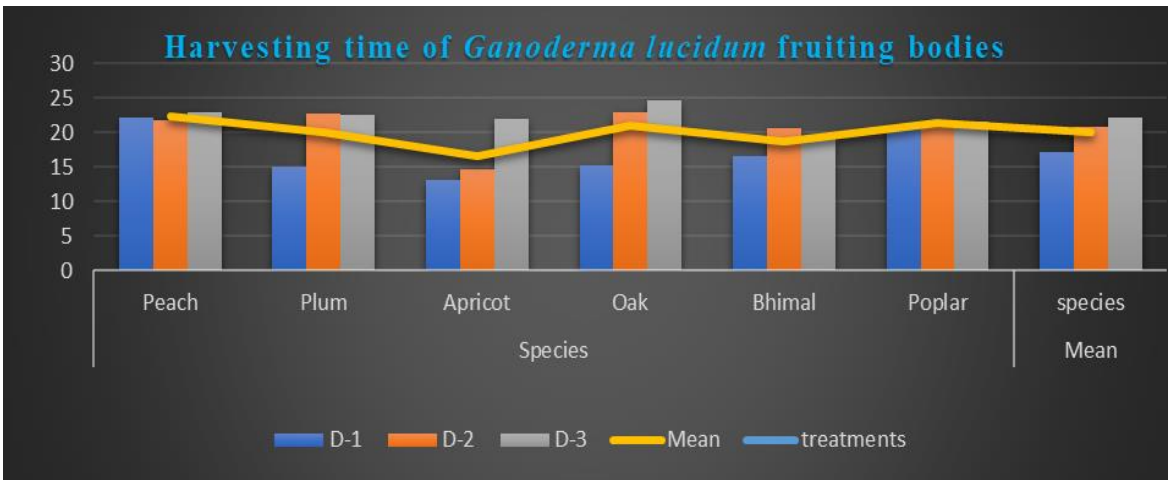


Fig. 4.3 Fruiting body of *Ganoderma lucidum* time taken for harvesting in third crop

Nithya *et al.* (2014) reported that the fruiting body of *Ganoderma lucidum* mushrooms was harvested when the caps were full size at 30 days after primordia initiation. On the country, **Gurung *et al.* (2012)** concluded that the average initial harvest days for *Alnus nepalensis* and *Shorea robusta*, were 66 and 60 days respectively. Similarly, **Roy *et al.* (2015)** recorded that the first harvest days of *Ganoderma lucidum* fruiting bodies for Mahogani and Gerjan with rice and wheat bran were 60-71 days and 66-90 days respectively. After first harvest of *Ganoderma lucidum* fruiting bodies, the second, third, and fourth harvests of *Ganoderma lucidum* fruiting bodies were harvested in every 18-20 days. On other hand, **Singh *et al.* (2014)** concluded that fruiting bodies of *Ganoderma lucidum* took 70-80 days from spawn run to fully development for harvesting in first crop while three flushes of *Ganoderma lucidum* took 130-140 days for harvesting. Similarly, **Bijalwan *et al.* (2021)** concluded his experiment fruiting bodies of *Ganoderma lucidum* took average 60-70 days for harvesting in first crop while three flushes took 132-145 days. Similarly, **Gonzalez *et al.* (2015)** concluded his experiment after spawning, the mature basidiocarps of *Ganoderma lucidum* took 70 and 72 days for harvesting in strains CP-145 and CP-405 respectively.

4.2 To compare the physical properties at different growth stages of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

4.2.2 Pinhead formation

4.2.2.1 Pinhead length

Pinhead length of *Ganoderma lucidum* in different wood species billets were studied and the observations are presented in table 4.6.

After installation of *Ganoderma lucidum* mycelium run billets into the soil, pinhead length in different wood species S-1 (Peach), S-2 (Plum), S-3 (Apricot), S-4 (Oak), S-5 (Bhimal) and S-6 (Poplar) billets with different diameter D-1 (4-5 cm), D-2 (5-6 cm) and D-3 (6-7 cm) were studied. Pinhead length of *Ganoderma lucidum* in different wood species was varied significant, different type of diameter and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.6 indicates that Poplar billets showed highest pinhead length (2.50 cm) and Apricot billets showed lowest pinhead length (1.33 cm) in D-1 diameter. In D-2 diameter, Poplar billets showed highest pinhead length (2.58 cm) and Apricot billets showed lowest pinhead length (1.45 cm). In D-3 diameter, Poplar billets showed highest pinhead length (2.36 cm) and Apricot billets showed lowest pinhead length (1.55 cm). Result indicates that different wood species showed significant variation in each other, Poplar billets showed highest pinhead length (2.48 cm) while the Apricot billets showed lowest pinhead length (1.44 cm). However, Poplar billets showed highest pinhead length (2.48 cm) followed by Oak billets (2.27 cm), Plum and Bhimal billets (2.22 cm), Peach billets (1.79 cm) and Apricot billets (1.44 cm). In different diameter, diameter D-1 billets showed highest pinhead length (2.04 cm) followed by diameter D-3 billets (2.07 cm) and diameter D-2 billets (2.09 cm).

Pinhead length of *Ganoderma lucidum* in different wood species, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.6 indicates that Bhimal billets showed highest pinhead length

Table-4.6: Pinhead length (cm) of *Ganoderma lucidum* in different wood species billets

First crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.63	2.03	1.33	2.20	2.60	2.50	2.04
D-2	1.73	2.20	1.45	2.51	2.10	2.58	2.09
D-3	2.03	2.43	1.55	2.11	1.98	2.36	2.07
Mean species	1.79	2.22	1.44	2.27	2.22	2.48	2.07
CD values (at 5% levels): Species: 0.5*; Diameter: NS; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.56	1.90	1.03	1.20	2.00	1.40	1.51
D-2	1.66	1.36	1.03	1.61	1.36	1.71	1.45
D-3	1.58	1.71	1.96	1.80	1.66	1.38	1.68
Mean species	1.60	1.65	1.34	1.53	1.67	1.49	1.55
CD values (at 5% levels): Species: NS; Diameter: NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.51	0.96	0.80	1.10	0.93	1.41	1.11
D-2	2.65	2.13	0.43	1.34	1.76	1.59	1.65
D-3	2.82	2.10	1.40	1.49	2.14	2.01	1.99
Mean species	2.32	1.73	0.87	1.31	1.61	1.67	1.58
CD values (at 5% levels): Species: 0.55*; Diameter: 0.39*; Species × Diameter: NS							

(2.0 cm) and Apricot billets showed lowest pinhead length (1.03 cm) in D-1 diameter. In D-2 diameter, Poplar billets showed highest pinhead length (1.71 cm) and Apricot billets showed lowest pinhead length (1.03 cm). In D-3 diameter, Apricot billets showed highest pinhead length (1.96 cm) and Poplar billets showed lowest pinhead length (1.38 cm). Result indicates that Bhimal billets showed highest pinhead length (1.67 cm) while the Apricot billets showed lowest pinhead length (1.34 cm). However, Bhimal billets showed highest pinhead length (1.67 cm) followed by Plum billets (1.65 cm), Peach billets (1.6

cm), Oak billets (1.53 cm), Poplar billets (1.49 cm) and Apricot billets (1.34 cm). In different diameter, diameter D-3 billets showed highest pinhead length (1.68 cm) followed by diameter D-1 billets (1.51 cm) and diameter D-2 billets (1.45 cm).

Pinhead length of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.6 indicates that Peach billets showed highest pinhead length (1.51 cm) and Apricot billets showed lowest pinhead length (0.80 cm) in D-1 diameter. In D-2 diameter, Peach billets showed highest pinhead length (2.65 cm) and Apricot billets showed lowest pinhead length (0.43 cm). In D-3 diameter, Peach billets showed highest pinhead length (2.82 cm) and Apricot billets showed lowest pinhead length (1.4 cm). Result indicates that different wood species and diameter showed significant variation, Peach billets showed highest pinhead length (2.32 cm) while the Apricot billets showed lowest pinhead length (0.87 cm). However, Peach billets showed highest pinhead length (2.32 cm) followed by Plum billets (1.73 cm), Poplar billets (1.67 cm), Bhimal billets (1.61 cm), Oak billets (1.31 cm) and Apricot billets (0.87 cm). In different diameter, diameter D-3 billets showed highest pinhead length (1.99 cm) followed by diameter D-2 billets (1.65 cm) and diameter D-1 billets (1.11 cm).

4.2.1.2 Number of pinheads

The number of *Ganoderma lucidum* pinheads emerged in different wood species billets were counted and the observations are presented in table 4.7.

The significance of number of *Ganoderma lucidum* pinheads emerged in different wood species was varied significant while in different diameter and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.7 indicates that Bhimal billets produced maximum number of pinheads (4.66) and Plum billets minimum number of pinheads (1.33) in D-1 diameter. In D-2 diameter, Bhimal billets produced maximum number of pinheads (4) and Peach billets minimum number of pinhead

Table-4.7: Number of *Ganoderma lucidum* pinheads (Nos.) in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.66	1.33	2.00	2.33	4.66	3.33	2.71
D-2	1.00	2.66	3.66	3.33	4.00	2.66	2.88
D-3	2.00	2.66	3.00	3.33	3.00	4.00	2.99
Mean species	1.88	2.21	2.88	2.99	3.88	3.33	2.86
CD values (at 5% levels): Species: 1.21*; Diameter: NS; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.33	3.00	4.33	3.00	4.33	3.36	3.39
D-2	2.33	2.33	2.33	5.33	4.00	3.33	3.27
D-3	3.33	3.33	5.33	6.33	5.00	4.33	4.60
Mean species	2.66	2.88	3.99	4.88	4.44	3.67	3.75
CD values (at 5% levels): Species: NS; Treatments (Diameter): NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.33	1.00	1.00	2.33	1.66	2.66	1.83
D-2	3.00	3.33	1.66	5.33	3.33	3.00	3.27
D-3	3.00	3.00	3.30	4.00	3.66	3.66	3.43
Mean species	2.77	2.44	1.98	3.88	2.88	3.10	2.84
CD values (at 5% levels): Species: NS; Treatments (Diameter): 0.89*; Species × Diameter: NS							

(1.0). In D-3 diameter, Poplar billets produced maximum number of pinheads (4.0) and Peach billets minimum number of pinheads (2.0). Result indicates that different wood species showed significant variation in each other, Bhimal billets produced maximum number of pinheads (3.88) while the Peach billets minimum number of pinheads (1.88). However, Bhimal billets produced maximum number of pinheads (3.88) followed by

Poplar billets (3.33), Oak billets (2.99), Apricot billets (2.88), Plum billets (2.21) and Peach billets (1.88). In different diameter, diameter D-3 billets produced maximum number of pinheads (2.99) followed by diameter D-2 billets (2.88) and diameter D-1 billets (2.71).

The significance of number of *Ganoderma lucidum* pinheads emerged in different wood species, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.7 indicates that Apricot and Bhimal billets produced maximum number of pinheads (4.33) and Peach billets minimum number of pinheads (2.33) in D-1 diameter. In D-2 diameter, Oak billets produced maximum number of pinheads (5.33) and Peach, Plum and Apricot billets minimum number of pinheads (2.33). In D-3 diameter, Oak billets produced maximum number of pinheads (6.33) and Peach & Plum billets minimum number of pinheads (3.33). Result indicates that Oak billets produced maximum number of pinheads (4.88) while the Peach billets minimum number of pinheads (2.66). However, Oak billets produced maximum number of pinheads (4.88) followed by Bhimal billets (4.44), Apricot billets (3.99), Poplar billets (3.67), Plum billets (2.88) and Peach billets (2.66). In different diameter, diameter D-3 billets produced maximum number of pinheads (4.60) followed by diameter D-1 billets (3.39) and diameter D-2 billets (3.27).

The significance of number of *Ganoderma lucidum* pinheads emerged in different type of diameter was varied significant, different wood species and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.7 indicates that Poplar billets produced maximum number of pinheads (2.66) and Plum & Apricot billets minimum number of pinheads (1.0) in D-1 diameter. In D-2 diameter, Oak billets produced maximum number of pinheads (5.33) and Apricot billets minimum number of pinheads (1.66). In D-3 diameter, Oak billets produced maximum number of pinheads (4.0) and Peach & Plum billets minimum number of pinheads (3.00). Result indicates that Oak billets produced maximum number of pinheads (3.88) while the Apricot billets minimum

number of pinheads (1.98). However, Oak billets produced maximum number of pinheads (3.88) followed by Poplar billets (3.10), Bhimal billets (2.88), Peach billets (2.77), Plum billets (2.44) and Apricot billets (1.98). In different diameter, diameter D-3 billets produced maximum number of pinheads (3.43) followed by diameter D-2 billets (3.27) and diameter D-1 billets (1.83).

4.2.3 Cap formation

Cap diameter of *Ganoderma lucidum* in different wood species billets were studied and the observations are presented in table 4.8.

Cap diameter of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant while interaction of species and diameter was not showed significant variation in second crop. Result presented in table 4.8 indicates that Apricot billets showed highest cap diameter (3.38 cm) and Peach billets lowest cap diameter (1.33 cm) in D-1 diameter. In D-2 diameter, Bhimal billets showed highest cap diameter (5.56 cm) and Apricot billets lowest cap diameter (2.41 cm). In D-3 diameter, Bhimal billets showed highest cap diameter (6.72 cm) and Peach billets lowest cap diameter (3.89 cm). Result indicates that different wood species and diameter showed significant variation, Bhimal billets showed highest cap diameter (5.33 cm) while the Apricot billets lowest cap diameter (3.08 cm). However, Bhimal billets showed highest cap diameter (5.33 cm) followed by Oak billets (4.81 cm), Poplar billets (4.44 cm), Plum billets (3.33 cm), Peach billets (3.26 cm) and Apricot billets (3.08 cm). In different diameter, diameter D-3 billets showed highest cap diameter (5.19 cm) followed by diameter D-2 billets (4.05 cm) and diameter D-1 billets (2.89 cm).

Cap diameter of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.8 indicates that Bhimal billets showed highest cap diameter (3.73 cm) and Apricot billets lowest cap diameter (1.99 cm)

Table-4.8: Cap diameter (cm) of *Ganoderma lucidum* in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.33	2.00	3.38	3.35	3.37	2.33	2.62
D-2	2.81	2.84	4.11	4.17	4.56	3.68	3.69
D-3	3.84	3.79	4.64	5.72	5.88	5.33	4.86
Mean species	2.66	2.87	4.04	4.41	4.60	3.78	3.72
CD values (at 5% levels): Species: 0.49*; Diameter: 0.34*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.80	2.62	1.99	2.84	3.73	3.37	2.89
D-2	3.11	3.34	2.41	5.37	5.56	4.52	4.05
D-3	3.89	4.05	4.86	6.23	6.72	5.44	5.19
Mean species	3.26	3.33	3.08	4.81	5.33	4.44	4.04
CD values (at 5% levels): Species: 1.12*; Diameter: 0.79*; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.79	1.20	1.87	2.73	2.09	2.60	2.04
D-2	2.51	2.85	0.92	5.33	3.70	3.54	3.14
D-3	3.86	3.91	3.99	6.18	3.83	4.60	4.39
Mean species	2.72	2.65	2.26	4.74	3.20	3.58	3.19
CD values (at 5% levels): Species: 1.21*; Diameter: 0.85*; Species × Diameter: NS							

in D-1 diameter. In D-2 diameter, Bhimal billets showed highest cap diameter (5.56 cm) and Apricot billets lowest cap diameter (2.41 cm). In D-3 diameter, Oak billets showed highest cap diameter (6.73 cm) and Peach billets lowest cap diameter (3.89 cm). Result indicates that different wood species and diameter showed significant variation, Bhimal billets showed highest cap diameter (5.33 cm) while the Apricot billets lowest cap diameter (3.08 cm). However, Bhimal billets showed highest cap diameter (5.33 cm) followed by

Oak billets (4.81 cm), Poplar billets (4.44 cm), Plum billets (3.33 cm), Peach billets (3.26 cm) and Apricot billets (3.08 cm). In different diameter, diameter D-3 billets showed highest cap diameter (5.19 cm) followed by diameter D-2 billets (4.05 cm) and diameter D-1 billets (2.89 cm).

Cap diameter of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.8 indicates that Oak billets showed highest cap diameter (2.73 cm) and Plum billets lowest cap diameter (1.20 cm) in D-1 diameter. In D-2 diameter, Oak billets showed highest cap diameter (5.33 cm) and Apricot billets lowest cap diameter (0.92 cm). In D-3 diameter, Oak billets showed highest cap diameter (6.18 cm) and Bhimal billets lowest cap diameter (3.83 cm). Result indicates that different wood species and diameter showed significant variation, Oak billets showed highest cap diameter (4.74 cm) while the Apricot billets lowest cap diameter (2.26 cm). However, Oak billets showed highest cap diameter (4.74 cm) followed by Poplar billets (3.58 cm), Bhimal billets (3.20 cm), Peach billets (2.72 cm), Plum billets (2.65 cm) and Apricot billets (2.26 cm). In different diameter, diameter D-3 billets showed highest cap diameter (4.39 cm) followed by diameter D-2 billets (3.14 cm) and diameter D-1 billets (2.04 cm).

4.2.4 Fruiting body formation

4.2.4.1 Stipe length

Stipe length of *Ganoderma lucidum* in different wood species billets were studied and the observations are presented in table 4.9.

Stipe length of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.9 and figure 4.4 indicates that Apricot billets showed

lowest stipe length (3.44 cm) and Peach billets highest stipe length (4.87 cm) in D-1 diameter. In D-2 diameter, Apricot billets showed lowest stipe length (2.70 cm) and Peach

Table-4.9: Stipe length (cm) of *Ganoderma lucidum* in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	4.87	4.13	3.44	4.12	4.17	4.00	4.12
D-2	3.95	3.41	2.70	3.10	3.13	3.43	3.28
D-3	2.85	2.79	2.24	2.52	2.48	2.03	2.48
Mean species	3.89	3.44	2.79	3.24	3.26	3.15	3.29
CD values (at 5% levels): Species: 0.31*; Diameter: 0.22*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	5.02	4.08	2.13	2.63	4.26	3.73	3.64
D-2	3.99	3.41	1.63	3.15	3.15	3.32	3.10
D-3	2.91	2.67	2.16	2.62	2.46	2.03	2.47
Mean species	3.97	3.38	1.90	2.8	3.29	3.02	3.07
CD values (at 5% levels): Species: 0.81*; Diameter: 0.57*; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	4.36	3.14	2.75	3.21	2.51	5.05	3.50
D-2	2.87	3.27	1.03	3.60	2.90	3.96	2.93
D-3	2.17	2.46	1.93	2.47	1.47	2.13	2.10
Mean species	3.13	2.95	1.90	3.09	2.29	3.71	2.84
CD values (at 5% levels): Species: NS; Diameter: 0.91*; Species × Diameter: NS							

billets highest stipe length (3.95 cm). In D-3 diameter, Poplar billets showed lowest stipe length (2.03 cm) and Peach billets highest stipe length (2.85 cm). Result indicates that different wood species and diameter showed significant variation, Apricot billets showed lowest stipe length (2.79 cm) while the Peach billets highest stipe length (3.89 cm).

However, Apricot billets showed lowest stipe length (2.79 cm) followed by Poplar billets (3.15 cm), Oak billets (3.24 cm), Bhimal billets (3.26 cm), Plum billets (3.44 cm) and Peach billets (3.89 cm). In different diameter, diameter D-3 billets showed lowest stipe length (2.48 cm) followed by diameter D-2 billets (3.28 cm) and diameter D-1 billets (4.12 cm).

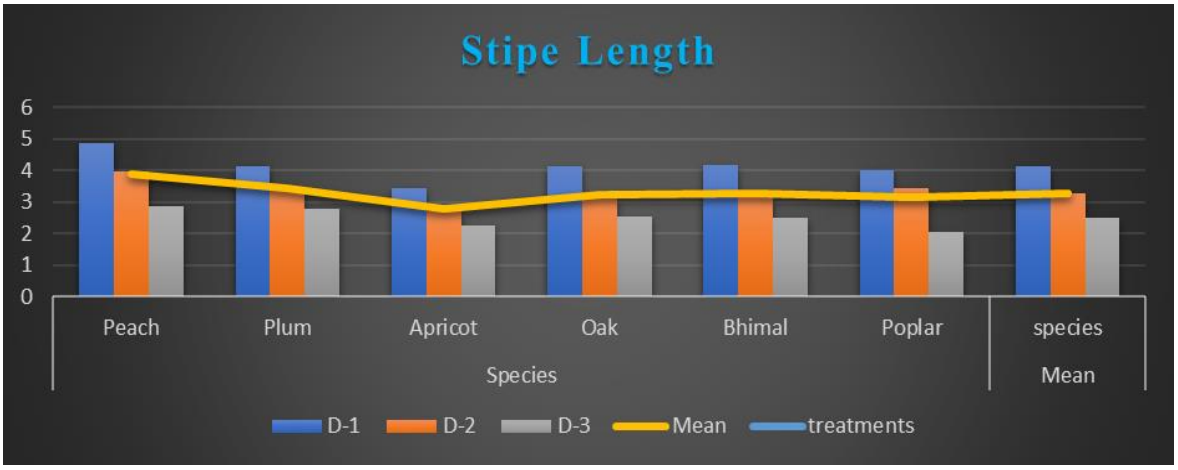


Fig. 4.4 Stipe length of *Ganoderma lucidum* in first crop

Stipe length of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.9 and figure 4.5 indicates that Apricot billets showed lowest stipe length (2.13 cm) and Peach billets highest stipe length (5.02 cm) in D-1 diameter. In D-2 diameter, Apricot billets showed lowest stipe length (1.63 cm) and Peach billets showed stipe length (3.99 cm). In D-3 diameter, Poplar billets showed lowest stipe length (2.03 cm) and Peach billets highest stipe length (2.91 cm). Result indicates that different wood species and diameter showed significant variation, Apricot billets showed lowest stipe length (1.90 cm) while the Peach billets highest stipe length (3.97 cm). However, Apricot billets showed lowest stipe length (1.90 cm) followed by Oak billets (2.8 cm), Poplar billets (3.02 cm), Bhimal billets (3.29 cm), Plum billets (3.38 cm) and Peach billets (3.97 cm). In different diameter, diameter D-3 billets showed

lowest stipe length (2.47 cm) followed by diameter D-2 billets (3.10 cm) and diameter D-1 billets (3.64 cm).

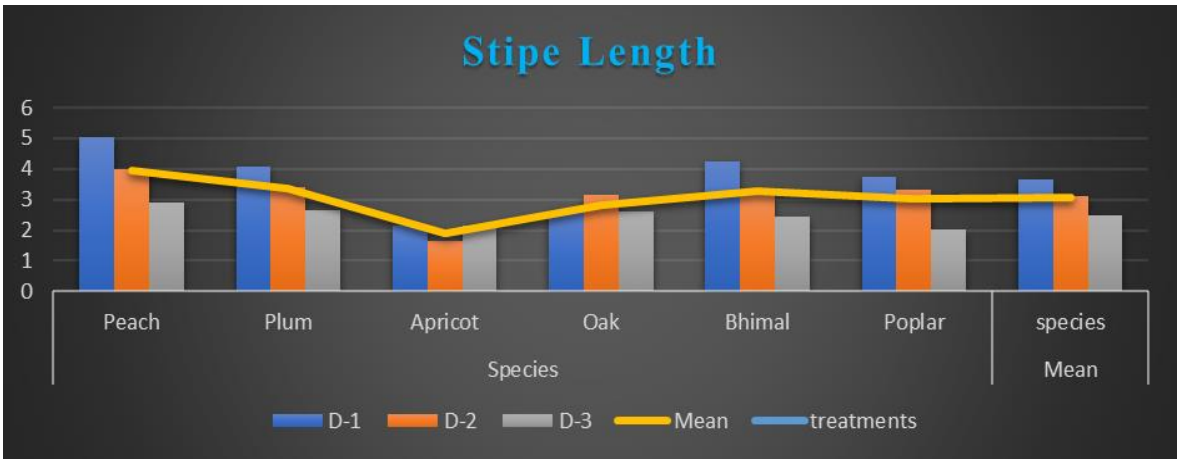


Fig. 4.5 Stipe length of *Ganoderma lucidum* in second crop

Stipe length of *Ganoderma lucidum* in different type of diameter was varied significant while different wood species and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.9 and figure 4.6 indicates that Bhimal billets showed lowest stipe length (2.51 cm) and Poplar billets highest stipe length (5.05 cm) in D-1 diameter. In D-2 diameter, Apricot billets showed lowest stipe length (1.03 cm) and Poplar billets highest stipe length (3.96 cm). In D-3 diameter, Bhimal billets

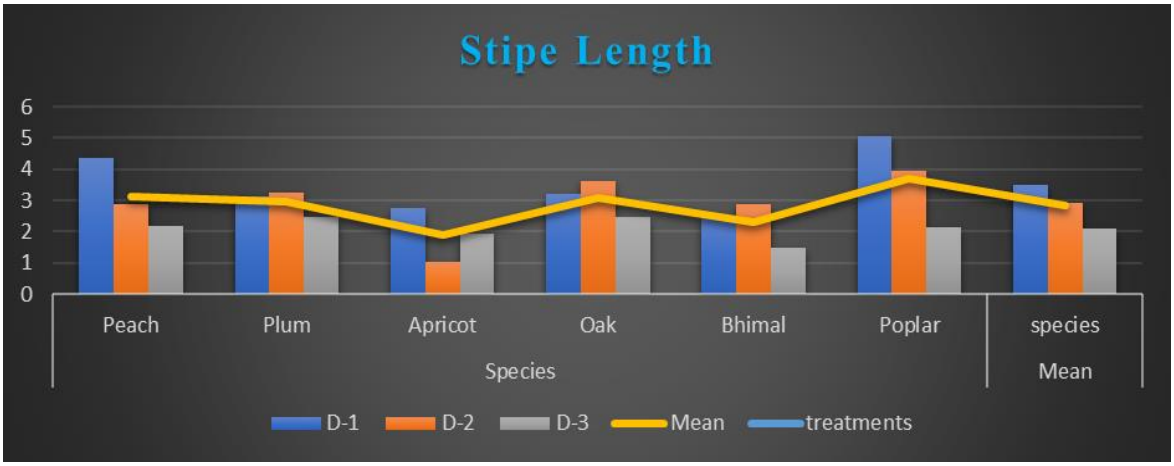


Fig. 4.6 Stipe length of *Ganoderma lucidum* in third crop

showed lowest stipe length (1.47 cm) and Oak billets highest stipe length (2.47 cm). Result indicates that Apricot billets showed lowest stipe length (1.90 cm) while the Poplar billets highest stipe length (3.71 cm). However, Apricot billets showed lowest stipe length (1.90 cm) followed by Bhimal billets (2.29 cm), Plum billets (2.95 cm), Oak billets (3.09 cm), Peach billets (3.13 cm) and Poplar billets (3.71 cm). In different diameter, diameter D-3 billets showed lowest stipe length (2.10 cm) followed by diameter D-2 billets (2.93 cm) and diameter D-1 billets (3.50 cm).

Stipe of *Ganoderma lucidum* generally grows between 3-14 cm length and 0.5-4 cm thick with turned, magnified at the base and have a similar shade to the cap surface was reported by **Kumar (2021)**. Our results are in line with similar results have been reported by **Bijalwan *et al.* (2021)** wherein they concluded that the average stipe length of *Ganoderma lucidum* (2.29 cm) in district Tehri Garhwal, Uttarakhand and (2.42 cm) in district Dehradun. Similarly, **Kapoor and Sharma (2014)** reported that the length and thickness of the stem between 1.5-4.5 cm and 0.5- 2.0. On the country, **Bhatt *et al.* (2018)** reported that the average stipe length and thickness of *Ganoderma lucidum* was 35-110 mm and 10-25 mm. Similarly, (**Siwulski *et al.*, 2015)** reported that the stipe of *Ganoderma lucidum* was 50-120 x 10-20 mm in size. On other hand, **Veena and Pandey (2011)** studied the morphological characteristics of *Ganoderma lucidum* fruiting body and they concluded that the stipe length ranged between (58-74 mm) and (5.8–7.3 mm) thickness of stipe.

4.2.3.2 Fruiting body diameter

Fruiting body diameter of *Ganoderma lucidum* in different wood species billets were studied and the observations are presented in table 4.10.

After cap formation of *Ganoderma lucidum*, fruiting body diameter in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.10 and figure 4.7 indicates that Bhimal billets showed highest fruit body diameter (7.86 cm) and Peach billets lowest fruit body diameter (3.63 cm) in D-1 diameter. In D-2 diameter, Bhimal billets showed highest fruit body diameter (8.80 cm) and Peach billets lowest fruit

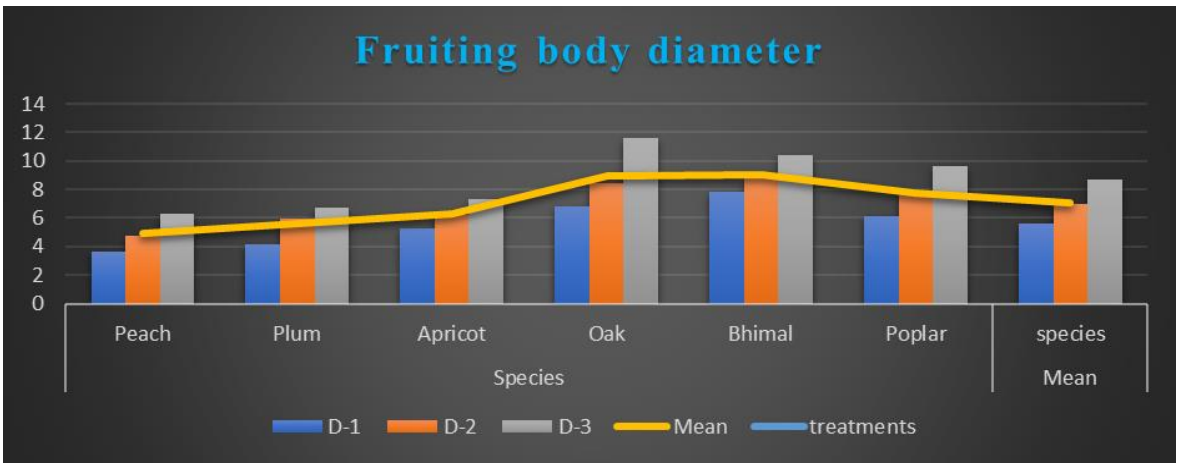


Fig. 4.7 Fruiting body diameter of *Ganoderma lucidum* in first crop

body diameter (4.80 cm). In D-3 diameter, Oak billets showed highest fruit body diameter (11.6 cm) and Peach billets lowest fruit body diameter (6.26 cm). Result indicates that different wood species and diameter showed significant variation, Bhimal billets showed highest fruit body diameter (9.03 cm) while the Peach billets lowest fruit body diameter (4.89 cm). However, Bhimal billets showed highest fruit body diameter (9.03 cm) followed by Oak billets (8.94 cm), Poplar billets (7.79 cm), Apricot billets (6.28 cm), Plum billets (5.6 cm) and Peach billets (4.89 cm). In different diameter, diameter D-3 billets showed highest fruit body diameter (8.66 cm) followed by diameter D-2 billets (6.97 cm) and diameter D-1 billets (5.64 cm).

Fruit body diameter of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.10 and figure 4.8 indicates that Bhimal billets showed highest fruit body diameter (6.58 cm) and Apricot billets lowest fruit body diameter (3.38 cm) in D-1 diameter. In D-2 diameter, Oak billets showed highest fruit body diameter (9.78 cm) and Apricot billets lowest fruit body diameter (4.46 cm). In D-3 diameter, Oak billets showed highest fruit body diameter (11.75 cm) and Peach billets lowest fruit body diameter (6.37 cm). Result indicates that different wood species and diameter showed significant variation, Oak billets showed highest fruit body diameter (8.75

Table-4.10: Fruiting body diameter (cm) of *Ganoderma lucidum* in different wood species billets

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	3.63	4.13	5.29	6.83	7.86	6.13	5.64
D-2	4.80	5.95	6.23	8.40	8.80	7.66	6.97
D-3	6.26	6.73	7.34	11.60	10.43	9.60	8.66
Mean species	4.89	5.60	6.28	8.94	9.03	7.79	7.03
CD values (at 5% levels): Species: 0.72*; Diameter: 0.51*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	4.25	4.90	3.38	4.73	6.58	6.04	4.98
D-2	5.35	6.26	4.46	9.78	8.14	7.39	6.89
D-3	6.37	7.34	7.53	11.75	10.20	9.75	8.82
Mean species	5.32	6.16	5.12	8.75	8.30	7.72	6.90
CD values (at 5% levels): Species: 1.56*; Diameter: 1.10*; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	4.23	1.95	2.79	3.87	3.31	4.75	3.48
D-2	5.03	5.04	1.77	8.27	6.41	5.98	5.41
D-3	6.34	6.33	6.89	10.59	6.43	8.15	7.45
Mean species	5.2	4.44	3.81	7.57	5.38	6.29	5.45
CD values (at 5% levels): Species: 1.93*; Diameter: 1.36*; Species × Diameter: NS							

cm) while the Apricot billets lowest fruit body diameter (5.12 cm). However, Oak billets showed highest fruit body diameter (8.75 cm) followed by Bhimal billets (8.30 cm), Poplar billets (7.72 cm), Plum billets (6.16 cm), Peach billets (5.32 cm) and Apricot billets (5.12 cm). In different diameter, diameter D-3 billets showed highest fruit body diameter (8.82 cm) followed by diameter D-2 billets (6.89 cm) and diameter D-1 billets (4.98 cm).

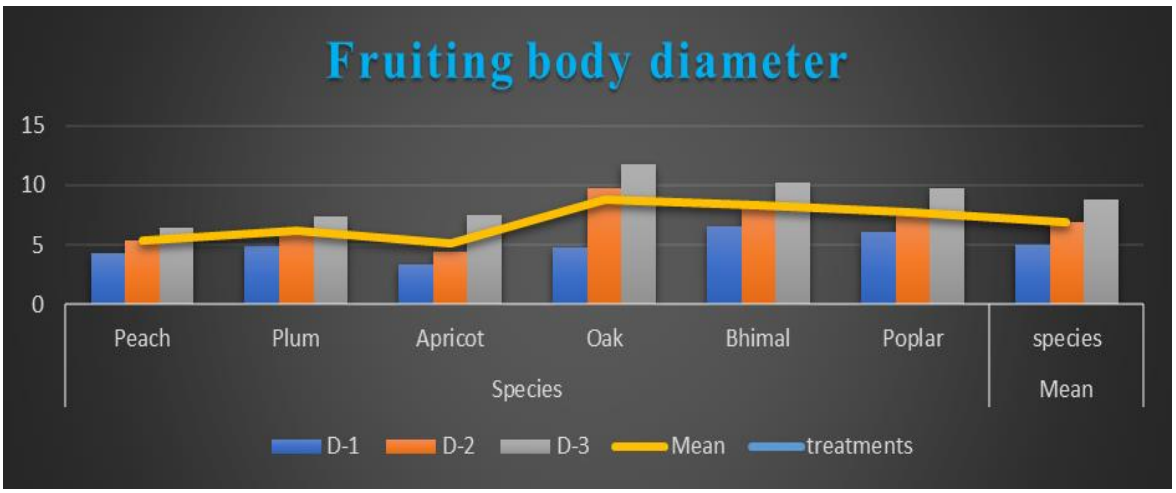


Fig. 4.8 Fruiting body diameter of *Ganoderma lucidum* in second crop

Fruiting body diameter of *Ganoderma lucidum* in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.10 and figure 4.9 indicates that Poplar billets showed highest fruit body diameter (4.75 cm) and Plum billets lowest fruit body diameter (1.95 cm) in D-1 diameter. In D-2 diameter, Oak billets showed highest fruit body diameter (8.27 cm) and Apricot billets lowest fruit body diameter (1.77 cm). In D-3 diameter, Oak billets showed highest fruit body diameter (10.59 cm) and Plum billets lowest fruit body diameter (6.33 cm). Result indicates that Oak billets showed highest fruit body diameter (7.57 cm) while the Apricot billets lowest fruit body diameter (3.81 cm). However, Oak billets showed highest fruit body diameter (7.57 cm) followed by Poplar billets (6.29 cm), Bhimal billets (5.38 cm), Peach billets (5.2 cm), Plum billets (4.44 cm) and Apricot billets (3.81 cm). In different diameter, diameter D-3 billets showed highest fruit body diameter (7.45 cm) followed by diameter D-2 billets (5.41 cm) and diameter D-1 billets (3.48 cm).

The present study supports the earlier work done by **Siwulski *et al.* (2015)** wherein they reported that *Ganoderma lucidum* produces a fruiting body with a cap diameter range

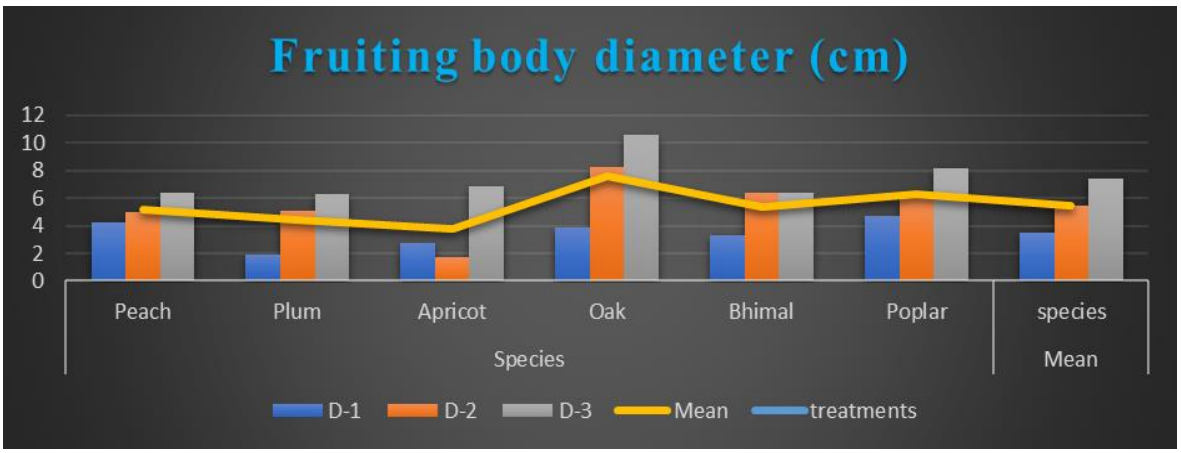


Fig. 4.9 Fruiting body diameter of *Ganoderma lucidum* in third crop

from (3-25 cm). On other hand similar results have been reported by **Veena and Pandey (2011)** concluded that the average pileal width of *Ganoderma lucidum* (73-93 mm) with pileal thickness (6.9-8.1 mm). Similarly, **Gonzalez *et al.* (2015)** observed that the *Ganoderma lucidum* mushroom morphology in two strains which was strain CP-145 (average pileus length 31-38 mm and width 45-65 mm) and strain CP-405 (average pileus length 27-55 mm and width 47-78 mm). On the country, **Bhatt *et al.* (2018)** reported that the fruiting body of *Ganoderma lucidum* grows between 25-120 mm wide. On other hand, **Stamets (1993) and Kumar (2021)** reported that *Ganoderma lucidum* produce the fruiting body with diameter ranged between 2-20 cm. Our results are in line with **Seephueak *et al.* (2019)** wherein they concluded that rubber sawdust supplemented with 15% palm oil sludge produced the largest pileus diameter (5.84 cm) followed by 5% rice bran in sawdust substrate (5.03 cm) and non-supplemented sawdust (1.34 cm). On other hand, **Bijalwan *et al.* (2021)** reported that *Ganoderma lucidum* mushroom was cultivated on *Populus deltoids* billets with an average fruiting body diameter of 3.7 cm in district Tehri Garhwal, Uttarakhand and an average fruiting body diameter of 4.28 cm in district Dehradun, Uttarakhand.

4.2.5 Physical appearance of *Ganoderma lucidum* fruiting body

Medicinal mushroom *Ganoderma lucidum* was cultivated and the effect of different wood species on overall physical appearance (colour, texture, shape) of *Ganoderma lucidum* fruiting bodies were observed in different growth stages. The observation shows no significant difference in the physical appearance of fruiting bodies growing on different wood species. The overall physical appearance of cultivated fruiting bodies of *Ganoderma lucidum* is described below.

After 6-10 days of billets installation into the soil, small sized pinheads/primordia start to appear on the upper surface of soil. These pinheads were of small sized and white in colour which slowly turn into pale yellow in colour with length ranging between 1-2.5 cm. The number of pinheads varied with different wood species and number of flushes. Some species produced 2-3 pinheads and some species produced 8-12 number of pinheads. After first flush, some species was produced more than 20 number of pinheads.

After 4-8 days of pinhead emergence, the upper surface of pinheads become round shaped like umbrella with flat upper surface. The round shape cap grew further with the diameter ranging between 3-7 cm. and turn from white color to yellow from center towards the periphery of the fruiting body. Stipe of *Ganoderma lucidum* was glossy, hymenophore was trimitic, subcylindrical, elastic, fine, brown in colour, turned, amplified at base, similar shading or appearance as upper surface of the cap. The stipe length of *Ganoderma lucidum* was recorded between (0.7-6.5 cm) in different wood species.

After 10-12 days of cap development, fruiting bodies of *Ganoderma lucidum* was generally rounded to crescent, flat, kidney shaped, superior smooth upper surface with stipe emergence and turn slowly golden brown in color from center towards of fruiting bodies and yellowish to side-line with diameter ranging between (5-14 cm) in different wood species.

During maturity stages, fruiting bodies of *Ganoderma lucidum* was produced red powdery colour of spores and start to shed the upper surface of fruiting bodies. The spores powdered of *Ganoderma lucidum* was dark brown in colour, ovate with a rounded shape.

When the spores of *Ganoderma lucidum* spreads around the upper surface of fruiting bodies and soil, at this stage fruiting bodies of *Ganoderma lucidum* mushroom was completely developed.

The fruiting body of *Ganoderma lucidum* is composed of three main parts: a kidney-shaped cap, steams and spores reported by **(Babu and Subhasree, 2008).** Our results are in line with **Kapoor and Sharma (2014)** wherein who observed that the fruiting body of *Ganoderma lucidum* was usually large, stipitate, dimidiate, rarely suborbicular, reddish brown and their lateral and upper surface coated with a hard, shiny substance resembling sealing wax and basidiospores of *Ganoderma lucidum* was brown, ovate with rounded base, truncate to a narrowly rounded apex. On the other hand, **Rawat (2018)** reported that the fruiting bodies morphology of *Ganoderma lucidum* from different isolates was irregular in shape, kidney-shaped, copper red, brown-golden brown/Dark brown in color. Similar results have been reported by other workers, **Du *et al.* (2004)** reported that the pileus of *Ganoderma lucidum* is composed of context, cutis and tube, which come in a variety of colors and shapes, including light brown, yellowish-brown, brown, reddish-brown, dark brown, puce and black, as well as flabelliform, suborbicular, cochlear, reniform, hippocrepiform and other irregular shapes. The stipe on pileus has a variety of attachment types, ranging from lateral to nearly central. Basidiospores shape of *Ganoderma lucidum* ovoid to rectangular with a truncate or untruncate apex. Similarly, **Siwulski *et al.* (2015)** reported that the fruiting body of *Ganoderma lucidum* is lustrous, crimson, cherry-red, reddish-brown, or reddish-black in color and is flat, rounded, or kidney-shaped. The juvenile fruiting bodies are yellow-brown or yellow-red in color but as they mature, they become darker. The stipe is lustrous and unevenly twisted, spongy or corky, pale, beige, or brown in color, the hymenophore is trimitic. Spores are ellipsoid or oval with two covering layers. On other hand, **Bhatt *et al.* (2018)** reported that the pileus of *Ganoderma lucidum* is elongated when young, more or less fan-shaped with maturity, surface smooth, glossy, shining, concentrically sulcate, yellowish brown to reddish brown in color. The stipe of *Ganoderma lucidum* is subcylindrical, concolorous with pileus to purplish brown, central to eccentric. Similarly, **Palanna *et al.* (2020)** reported that the fruiting body of *Ganoderma lucidum* mushroom is stipitate, dimidiate or reniform and

occasionally suborbicular, thick, corky, yellowish in margins that turn brownish with shiny laccate on the surface. The stems is white to yellow in color, gradually turning brown or black, eccentrically or laterally linked to the cap and basidiospores of *Ganoderma lucidum* are brown in color, oblong in shape with a rounded base and a truncate to narrowly rounded tip.

4.3 To compare the production potential/biological efficiency of *Ganoderma lucidum* fruiting bodies cultivated on different wooden billets.

4.1.1 Fresh weight of *Ganoderma lucidum* fruiting bodies

Fresh weight of *Ganoderma lucidum* fruiting bodies in different wood species billets were studied and the observations are presented in table 4.11.

After harvesting the fruiting bodies of *Ganoderma lucidum*, fresh weight of fruiting bodies in different wood species S-1 (Peach), S-2 (Plum), S-3 (Apricot), S-4 (Oak), S-5 (Bhimal) and S-6 (Poplar) billets with different diameter D-1 (4-5 cm), D-2 (5-6 cm) and D-3 (6-7 cm) were studied. Fresh weight of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter and interaction of species and diameter was varied significant in first crop. Result presented in table 4.11 and figure 4.10 indicates that Oak billets produced highest fresh weight (12.36 g) and Peach billets lowest (3.79 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest fresh weight (20.57 g) and Peach billets lowest (4.46 g). In D-3 diameter, Oak billets showed highest fresh

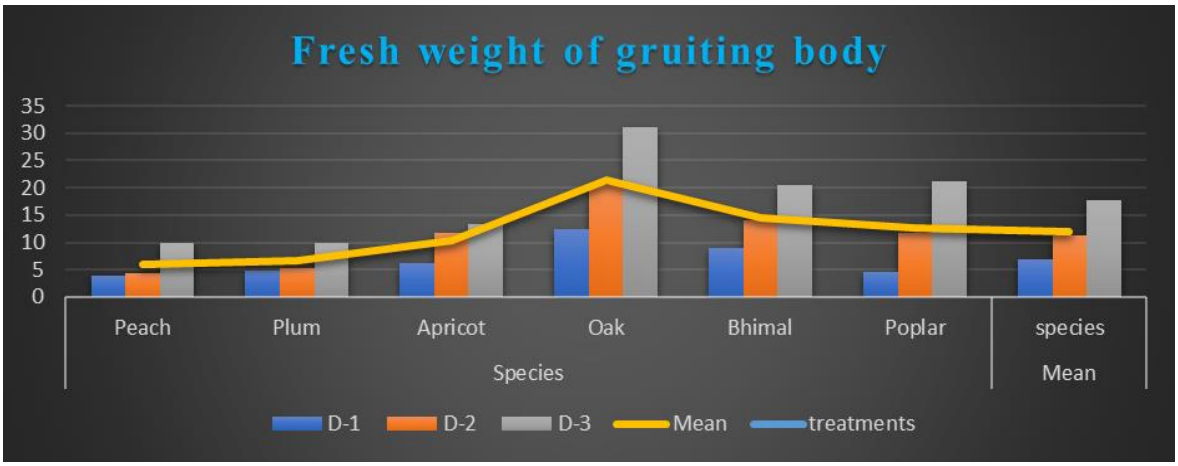


Fig. 4.10 Fresh weight of *Ganoderma lucidum* fruiting bodies in first crop

weight (31.16 g) with the Peach billets being lowest (9.84 g). Result indicates different wood species, different type of diameter and interaction of species and diameter showed

significant variation, Oak billets produced highest fresh weight (21.36 g) while the Peach billets lowest (6.03 g). However, Oak billets produced highest fresh weight (21.36 g) followed by Bhimal billets (14.47 g), Poplar billets (12.57 g), Apricot billets (10.45 g), Plum billets (6.72 g) and Peach billets (6.03 g). In different diameter, diameter D-3 billets produced highest fresh weight (17.65 g) followed by diameter D-2 billets (11.35 g) and diameter D-1 billets (6.81g).

Table-4.11: Fresh weight (g) of *Ganoderma lucidum* fruiting bodies in different wood species in each billet

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	3.79	4.92	6.10	12.36	9.02	4.68	6.81
D-2	4.46	5.38	11.83	20.57	14.03	11.83	11.35
D-3	9.84	9.88	13.43	31.16	20.38	21.21	17.65
Mean species	6.03	6.72	10.45	21.36	14.47	12.57	11.93
CD values (at 5% levels): Species: 3.33*; Diameter: 2.35*; Species × Diameter: 5.77*							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	4.56	4.80	5.71	9.08	8.00	8.04	6.69
D-2	6.40	7.28	10.05	17.53	13.13	11.53	10.98
D-3	8.70	8.61	17.85	28.97	18.64	14.88	16.27
Mean species	6.55	6.89	11.20	18.52	13.24	11.48	11.32
CD values (at 5% levels): Species: 2.65*; Diameter: 1.87*; Species × Diameter: 4.59*							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	3.67	3.45	6.39	9.39	9.16	5.94	6.33
D-2	5.44	8.34	10.91	17.24	11.62	8.53	10.34
D-3	8.32	11.61	14.22	25.51	21.98	14.70	16.05
Mean species	5.81	7.80	10.50	17.38	14.25	9.72	10.91
CD values (at 5% levels): Species: 1.66*; Diameter: 1.17*; Species × Diameter: 2.87*							

Fresh weight of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter and interaction of species and diameter was varied significant in second crop. Result presented in table 4.11 and figure 4.11 indicates that Oak billets produced highest fresh weight (9.08 g) and Peach billets lowest (4.56 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest fresh weight (17.53 g) and Peach billets lowest (6.40 g). In D-3 diameter, Oak billets produced highest fresh weight (28.97 g) and Plum billets lowest (8.61 g). Result indicates that different wood species, different type of diameter and interaction of species and diameter showed significant variation, Oak billets produced highest fresh weight (18.52 g) while the Peach billets lowest (6.55 g). However, Oak billets produced highest fresh weight (18.52 g) followed by Bhimal billets (13.24 g), Poplar billets (11.48 g), Apricot billets (11.20 g), Plum billets (6.89 g) and Peach billets (6.55 g). In different diameter, diameter D-3 billets showed highest fresh weight (16.27 g) followed by diameter D-2 billets (10.98 g) and diameter D-1 billets (6.69 g).

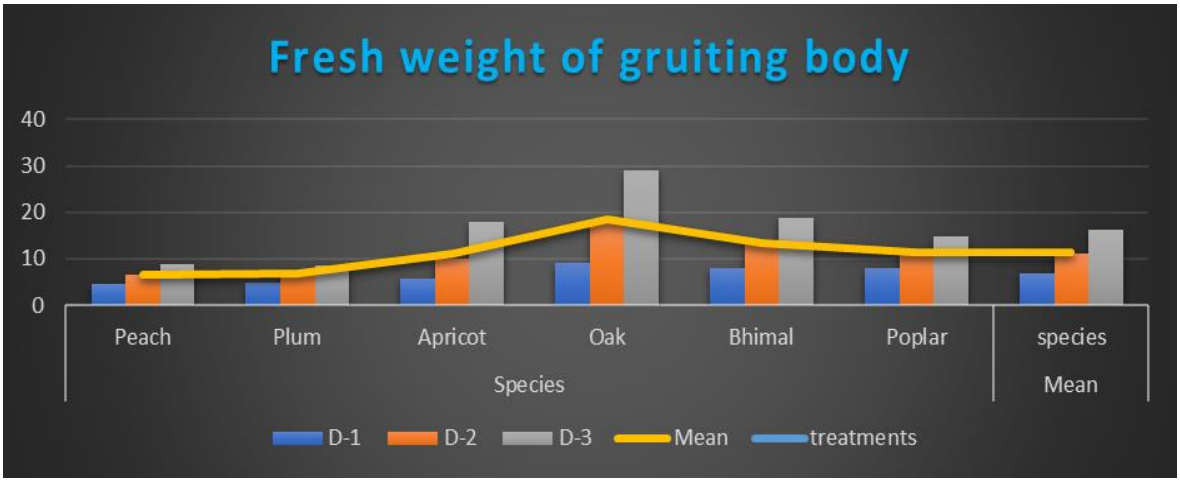


Fig. 4.11 Fresh weight of *Ganoderma lucidum* fruiting bodies in second crop

Fresh weight of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter and interaction of species and diameter was varied significant in third crop. Result presented in table 4.11 and figure 4.12 indicates that Oak billets produced highest fresh weight (9.39 g) and Plum billets lowest (3.45 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest fresh weight (17.24 g) and Peach billets lowest

(5.44 g). In D-3 diameter, Oak billets produced highest fresh weight (25.51 g) and Peach billets lowest (8.32 g). Result indicates that different wood species, different type of diameter and interaction of species and diameter showed significant variation, Oak billets produced highest fresh weight (17.38 g) while the Peach billets lowest (5.81 g). However, Oak billets produced highest fresh weight (17.38 g) followed by Bhimal billets (14.25 g), Apricot billets (10.50 g), Poplar billets (9.72 g), Plum billets (7.80 g) and Peach billets (5.81 g). In different diameter, diameter D-3 billets showed highest fresh weight (16.05 g) followed by diameter D-2 billets (10.34 g) and diameter D-1 billets (6.33 g).

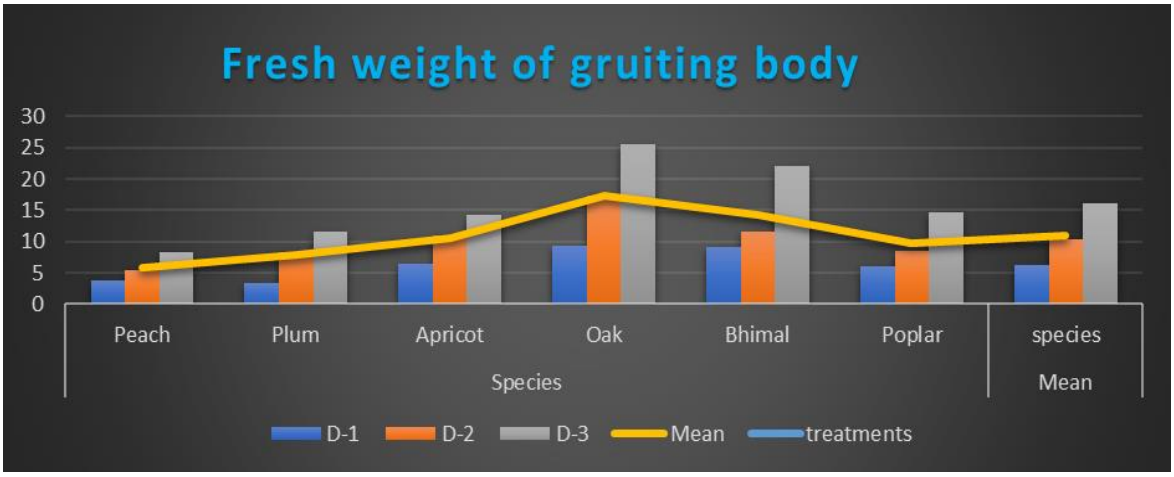


Fig. 4.12 Fresh weight of *Ganoderma lucidum* fruiting bodies in third crop

The results are in accordance with the studies of **Erkel (2009)** who studied the effect of various kinds of sawdust and bran on the yield of *Ganoderma lucidum* and obtained the highest yield from oak sawdust and wheat bran combination. On the other hand, **Jeewanthi *et al.* (2017)** wherein they concluded that average yield of *Ganoderma lucidum* fruiting bodies in substrates Mango (100%), Rubber (100%), Rubber + Mango (50%:50%) and Rubber + Lunumidella (50%:50%) sawdust resulted in per bag (49.3 g, 42.5 g, 45.7 g and 43.7 g) respectively. The total highest yield of 3 months was resulted by 100% Mango sawdust (541.91 g/bag) followed by Rubber + Mango sawdust (502.37 g/bag), Rubber + Lunumidella sawdust (480.92 g/bag), Rubber (467.39 g/bag) and lowest yield Rubber + Jack sawdust mixture (289.08 g/bag) respectively. Similarly, **Magday *et al.***

(2014) concluded that the highest yield was obtained from 70% rice straw and 30% sawdust combinations (17.76 g), followed by 100% RS (17.40 g), 50% RS + 50% SD (16.14 g), 100% SD (14.64 g) and 30% RS + 70% SD (13.62 g), respectively. On the country, **Thakur and Sharma (2015)** evaluated that optimal substrate for *Ganoderma lucidum* cultivation and they obtained the average highest yield from *Jacaranda mimosifolia* sawdust with various combinations of wheat bran (156 g/kg) followed by *Mangifera indica* sawdust with various combinations of wheat bran (138.83 g/kg) and *Dalbergia Sissoo* (66.3 g/kg) respectively. On other hand, **Rani *et al.* (2015)** concluded that the yield of *Ganoderma lucidum* fruiting bodies was obtained 42.06±2.14 g/packet. Similarly, **Gonzalez *et al.* (2015)** concluded that the fruiting bodies yield of *Ganoderma lucidum* was obtained in two strains CP-405 (47.9g) and CP-145 (40.9g). Similarly, **Gurung *et al.* (2012)** evaluated the impact of different types of sawdust supplement on yield of *Ganoderma lucidum* and they obtained the maximum yield from *Alnus nepalensis* sawdust (15.05 g/400 g) while *Shorea robusta* sawdust produced the lowest yield (1.5 g/400 g).

4.1.2 Dry weight of *Ganoderma lucidum* fruiting bodies

Dry weight of *Ganoderma lucidum* fruiting bodies in different wood species billets were studied and the observations are presented in table 4.12.

After drying the fresh harvested fruiting bodies of *Ganoderma lucidum*, dry weight of fruiting bodies in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.12 indicates that Oak billets produced highest dry weight (3.59 g) and Peach billets lowest (1.16 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest dry weight (5.76 g) and Peach billets lowest (1.41 g). In D-3 diameter, Oak billets produced highest dry weight (7.78 g) and Plum billets lowest (2.64 g). Result indicates that different wood species and diameter showed significant variation

Table-4.12: Dry weight (g) of *Ganoderma lucidum* fruiting bodies in different wood species in each billet

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.16	1.57	1.97	3.59	2.40	1.59	2.04
D-2	1.41	1.64	3.16	5.76	3.71	3.22	3.15
D-3	2.88	2.64	3.52	7.78	5.95	5.64	4.73
Mean species	1.81	1.95	2.88	5.71	4.02	3.48	3.31
CD values (at 5% levels): Species: 0.89*; Diameter: 0.63*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.23	1.41	1.60	2.27	2.24	2.13	1.81
D-2	1.91	2.02	2.56	4.49	3.50	2.94	2.90
D-3	2.38	2.60	4.32	8.17	5.48	4.02	4.49
Mean species	1.84	2.01	2.82	4.97	3.74	3.03	3.07
CD values (at 5% levels): Species: 0.76*; Diameter: 0.54*; Species × Diameter: 1.33*							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.05	0.67	1.85	2.11	2.07	1.99	1.62
D-2	1.29	2.07	2.23	4.68	3.40	2.89	2.76
D-3	2.09	2.67	4.32	7.43	7.08	4.19	4.63
Mean species	1.47	1.80	2.80	4.74	4.18	3.02	3.00
CD values (at 5% levels): Species: 0.66*; Diameter: 0.46*; Species × Diameter: 1.14*							

, Oak billets produced highest dry weight (5.71 g) while the Peach billets lowest (1.81 g). However, Oak billets produced highest dry weight (5.71 g) followed by Bhimal billets (4.02 g), Poplar billets (3.48), Apricot billets (2.88 g), Plum billets (1.95 g) and Peach billets (1.81 g). In different diameter, diameter D-3 billets produced highest dry weight (4.73 g) followed by diameter D-2 billets (3.15 g) and diameter D-1 billets (2.04 g).

Dry weight of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter and interaction of species and diameter was varied significant in second crop. Result presented in table 4.12 indicates that Oak billets produced highest dry weight (2.27 g) and Peach billets lowest (1.23 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest dry weight (4.49 g) and Peach billets lowest (1.91 g). In D-3 diameter, Oak billets produced highest dry weight (8.17 g) and Peach billets lowest (2.38 g). Result indicates that different wood species, different type of diameter and interaction of species and diameter showed significant variation, Oak billets produced highest dry weight (4.97 g) while the Peach billets lowest (1.84 g). However, Oak billets produced highest dry weight (4.97 g) followed by Bhimal billets (3.74 g), Poplar billets (3.03 g), Apricot billets (2.82 g), Plum billets (2.01 g) and Peach billets (1.84 g). In different diameter, diameter D-3 billets produced highest dry weight (4.49 g) followed by diameter D-2 billets (2.90 g) and diameter D-1 billets (1.81 g).

Dry weight of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter and interaction of species and diameter was varied significant in third crop. Result presented in table 4.12 indicates that Oak billets produced highest dry weight (2.11 g) and Plum billets lowest (0.67 g) in D-1 diameter. In D-2 diameter, Oak billets produced highest dry weight (4.68 g) and Peach billets lowest (1.29 g). In D-3 diameter, Oak billets produced highest dry weight (7.43 g) and Peach billets lowest (2.09 g). Result indicates that different wood species, different type of diameter and interaction of species and diameter showed significant variation, Oak billets produced highest dry weight (4.74 g) while the Peach billets lowest (1.47 g). However, Oak billets produced highest dry weight (4.74 g) followed by Bhimal billets (4.18 g), Poplar billets (3.02 g), Apricot billets (2.80 g), Plum billets (1.80 g) and Peach billets (1.47 g). In different diameter, diameter D-3 billets produced highest dry weight (4.63 g) followed by diameter D-2 billets (2.76 g) and diameter D-1 billets (1.62 g).

The present study supports the earlier work done by **Bijalwan *et al.* (2021)** who concluded that the dried fruiting bodies yield of *Ganoderma lucidum* in first crop from 50

billets was 160.1 g (dry weight) while the overall production of dried fruiting bodies from three flushes was 362.8 g and the average weight of the fruiting body was 3.02 g in village Sherpur. In village Manjgaun, the dried fruiting bodies yield of *Ganoderma lucidum* in first crop from 50 billets was 151.2 g while the overall production of dried fruiting bodies from three flushes was 316.5 g and the average weight of a fruiting body was 3.2 g.

4.1.3 Biological efficiency of *Ganoderma lucidum* fruiting bodies

Biological efficiency of *Ganoderma lucidum* fruiting bodies in different wood species were studied and the observations are presented in table 4.13.

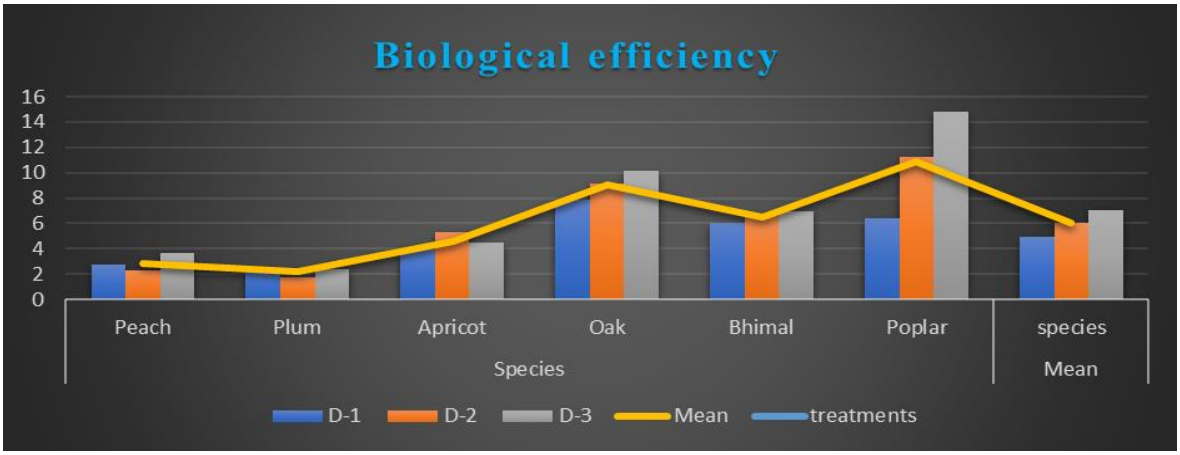


Fig. 4.13 Biological efficiency of *Ganoderma lucidum* fruiting bodies in first crop

Biological efficiency of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.13 and figure 4.13 indicates that Oak billets showed maximum biological efficiency (7.91%) and Plum billets minimum (2.34%) in D-1 diameter. In D-2 diameter, Poplar billets showed maximum biological efficiency (11.27%) and Plum billets minimum (1.78%). In D-3 diameter, Poplar billets showed maximum biological efficiency (14.84%) and Plum billets minimum (2.40%). Results indicates that different wood species and diameter showed sign-

Table-4.13: Biological efficiency (%) of G*anoderma lucidum* fruiting bodies in different wood species

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.76	2.34	3.96	7.91	6.07	6.41	4.90
D-2	2.25	1.78	5.33	9.11	6.55	11.27	6.04
D-3	3.65	2.40	4.44	10.12	6.99	14.84	7.07
Mean species	2.88	2.17	4.57	9.04	6.53	10.84	6.01
CD values (at 5% levels): Species: 2.00*; Diameter: 1.41*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	3.31	2.28	3.70	5.81	5.38	11.02	5.25
D-2	3.23	2.40	4.53	7.76	6.13	10.99	5.84
D-3	3.22	2.09	5.91	9.41	6.39	10.41	6.23
Mean species	3.25	2.25	4.71	7.66	5.96	10.80	5.77
CD values (at 5% levels): Species: 1.42*; Diameter: NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.66	1.64	5.45	6.01	6.17	8.13	5.01
D-2	2.74	2.76	4.92	7.63	5.42	8.12	5.26
D-3	3.08	2.82	5.37	8.29	7.54	10.29	6.23
Mean species	2.82	2.40	5.24	7.31	6.37	8.84	5.50
CD values (at 5% levels): Species: 0.84*; Diameter: 0.59*; Species × Diameter: NS							

ificant variation, Poplar billets showed maximum biological efficiency (10.84%) while the Plum billets minimum (2.17%). However, Poplar billets showed maximum biological efficiency (10.84%) followed by Oak billets (9.04%), Bhimal billets (6.53%), Apricot billets (4.57%), Peach billets (2.88%) and Plum billets (2.17%). In different diameter,

diameter D-3 billets showed maximum biological efficiency (7.07%) followed by diameter D-2 billets (6.04%) and diameter D-1 billets (4.90%).

Biological efficiency of *Ganoderma lucidum* fruiting bodies in different wood species was varied significant, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.13 and figure 4.14 indicates that Poplar billets showed maximum biological efficiency (11.02%) and Plum billets minimum (2.28%) in D-1 diameter. In D-2 diameter, Poplar billets showed maximum biological efficiency (10.99%) and Plum billets minimum (2.40%). In

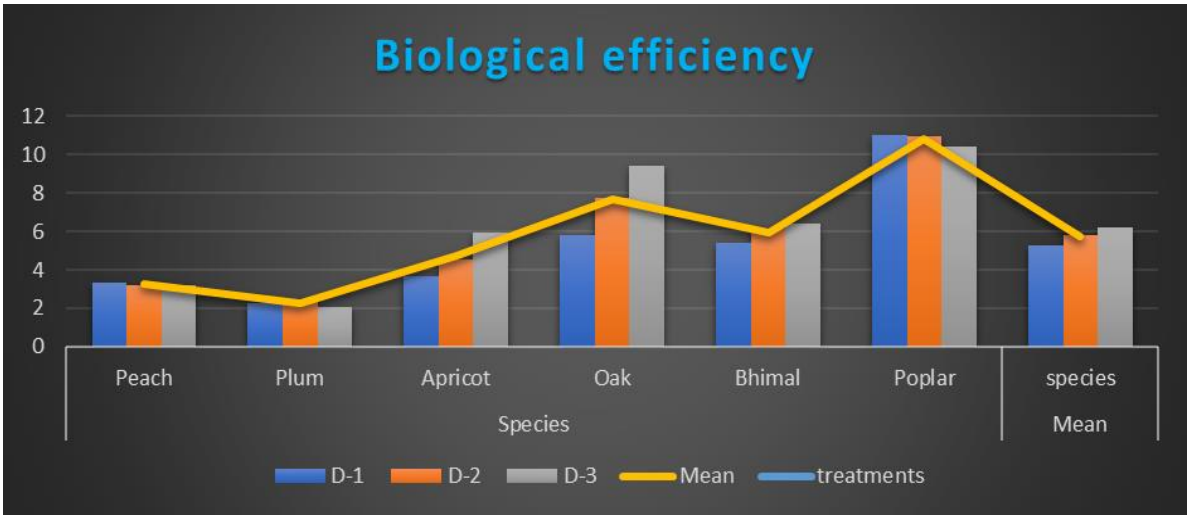


Fig. 4.14 Biological efficiency of *Ganoderma lucidum* fruiting bodies in second crop

D-3 diameter, Poplar billets showed maximum biological efficiency (10.41%) and Plum billets minimum (2.09%). Result indicates that different wood species showed significant variation in each other, Poplar billets showed maximum biological efficiency (10.80%) while the Plum billets minimum (2.25%). However, Poplar billets showed maximum biological efficiency (10.80%) followed by Oak billets (7.66%), Bhimal billets (5.96%), Apricot billets (4.71%), Peach billets (3.25%) and Plum billets (2.25%). In different diameter, diameter D-3 billets showed maximum biological efficiency (6.23%) followed by diameter D-2 billets (5.84%) and diameter D-1 billets (5.25%).

Biological efficiency of *Ganoderma lucidum* fruiting bodies in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in third crop. Result presented in table 4.13 and figure 4.15 indicates that Poplar billets showed maximum biological efficiency (8.13%) and plum billets minimum (2.74%). In D-2 diameter, Poplar billets showed highest biological efficiency (8.12%) and Peach billets lowest (2.74%). In D-3 diameter, Poplar billets showed maximum biological efficiency (10.29%) and Plum billets minimum (2.82%). Result indicates that different wood species and diameter showed significant variation, Poplar billets showed maximum biological efficiency (8.84%) while the Plum billets minimum (2.40%). However, Poplar billets showed maximum biological efficiency (8.84%) followed by Oak billets (7.31%), Bhimal billets (6.37%), Apricot billets (5.24%), Peach billets (2.82%) and Plum billets (2.40%). In ddifferent diameter, diameter D-3 billets showed maximum biological efficiency (6.23%) followed by diameter D-2 billets (5.26%) and diameter D-1 billets (5.01%).

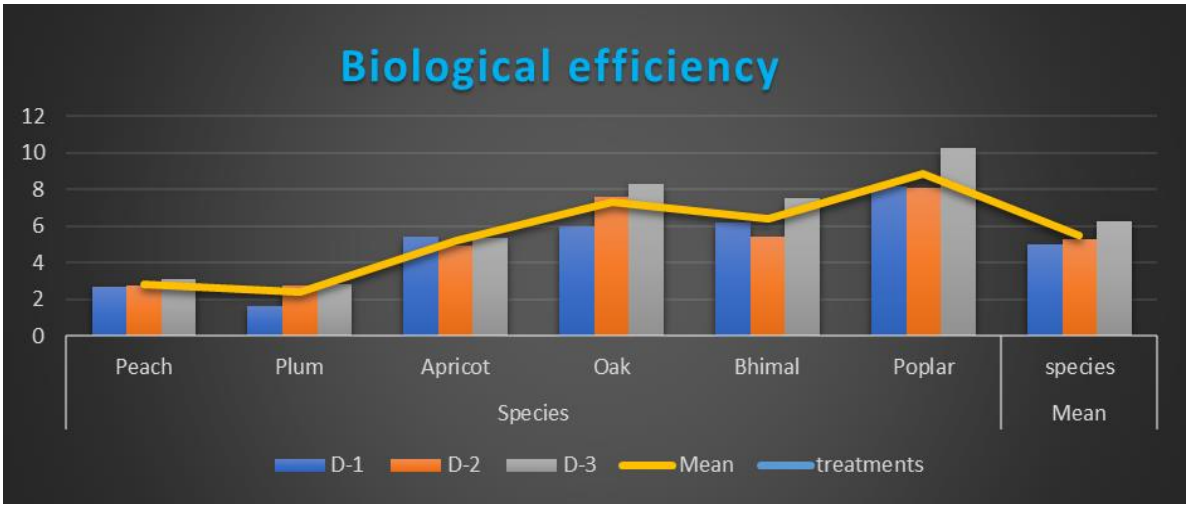


Fig. 4.15 Biological efficiency of *Ganoderma lucidum* fruiting bodies in third crop

The biological efficiency varies depending on the types of sawdust and bran used as well as their combinations was reported by **Rani *et al.*, (2015)** and they concluded that the biological efficiency of *Ganoderma lucidum* fruiting bodies was obtained 8.41±0.48%. The results are in accordance with the studies of **Roy *et al.* (2015)** wherein they concluded that

the biological efficiency from Mahogani and Gerjan supplemented with wheat bran was 7.6% and 6.8% respectively. The overall biological efficiency from Mahogani and Gerjan supplemented with straw bran was 4.3% and 3.6% respectively. On other hand, **Gurung *et al.* (2012)** concluded that they obtained the maximum biological efficiency from *Alnus nepalensis* sawdust (15.69%) while *Shorea robusta* sawdust produced the lowest biological efficiency (0.512%). Similar results have been reported by **Jeewanthi *et al.* (2017)** they concluded that the biological efficiency of *Ganoderma lucidum* fruiting bodies in substrates Mango (100%), Rubber (100%), Rubber + Mango (50%:50%) and Rubber + Lunumidella (50%:50%) sawdust obtained in per bag (5.4%, 5.1%, 5.3% and 5.7%) respectively. Similarly, **Kaur *et al.* (2015)** investigated that the fruiting bodies yield of *Ganoderma lucidum* in three strains and they obtained the maximum biological efficiency in 5% level GL-2 with wheat bran supplement (13%) while strains GL-1 with wheat bran supplement produce minimum BE (10.3%) and strain GL-3 with wheat bran supplement did not produce any fruiting bodies yield. On the country, **Singh *et al.* (2014)** reported that the total fruiting bodies biological efficiency of *Ganoderma lucidum* was obtained 22%. Similarly, **Veena and Pandey (2011)** reported that the dry recovery biological efficiency of *Ganoderma lucidum* was obtained to be 24.1-29.8%.

4.1.4 Total number of *Ganoderma lucidum* fruiting bodies obtained

Total number of *Ganoderma lucidum* fruiting bodies obtained in different wood species were counted and the observations are presented in table 4.14.

After harvesting the *Ganoderma lucidum* fruiting bodies, the significance of number of fruiting bodies obtained in different wood species, different type of diameter was varied significant and interaction of species and diameter was varied nonsignificant in first crop. Result presented in table 4.14 indicates that Poplar billets showed highest number of fruiting bodies (2.33) and Apricot billets lowest (1.0) in D-1 diameter. In D-2 diameter, Oak billets showed highest number of fruiting body (3.33) and Peach & Bhimal billets lowest (1.66). In D-3 diameter, Poplar billets showed highest number of fruiting body (3.0) and Peach billets lowest (1.66). Result indicates that different wood species and

diameter showed significant variation, Poplar billets showed highest number of fruiting body (2.77) while the Peach billets lowest (1.55). However, Poplar billets showed highest

Table-4.14: Total number of *Ganoderma lucidum* fruiting bodies (Nos./billet) obtained in different wood species

First Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.33	1.33	1.00	2.00	1.66	2.33	1.60
D-2	1.66	2.00	2.33	3.33	1.66	3.00	2.33
D-3	1.66	2.00	2.66	2.33	2.33	3.00	2.33
Mean species	1.55	1.77	1.99	2.55	1.88	2.77	2.08
CD values (at 5% levels): Species: 0.76*; Treatments (Diameter): 0.53*; Species × Diameter: NS							
Second Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	2.00	1.33	3.33	1.66	3.00	3.00	2.38
D-2	1.66	1.66	2.00	4.66	2.33	3.00	2.55
D-3	2.33	2.66	3.00	4.00	5.00	3.00	3.33
Mean species	1.99	1.88	2.77	3.44	3.44	3.00	2.75
CD values (at 5% levels): Species: NS; Treatments (Diameter): NS; Species × Diameter: NS							
Third Crop							
Diameter	**Species**						**Mean diameter**
	Peach	**Plum**	**Apricot**	**Oak**	**Bhimal**	**Poplar**	
D-1	1.33	1.33	2.66	1.66	1.33	1.66	1.66
D-2	2.33	2.00	1.33	3.66	3.00	3.00	2.55
D-3	2.66	3.00	3.00	3.66	3.66	3.66	3.27
Mean species	2.10	2.11	2.33	2.99	2.66	2.77	2.49
CD values (at 5% levels): Species: 0.6792; Treatments (Diameter): 0.0058*; Species × Diameter: 0.8258							

number of fruiting body (2.77) followed by Oak billets (2.55), Apricot billets (1.99), Bhimal billets (1.88), Plum billets (1.77) and Peach billets (1.55). In different diameter,

diameter D-2 and D-3 billets showed highest number of fruiting body (2.33) while the diameter D-1 billets showed lowest number of fruiting body (1.60).

The significance of number of *Ganoderma lucidum* fruiting bodies obtained in different wood species, different type of diameter and interaction of species and diameter was varied nonsignificant in second crop. Result presented in table 4.14 indicates that Bhimal and Poplar billets showed highest number of fruiting body (3.0) and Plum billets lowest (1.33) in D-1 diameter. In D-2 diameter, Oak billets showed highest number of fruiting bodies (4.66) and Peach & Plum billets lowest (1.66). In D-3 diameter, Bhimal billets showed highest number of fruiting body (5.0) and Peach billets lowest (2.33). Result indicates that Oak and Bhimal billets showed highest number of fruiting body (3.44) while the Plum billets lowest (1.88). However, Oak and Bhimal billets showed highest number of fruiting body (3.44) followed by Poplar billets (3.0), Apricot billets (2.77), Peach billets (1.99) and Plum billets (1.88). In different diameter, diameter D-3 billets showed highest number of fruiting bodies (3.33) followed by diameter D-2 billets (2.55) and diameter D-1 billets (2.38).

The significance of number of *Ganoderma lucidum* fruiting bodies obtained in different type of diameter (0.0058) was varied significant, different wood species (0.6792) and interaction of species and diameter (0.8258) was varied nonsignificant in third crop. Result presented in table 4.14 indicates that Apricot billets showed highest number of fruiting body (2.66) and Peach, Plum & Bhimal billets lowest (1.33) in D-1 diameter. In D-2 diameter, Oak billets showed highest number of fruiting body (3.66) and Apricot billets lowest (1.33). In D-3 diameter, Oak, Bhimal and Poplar billets showed highest number of fruiting body (3.66) and Peach billets lowest (2.66). Result indicates that Oak billets showed highest number of fruiting body (2.99) while the Peach billets lowest (2.10). However, Oak billets showed highest number of fruiting body (2.99) followed by Poplar billets (2.77), Bhimal billets (2.66), Apricot billets (2.33), Plum billets (2.11) and Peach billets (2.10). In different diameter showed significant variation, diameter D-3 showed

highest number of fruiting body (3.27) followed by diameter D-2 billets (2.55) and diameter D-1 billets (1.66)

.

Our results are having relevance to the studies being reported by **Bijalwan *et al.* (2021)** wherein they reported that *Ganoderma lucidum* mushroom was cultivated on *Populus deltoids* billets in two village, Sherpur and Manjgaun wherein they obtained the 58, 43 and 34 numbers of fruiting bodies from first, second and third flush respectively in village Sherpur while in village Manjgaun, they obtained the 56, 39 and 28 numbers of fruiting bodies from first, second and third flush respectively.

CHAPTER 6 SUMMERY AND CONCLUSSION

Ganoderma lucidum is a well-known medicinal mushroom that has a long history of use and cultivation. It has been recognized and used extensively in Chinese and Japanese culture for about 2000 years. It is a wood-decaying pathogenic fungus associated with root and butt rot. It grows near stumps of broad-leaved trees species in summer and autumn in the wild. It is a wild species found in tropical and temperate regions throughout all over world and survive in hot and moist conditions. It also grows saprophytically or parasitically on the wooden billets (logs).

The present study entitled **"Comparative Study on Cultivation of Medicinal Mushroom (*Ganoderma lucidum)* in Different Tree Species of Garhwal Himalaya, India"** was conducted owing to its medicinal importance and global trade. The research explorations presented in the preceding chapter were conducted on various aspects of growth performance, physical properties of *Ganoderma lucidum* fruiting bodies and yield potential/ biological efficiency of *Ganoderma lucidum* by using substrate (billets) of different tree species. The summary and conclusions of present investigation are as under:

The six broad-leaf tree species: Peach, Plum, Apricot, Oak, Bhimal and Poplar were selected and designated as S-1, S-2, S-3, S-4, S-5 and S-6 respectively with three types of dimensions of each species D-1, D-2 and D-3 for the cultivation of *Ganoderma lucidum.*

The main findings of the present study are summarized below:

- Six different wooden billets with three diameters from each wooden billets were evaluated for the cultivation studies of *Ganoderma lucidum.* Apricot billets were significantly earliest to complete the mycelial colonization as compared to other wooden billets.
- The earliest time for pinhead formation was observed in Bhimal billets as compared to other species billets and diameter D-1 took minimum time for pinhead formation as compared to other diameters in all three crops.
- The minimum time taken to attain cap formation was observed in Bhimal billets as compared to other species billets in first and third crops while Poplar billets were earliest to

reach cap formation stage in second crop. Diameter D-2 took minimum time to reach cap formation stage in first crop while diameter D-1 was earliest to reach cap formation stage in second and third crop.

- The minimum time for fruiting body development was observed in Bhimal billets in first and second crop while Apricot took minimum time for fruiting body development in third crop. The earliest fruiting body development stage was observed in diameter D-2 in first and second crop while the diameter D-1 took minimum time for fruiting body development in third crop.
- The minimum time for harvesting was observed in Bhimal billets in first and second crop while Apricot took minimum time for harvesting in third crop. Diameter D-2 was earliest to harvest in first and second crops while diameter D-1 took minimum time for harvesting in third crop.
- The lowest pinhead lengths were recorded in Apricot billets in all three crops. The lowest pinhead lengths were recorded in diameter (D-1) in first and third crop while in second crop, lowest pinhead lengths were recorded in diameter (D-3).
- Bhimal billets produced the maximum numbers of pinhead in first crop while Oak billets produced maximum numbers of pinhead in second and third crop. Diameter D-3 produced the maximum numbers of pinhead all three crops.
- The highest cap diameter was recorded in Bhimal billets in first and second crop while the highest cap diameter in third crop was recorded in Oak billets. Diameter (D-3) produced the maximum cap diameter in all three crops.
- The lowest stipe length was recorded in Apricot billets in all three crops while the diameter (D-3) showed the lowest stipe length in all three crops.
- The highest fruiting body diameter (9.03 cm) was recorded in Bhimal billets in first crop. The highest fruiting body diameter of 8.75 cm and 7.57 cm was recorded in Oak billets in second and third crops respectively. Diameter (D-3) produced the maximum fruiting body diameter in second crop (8.82 cm) followed by first crop (8.66 cm) and third crop (7.45 cm) respectively.

- Physical appearance (colour, texture and shape) of all the fruiting bodies of *Ganoderma lucidum* obtained from different wood species and diameters were more or less similar and there were no significant changes in their physical appearance.

- The maximum fresh and dry weight of *Ganoderma lucidum* fruiting bodies was obtained in Oak billets in all three crops. diameter (D-3) produced the maximum fresh and dry weight of *Ganoderma lucidum* fruiting bodies in all three crops.
- The maximum biological efficiency of 10.84%, 10.80% and 8.84% was obtained in Poplar billets in first, second and third crops respectively. The maximum biological efficiency was obtained in diameter (D-3) in first crop (7.07 %) followed by second (6.23%) and third crop (6.23 %).
- The maximum numbers of fruiting bodies were obtained in poplar billets in first crop, Oak and Bhimal billets in second crop and Oak billets in third crop. diameter D-2 and D-3 produced the maximum numbers of fruiting bodies in first crop while diameter (D-3) produced the maximum numbers of fruiting bodies in second and third crops.

  Overall, the maximum production of *Ganoderma lucidum* fruiting bodies was attained from Oak and Bhimal with the highest biological efficiency being in poplar wood billets. Plum and peach wood gave the least production of *Ganoderma lucidum* fruiting bodies. The fruiting body development was comparatively better in Oak, Bhimal and Poplar species as compared to the Apricot, Plum and Peach species billets.

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PHOTO PLATES

Plate 1: Preparation of wood Billets

Plate 2: Billets/Logs after debarking

Plate 3 and 4 *Ganoderma lucidum* mycelium run billets


Plate 5 and 6: Casing soil preparation and solarization


Plate 7 and 8 *Ganoderma lucidum* Pinhead formation stage


Plate 9 and 10 *Ganoderma lucidum* cap development stage


Plate 11 and 12 Young fruiting body of *Ganoderma lucidum*

Plate 13 and 14 Mature fruiting bodies of *Ganoderma lucidum*

Plate 15 *Ganoderma lucidum* matured Fruiting bodies ready to harvest

Plate 16 and 17 Sun drying of *Ganoderma lucidum* fruiting bodies

Plate 18 *Ganoderma lucidum* Spore Powder

Plate 19 Packaging of fruiting bodies

APPENDICES

1. Analysis of variance for growth performance of *Ganoderma lucidum* in different wood species.

Appendix –I

Analysis of variance for time taken for pinhead formation (days) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedon	Sum of squares	Mean square	F ratio
Model	17	24.314815	1.43028	1.4369
Error	36	35.833333	0.99537	Prob > F
C. Total	53	60.148148		0.1764

Appendix –II

Analysis of variance for time taken for pinhead formation (days) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedon	Sum of squares	Mean square	F ratio
Model	17	35.333333	2.07843	2.1277
Error	36	35.166667	0.97685	Prob > F
C. Total	53	70.500000		0.0281*

Appendix –III

Analysis of variance for time taken for pinhead formation (days) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedon	Sum of squares	Mean square	F ratio
Model	17	72.50000	4.26471	1.0145
Error	36	151.33333	4.20370	Prob > F
C. Total	53	223.83333		0.4664

Appendix –IV

Analysis of variance for time taken for cap formation (days) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	123.16667	7.24510	4.3230
Error	36	60.33333	1.67593	Prob > F
C. Total	53	183.50000		0.0001*

Appendix –V

Analysis of variance for time taken for cap formation (days) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	108.87500	6.40441	4.2696
Error	36	54.00000	1.50000	Prob > F
C. Total	53	162.87500		0.0001*

Appendix –VI

Analysis of variance for time taken for cap formation (days) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	139.03704	8.17865	1.4612
Error	36	201.50000	5.59722	Prob > F
C. Total	53	340.53704		0.1659

Appendix –VII

Analysis of variance for time taken for fruiting body development (days) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	160.63426	9.44907	2.4472
Error	36	139.00000	3.86111	Prob > F
C. Total	53	299.63426		0.0118*

Appendix –VIII

Analysis of variance for time taken for fruiting body development (days) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	42.53704	2.50218	0.9176
Error	36	98.16667	2.72685	Prob > F
C. Total	53	140.70370		0.5610

Appendix –IX

Analysis of variance for time taken for fruiting body development (days) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	231.41204	13.6125	1.8492
Error	36	265.00000	7.3611	Prob > F
C. Total	53	496.41204		0.0598

Appendix –X

Analysis of variance for time taken by fruiting body of *Ganoderma lucidum* for harvesting (days) in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	563.35648	33.1386	5.2709
Error	36	226.33333	6.2870	Prob > F
C. Total	53	789.68981		< 0.0001*

Appendix –XI

Analysis of variance for time taken by fruiting body of *Ganoderma lucidum* for harvesting (days) in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	320.91204	18.8772	3.5705
Error	36	190.33333	5.2870	Prob > F
C. Total	53	511.24537		0.0006*

Appendix –XII

Analysis of variance for time taken by fruiting body of *Ganoderma lucidum* for harvesting (days) in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	1169.7083	68.8064	1.6190
Error	36	1530.0000	42.5000	Prob > F
C. Total	53	2699.7083		0.1103

2. Analysis of variance for physical properties of *Ganoderma lucidum* in different wood species.

Appendix –XIII

Analysis of variance for pinhead length (cm) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	8.090370	0.475904	1.7127
Error	36	10.003333	0.277870	Prob > F
C. Total	53	18.093704		0.0861

Appendix –XIV

Analysis of variance for pinhead length (cm) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	4.269676	0.251157	1.1004
Error	36	8.216667	0.228241	Prob > F
C. Total	53	12.486343		0.3902

Appendix –XV

Analysis of variance for pinhead length (cm) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	20.652098	1.21483	3.5956
Error	36	12.163200	0.33787	Prob > F
C. Total	53	32.815298		0.0006*

Appendix –XVI

Analysis of variance for number of pinheads emerged (Nos.) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	44.75926	2.63290	1.6532
Error	36	57.33333	1.59259	Prob > F
C. Total	53	102.09259		0.1008

Appendix –XVII

Analysis of variance for number of pinheads emerged (Nos.) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	130.59259	7.68192	1.4762
Error	36	187.33333	5.20370	Prob > F
C. Total	53	317.92593		0.1597

Appendix –XVIII

Analysis of variance for number of pinheads emerged (Nos.) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	61.64815	3.62636	2.1056
Error	36	62.00000	1.72222	Prob > F
C. Total	53	123.64815		0.0298

Appendix –XIX

Analysis of variance for cap diameter (cm) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	77.267193	4.54513	17.2104
Error	36	9.507333	0.26409	Prob > F
C. Total	53	86.774526		< 0.0001*

Appendix –XX

Analysis of variance for cap diameter (cm) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	97.95373	5.76198	6.6176
Error	36	31.34527	0.87070	Prob > F
C. Total	53	129.29899		< 0.0001*

Appendix –XXI

Analysis of variance for cap diameter (cm) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	99.36925	5.84525	3.6609
Error	36	57.47973	1.59666	Prob > F
C. Total	53	156.84899		0.0005*

Appendix –XXII

Analysis of variance for stipe length (cm) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	31.328476	1.84285	17.5151
Error	36	3.787733	0.10521	Prob > F
C. Total	53	35.116209		< 0.0001*

Appendix –XXIII

Analysis of variance for stipe length (cm) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	40.586143	2.38742	3.2818
Error	36	26.188867	0.72747	Prob > F
C. Total	53	66.775009		0.0013*

Appendix –XXIV

Analysis of variance for stipe length (cm) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	50.37703	2.96335	1.6472
Error	36	64.76653	1.79907	Prob > F
C. Total	53	115.14356		0.1025

Appendix –XXV

Analysis of variance for fruiting body diameter (cm) of *Ganoderma lucidum* in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	252.95019	14.8794	26.2095
Error	36	20.43760	0.5677	Prob > F
C. Total	53	273.38779		< 0.0001*

Appendix –XXVI

Analysis of variance for fruiting body diameter (cm) of *Ganoderma lucidum* in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	273.17556	16.0692	6.0765
Error	36	95.20187	2.6445	Prob > F
C. Total	53	368.37743		< 0.0001*

Appendix –XXVII

Analysis of variance for fruiting body diameter (cm) of *Ganoderma lucidum* in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	269.16594	15.8333	3.9168
Error	36	145.52560	4.0424	Prob > F
C. Total	53	414.69154		0.0003*

3. Analysis of variance for production potential/ biological efficiency of *Ganoderma lucidum* fruiting bodies in different wood species.

Appendix –XXVIII

Analysis of variance for fresh weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	2778.5396	163.444	13.5301
Error	36	434.8813	12.080	Prob > F
C. Total	53	3213.4209		< 0.0001*

Appendix –XXIX

Analysis of variance for fresh weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	1996.2001	117.424	15.3580
Error	36	275.2470	7.646	Prob > F
C. Total	53	2271.4471		< 0.0001*

Appendix –XXX

Analysis of variance for fresh weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	1836.0019	108.000	36.1733
Error	36	107.4828	2.986	Prob > F
C. Total	53	1943.4847		< 0.0001*

Appendix –XXXI

Analysis of variance for dry weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	176.78350	10.3990	12.0091
Error	36	31.17337	0.8659	Prob > F
C. Total	53	207.95687		< 0.0001*

Appendix –XXXII

Analysis of variance for dry weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	151.27970	8.89881	13.8890
Error	36	23.06555	0.64071	Prob > F
C. Total	53	174.34525		< 0.0001*

Appendix –XXXIII

Analysis of variance for dry weight (g) of *Ganoderma lucidum* fruiting body in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	183.18157	10.7754	22.5996
Error	36	17.16462	0.4768	Prob > F
C. Total	53	200.34619		< 0.0001*

Appendix –XXXIV

Analysis of variance for biological efficiency (%) of *Ganoderma lucidum* fruiting body in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	657.38715	38.6698	9.0164
Error	36	154.39875	4.2889	Prob > F
C. Total	53	811.78589		< 0.0001*

Appendix –XXXV

Analysis of variance for biological efficiency (%) of *Ganoderma lucidum* fruiting body in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	469.08439	27.5932	12.6333
Error	36	78.63005	2.1842	Prob > F
C. Total	53	547.71444		< 0.0001*

Appendix –XXXVI

Analysis of variance for biological efficiency (%) of *Ganoderma lucidum* fruiting body in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	371.68590	21.8639	6.4726
Error	36	121.60497	3.3779	Prob > F
C. Total	53	493.29087		< 0.0001*

Appendix –XXXVII

Analysis of variance for total numbers of *Ganoderma lucidum* fruiting bodies obtained in different wood species billets in first crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	20.537037	1.20806	2.1745
Error	36	20.000000	0.55556	Prob > F
C. Total	53	40.537037		0.0248*

Appendix –XXXVIII

Analysis of variance for total numbers of *Ganoderma lucidum* fruiting bodies obtained in different wood species billets in second crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	53.87037	3.16885	1.4260
Error	36	80.00000	2.22222	Prob > F
C. Total	53	133.87037		0.1813

Appendix –XXXIX

Analysis of variance for total numbers of *Ganoderma lucidum* fruiting bodies obtained in different wood species billets in third crop.

Source of variation	Degree of freedom	Sum of squares	Mean square	F ratio
Model	17	40.83333	2.40196	1.2236
Error	36	70.66667	1.96296	Prob > F
C. Total	53	111.50000		0.2961

VITAE

The author Maneesh Kumar was born on February 12, 1997 at Silyara, Ghansali, Tehri Garhwal, Uttarakhand, India. He has passed high school examination from G.I.C. Kemra, Kemar, Tehri Garhwal, Uttarakhand in 2013 from Uttarakhand board of school education with 48.6% and intermediate examination from G.I.C. Kemra, Kemar, Tehri Garhwal, Uttarakhand in 2015 from Uttarakhand board of school education with 75.6%. He joined B.Sc. (Hons.) Agriculture programme at R.M.P. (PG) college, Gurukul Narsan, Haridwar, Uttarakhand in 2015 and completed his B.Sc. (Hons.) agriculture degree in year, 2019 with percentage 70.93%. Thereafter he joined College of Forestry, Ranichauri, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand through entrance examination in 2019 for M.Sc. Forestry with specialization Forest Products and Utilization.

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