STANDARDIZATION OF RESIN TAPPING TECHNIQUE OF PINES IN TROPICAL DECIDUOUS FORESTS OF ACHANAKMAR-AMARKANTAK BIOSPHERE RESERVE

Ph.D. (Forestry) Thesis

by

AMIT PRAKASH NAYAK

DEPARTMENT OF FORESTRY

COLLEGE OF AGRICULTURE

FACULTY OF AGRICULTURE

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

RAIPUR (C.G.)

2022

STANDARDIZATION OF RESIN TAPPING TECHNIQUE OF PINES IN TROPICAL DECIDUOUS FORESTS OF ACHANAKMAR- AMARKANTAK BIOSPHERE RESERVE

Thesis

Submitted to the

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

by

AMIT PRAKASH NAYAK

IN PARTIAL FULFILMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

FORESTRY

U.E. ID No. 20192906 **ID No. 20192906**

OCTOBER, 2022

CERTIFICATE – I

This is to certify that the thesis entitled **"Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar Amarkantak Biosphere Reserve"** submitted in partial fulfillment of the requirements for the degree of **"Doctor of Philosophy in Forestry"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research works carried out by **Amit Prakash Nayak** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

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

Co-Chairman **Chairman**

Date:

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	(Dr. R.K. Prajapati)	----------
Co- Chairman	(Dr. Omprakash Madguni)	----------
Member	(Dr. V.Kog)	----------
Member	(Dr. S.S Tuteja)	----------
Member	(Dr. R.R. Saxena)	----------
Member	(Dr.Manish Mishra)	----------

CERTIFICATE - II

This is to certify that the thesis entitled **"Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar- Amarkantak Biosphere Reserve"** submitted by **Amit Prakash Nayak** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Forestry in the Department of Forestry** has been approved by the external examiner and student's Advisory Committee after oral examination.

Signature of External Examiner

(Name: Dr. Bhupender Dutt)

Date: 17.08.2022

Major Advisor

Head of the Department

Faculty Dean

Approved/Not approved

Director of Instructions

Acknowledgement

"Education plays vital role in personal and social development and teacher plays a fundamental role in imparting education. Teachers have crucial role in shaping young people not only to face the future with confidence but also to buildup it with aim and responsibility. There is no substitute for teacher pupil relationship". I start in the name of God-who has best owed up on me all the physical and mental attributes that I posses and skill to cut through and heal a fellow human.

First of all, I would like to thank and praise almighty "Jagannath Mahaprabhu" the most beneficent and merciful, for all his love and blessings conferred upon mankind. He, the creator, the hidden power behind the world, who lead our lives upto our aims and goals is praise-worthy

I take this golden opportunity to express my heartfelt sense of gratitude to those who helped me to make my research possible. These words are small acknowledgement but never fully recompensed for their great help and cooperation. From the core of my pellucid heart which I owe to express my deep sense of gratitude towards chairman of my advisory committee, ***Dr. R.K.Prajapati****, Professor, Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya Raipur, Chhattisgarh. I have no words to express my heartfelt thanks to him for his illuminating guidance; untiring supervision, constant efforts and reflections have given a touch of excellence and formed an invaluable and previous part of this manuscript. It gives me immense pleasure in expressing my sincere gratitude to Co-chairman of my Advisory Committee* ***Dr. M.D. Omprakash*** *Assistant Professor, and* ***Dr. Manish Mishra*** *member of my advisory committee, Faculty of Ecosystem and Environmental Management, Indian Institute of Forest Management, Bhopal, Madhya Pradesh for his their guidance, constant encouragement, scholarly advice, keen interest and constant encouragement throughout the study period,and also for critical evaluation of the manuscript.*

*I have immense pleasure in expressing my whole hearted sense of appreciation for the members of my advisory committee****, Dr. V. Kog*** *Assistant professor, Department of Forestry,* ***Dr. S.S Tutjea*** *Principal Scientist Centre of Excellence on NTFPs and MAPS,* ***Dr. R. R. Saxena,*** *Professor, Department of Statistics and Social Sciences for providing proper guidance and encouragement throughout the research work and without their kind co-operation it would have not been easy for me to complete this manuscript.*

I emphatically owe my venerable thanks to ***P.C.C.F & HoFF, Shri Ramesh Kumar Gupta, IFS*** *and* ***A.P.C.C.F Shri Chitaranjan Tyagi, IFS****,Madhya Pradesh Forest Department for granting permission to conduct the research work in AABR and for their invaluable help and suggestions. The critical ideological contributions* *of* ***Shri Adhar Gupta,IFS*** *(DFO, Anuppur Forest Division),**Shri MansinghMarvi**(SDO,Anuppur), Shri. Mithun Sisodiya (RFO Dindori Production),Shri .Mahendra Kumar Yadav(RFO Forest Training school Amarkantak),Shri Ajendra Singh (RFO,Amarkantak Range) ,Shri Brijlal Singh Paraste(Deputy RO),Rautel ji(Deputy RO), Shri Jaysingh Puri(Beat Guard),Shri Harilal Prajapati(Beat guard),Shri R N Verma (Range staff) for extending the facilities for field work and also for providing field staffs during the strenuous field works.*

I am highly obliged to other teaching staffs of Department of Forestry,Dr.Lalji Singh, Professor, Dr.S.L.Sawmi, Professor, Dr.M.N.Naugraiy, Principal scientist Dr. Pratap Toppo, Asst. Professor, Smt Sarita Bodalkar, Scientist, Smt. Shalini Toppo Asst. and Smt Shilpa Chandrakar, Senior Technical Asst . and also I am thankfull to Dr. Dharmendra Khokar Scientist, Dept. Plant physiology and Dr P.S.Pisalkar, Dept of Agricultural processing and Food Engineering, Assistant Professor, for providing technical advices for analyzing quality paramerts of resin samples and help received from the department of Environmental Science ,IGNTU (Amarkantak)

With deep and heartfelt respect, I extend my appreciation to ***Dr. Girish Chandel*** *, Hon'ble Vice Chancellor* ***Dr. S.S Sengar,****Director of Instructions,* ***Dr. K.L Nandhea ,*** *HOD Forestry & Dean IGKV, ,* ***Dr. P.K Chandrakar*** *Director Research services**,** Raipur and* ***Shri Subhash Chandra (IFS)*** *Director ,IIFM Bhopal for providing necessary facilities, technical and administrative supports for conducting of my research work.*

I am extremely grateful to all of my respected seniors Chandrasikha Patel,Sourav Padmashali ,Harmohan Rath, Arati Deshmukh, Manprti Singh for his support, affection, encouragement and cooperation which made my path easier. Thanks to my loving classmate and juniors, Vibha Sahu, Maxudhan, Yamini Verma, Jiwan Lal ,Mihir Ranjan, Sourav Mohapatra and Manish,Taman,Tapas Bhai, Satya Prakash ,Daya, Jaimnagal,Mithilesh for their support and back up which give me enough mental strength to get through all mind numbering circumstances. The caring and affectionate behavior of front line forest field staff of Amarkantak and Dindori Range (Laxman dada, Bhikamdada, Dukhudada, Soni ji)made me to stay at my research place and concentrate on my studies.

I would like to express my sincere gratitude to Dr. M. Pandey, Librarian Nehru Library, Raipur and Shri Nepal Singh Joradn, Chief Librarian ,IIFM, Bhopal for giving kind help during study.

Diction is not enough to express my gratitude to my beloved parents and guardians Mr.Pradep Kumar Nayak (Father), Smt. Anita Nayak (Mother),Bhuban Bhai, Shubham ,Baisakhi, Dr. Lokesh Sinha (Brother), whose affectionate encouragement and consistent support inspired me throughout my education carriers.

At last but not least, I would like to convey my cordial thanks to all unmentioned persons who directly and indirectly helped me for making my carrier and life as well. A word of apology to those have not mentioned in person and a note of thanks to one and all who worked for the successful compilation of this endeavor.

Department of Forestry **Amit Prakash Nayak**

College of Agriculture,

I.G.K.V., Raipur (Chhattisgarh)

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS/NOTATIONS

α	Alpha
Β	Beta
Δ	Delta
γ	Gamma
±	Error bar
X	Multiplication
%	Per cent
@	At the rate
SEm±	Standard error of mean
SEd	Standard error of Deviation
C.D	Critical Difference
Cp	Centipoise
;	Semicolon
:	Colon
-	Hyphen
/	Slash
₹	Indian rupees.
°C	Degree Celsius
M	Meter
m.a.s.l.	Meters above mean sea level
et al.	And co-workers or and others
I	One
II	Two
III	Three
IV	Fourth
V	Five
VI	Six
cm	Centimeter
sq. km	Square kilometer
ha.	Hectare
Fig.	Figure
g	Gram
Conc.	Concentration

LIST OF ABBREVIATIONS

NTFPs	Non Timber Forest Products
T.S.	Transverse section
US	United States
FAO	Food and Agriculture Organization
EXIM	Export-Import Bank of India
IINRG	Indian Institute of Natural Resins and Gums
FRI	Forest Research Institute
GLC	Gas Chromatography
HNO_3	Nitric Acid
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4,5-T	2,4,5-Tricholorophneoxyacetic acid
H_2SO_4	Sulfuric acid
CEPA	2-Chloroethyl phosphonic acid
HCI	Hydrochloric acid
CaOcl2,	Bleaching powder
GC-MS	Gas chromatography mass spectrometry
Rh	Relative humidity
PA	Protected Areas
AABR	Achanakmar-Amarkantak Biosphere Reserve
pH	Power of Hydrogen
FSI	Forest Survey of India
DBH	Diameter at Breast Height
R-237	Reserve Forest
P-231	Protected Forest
CQ	Chir pine Quarre method
CT	Chir pine Triangular method
CH	Chirpine Borehole method
KQ	Khasi pine Quarre method
KT	Khasi pine Triangular method
KH	Khasi pine Borehole method
PQ	Patula pine Quarre method
PT	Patula pine Triangular method
PH	Patula pine Borehole method
HRY	High Resin Yielders
RPM	Revolutions per minute
ICAR	Indian Council of AgriculturalResearch
IGKV	Indira Gandhi Krishi Vishwavidyalaya
IIFM	Indian Institute of Forest Management

THESIS ABSTRACT

a) Title of the Thesis	:	**"Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar-Amarkantak Biosphere Reserve"**
b) Full Name of the Student	:	Amit Prakash Nayak
c) Major Subject	:	Forestry
d) Name and Address of the Major Advisor	:	Dr. R.K.Prajapati Department of Forestry College of Agriculture, Raipur (CG)
e) Degree to be awarded	:	Doctor of Philosophy in Forestry

Amit Prakash Nayak
Signature of the Student

Signature of Major Advisor

Date: -------------------------

Signature of Head of the Department

ABSTRACT

The present study entitled **Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar- Amarkantak Biosphere Reserve** was carried out in Tropical pine plantation areas of Amarkantak and East Karanjiya range which comes under Anuppur and Dindori Forest Division, Madhya Pradesh during the year 2021-2022. In India, temperate and sub-temperate trees of several pine species have been used for resin tapping, but no one has established a sustainable method of resin tapping in the tropical pine trees. At present India depends on Indonesia, Brazil, Nepal, China, and Vietnam to meet out its resin based products like

varnishes, thinners, perfume, pine oil, soldering flux etc to full fill its domestic demand**,** regardless of the fact that pine species grow rapidly in height and diameter in many parts of the high altitude tropical environment of India. Therefore, the present investigation was aimed to standardize a proper sustainable method of resin tapping technology in tropical environment so that this may aid to provide an alternative source of income to the tribal people residing inside and outside forest fringes.

The purpose of three methods of resin tapping *i.e* Borehole, Quarre and Triangular method was implemented in two indigenous species of Pine (*Pinus roxburghii*,*Pinus kesiya)* and one exotic species of pine *i.e Pinus patula.* The chemical stimulants used for resin tapping in various treatments are T1 (Ethephon 10%),T2 (Ethephon 20%), T3 (Ethephon30%) ,T4 (Sulfuric acid(10%),T5 (Sulfuric acid 15%),T6 (Sulfuric acid 20%) and combine doses of both the chemicals *i.e* T7 (Ethephon 10%+Sulfuric acid 10%),T8 (Ethephon 10%+Sulfuric acid 15%), T9(Ethephon10%+Sulfuric acid 20%), T10 (Ethephon 20%+Sulfuric acid 10%), T11(Ethephon 20%+Sulfuric acid 15%), T12 (Ethephon 20%+Sulfuric acid 20%),T13(Ethephon 30%+Sulfuric acid 10%,),T14 (Ethephon 30%+Sulfuric acid 15%),T15 (Ethephon 30%+Sulfuric acid 20%). Experimental trees divided into different diameter classes according to the diameter growth for tapping purposes i.e For *Pinus roxburghii* (40-55 cm), *Pinus kesiya* (35-50 cm) and for *Pinus patula* (30-45 cm) .The incisions are made at 1 m height from the ground level of tree with the help of battery operated drill machine and wooden chisel, after that chemical stimulants at various concentration (4ml) each used at the injured portion to trigger the resin outflow. Freshening was done in 7 days interval to facilitated the outflow by prolonging the time during which the resin ducts remained open after wounding. In each method of tapping 45 trees per year were selected .After the tapping period the resin samples were collected and analyzed in the laboratory to observe the quality parameters such as Rosin and turpentine oil percent, moisture and ash content, solubility percent etc.

The results of the study on the quantity of resin exudation (g/tree) was found to be highest in *Pinus roxburghii*, followed by *Pinus kesiya* and *Pinus patula. In Pinusroxburghii*,among all the three methods used Borehole method of tapping in the diameter class of 45-50 cm yielded highest resin (261.95 g/tree) whereas in *Pinus kesiya* Quarre method of tapping in diameter class of 40-45cm yielded highest resin yield (62.01g/tree); similarly in *Pinus patula* Triangular method of tapping in the diameter class of 35-40 cm yielded highest resin yield(47.06 g/tree).Among various chemicals used for resin tapping combine dose of both the Ethephon and Sulfuric acid was found to be superior over single doses.

In *Pinus roxburghii* treatment number T13 CH (Ethephon 30%+H_2SO_4 10%) in borehole method of tapping was found to be significantly effective in terms of resin yield (348.56 g/tree),Whereas in *Pinus kesiya* treatment number T14 KQ (Ethephon 30%+$H_2SO_4$15%) in Quarre method of tapping was found to be significantly superior in terms of resin yield(90.44 g/tree).However, in *Pinus patula* it was observed that combined dose of chemical stimulants did not yield highest quantity of resin as compared to other two pine species , In Patula pine treatment number T5PT(Sulfuric acid 15%) in triangular method of tapping was found to be highest per tree resin yield(101.43 g/tree) in both the year of tapping. The result of the study also revealed that significantly highest resin yield was obtained in the month of April, followed by May and March in each species of Pines. The moisture content was found to be highest (1.1%) in resin samples of *Pinus patula*, whereas the ash content was highest (2%) in *Pinus roxburghii. Pinus kesiya and Pinus patula* was found to be highly soluble in Choloform, whereas *Pinus roxburghii* was equally soluble in Benzene and chloroform. In terms of rosin content , highest rosin content (91.48%) was observed in *Pinus patula* and highest turpentine content (18%) was observed in *Pinus kesiya*. Among all the resin samples *Pinus roxburghii* was found to be more viscous and sticky in nature. The rate of healing by formation of callus growth was found to be highest in *Pinus roxburghii*, followed by *Pinus kesiya* and minimum healing rate was recorded in *Pinus patula.*

शोध सारांश

अ) शोध ग्रंथ का शीर्षक: अचानकमार अमरकंटक बायोस्फियर रिज़र्व उष्ण पर्णपाती वनों में पाइन रेज़िन टैपिंग की विधि का मानकीकरण

ब) छात्र का पूरा नाम: अमित प्रकाश नायक

स) प्रमुख विषय: वानिकी

द) प्रमुख सलाहकार का नाम और पता: डॉ. आर के प्रजापति (प्राध्यापक), वानिकी विभाग इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर

इ) प्रदान की जाने वाली उपाधि: वानिकी में डॉक्टरेट ऑफ फिलोसफी

Amit Prakash Nayak

मुख्य सलाहकार के हस्ताक्षर छात्र के हस्ताक्षर

दिनांक: विभाग प्रमुख के हस्ताक्षर

सारांश

पाइन में रेज़िन टैपिंग की विधि का मानकीकरण अचानकमार अमरकंटक बायोस्फियर रिज़र्व उष्ण पर्णपाती वनों में वर्तमान प्रयोग जो कि पाइनस वृक्षों से रेज़िन निकालने के लिए विधि विकसित करने के लिए किया गया है। यह प्रयोग अमरकंटक के वन खंड अनूपपुर व पूर्वी करंजिया रेंज जो कि डिंडोरी वन खंड में आता है वर्ष 2021-22 में निरंतर 2 वर्षों के गहन अनुसंधान से रेज़िन निकालने की सुरक्षित व अधिक रेज़िन कैसे निकाले पर कार्य किया गया है । वर्तमान में हमारे देश में सिर्फ ठंडे वनों जैसे हिमांचल, उत्तराखंड, उत्तरपूर्व एवं कश्मीर में प्राकृतिक रूप से चीड़ व केसिया के वृक्ष होते है जबकि पाइनस पेटुला मैक्सिको देश का वृक्ष है। यह पौधारोपण छेत्र लगभग 50 वर्षों पूर्व 1970 में वन अनुसंधान

संस्थान देहरादून के वैज्ञानिकों द्वारा अमरकंटक की ऊंची पहाड़ियों पर पौधारोपण किया गया था जिनका 50 वर्षों में शानदार विकास हुआ पर चूंकि मध्यप्रदेश के वन पर्णपाती वनों की श्रेणी में आते हैं अतः उपरोक्त प्रजातियों की उत्तरजीविता के उद्देश्य से किया गया था। इन पाइनस के वृक्षों से कभी भी रेज़िन के दोहन का प्रयास वन विभाग द्वारा नही किया गया था| अतः हमने इन पर प्रयोग कर यह जानने का प्रयास किया कि क्या यहा भी हम रेज़िन निकाल सकते है तो हमने रेजिन निकलने की तीन विधियां जिनमे से एक भारत में प्रचलित है बोर होल विधि व त्रिकोणाकार विधि जो कि मलेशिया की विधि है व क्वारें विधि जो कि इंडोनेशिया में रेज़िन निकालने की विधि है। उपरोक्त तीनो विधियों से रेज़िन निकालने का प्रयोग किया साथ ही हमने इथोफोन और सल्फ्यूरिक एसिड के साथ ही इन रसायनो के कुल 15 ट्रीटमेंट लिये व प्रयोग 810 वृक्षो पर किया गया जिसमें प्रत्येक प्रजाति के 270 वृक्षो का चयन किया| इस प्रयोग में हमने सिर्फ 3 सेंटीमीटर गहरा छेद बोरहोल विधि से ड्रिलमशीन से किया व अन्य दो विधियों के लिए बढ़ाई के औजारों का प्रयोग कर वृक्षो में घाव बनाकर रेज़िन निकलने का कार्य किया।

प्रयोग से यह निष्कर्ष निकलता है कि चीड़ पाइन वृक्ष से सबसे अधिक रेज़िन जो कि 348.16 ग्राम प्रति वृक्ष जिसमे इथोफोन 30 % और सल्फ्यूरिक अम्ल 10 % में बोर होल विधि से प्राप्त हुआ । इसके बाद पाइनस पेटुला में हमें 101.43 ग्राम प्रति वृक्ष जो कि सल्फ्यूरिक अम्ल 15 % डालने पर मिला इसके बाद पाइनस केसिया में हमें 90.44 ग्राम प्रति वृक्ष जो कि इथोफोन 30% और सल्फ्यूरिक एसिड 15% में अच्छे परिणाम प्राप्त हुए है।

प्रयोग में हमने विभिन्न डायमीटर क्लास के वृक्षो का चुनाव किया था जिससे यह रिजल्ट मिला कि 45 से 50 सेंटीमीटर डायमीटर क्लास चीड़ में बोरहोल विधि से अधिक रेज़िन निकलता है यह मात्रा 261.95 ग्राम प्रति वृक्ष प्राप्त होती है जबकि पाइनस केसिया में 40-45 सेंटीमीटर डायमीटर क्लास में 62.01 ग्राम प्रति वृक्ष रेजिन निकला यह यह क्वारें विधि से प्राप्त हुआ । पाइनस पेटुला में 35 से 40 सेंटीमीटर डायमीटर क्लास के वृक्षों में 47.06 ग्राम प्रति वृक्ष त्रिकोणाकार विधि से प्राप्त हुआ ।

यह प्रयोग हमने मार्च से मई महीनों तक किया गया था| अतः हमें जो परिणाम प्राप्त हुये है उसमें सबसे अधिक रेज़िन अप्रैल माह फिर मई और सबसे कम मार्च माह में निकलता है जो कि वातावरण के तापमान बढ़ने पर ज्यादा और कम रहने पर कम निकलना पाया गया।

प्रयोगशाला में हमने रेजिन के विभिन्न गुणों हेतु प्रयोग किये जिसमे नमी सबसे अधिक 1.1% चीड़ पाइन, राख का प्रतिशत 2% सबसे अधिक प्राप्त हुआ । इसके धुलनशीलता के अध्यन से हमे जो परिणाम मिले उसमें ये पाया गया की पाइनस पेटुला एवं पाइनस केसिया क्लोरोफार्म में अधिक घुलनशील है। जबकि चीड़ पाइन दोनो रसायन क्लोरोफार्म और बेंजीन में बराबर घुलनशील है ।

रोजिन कंटेंट 91.48% सबसे अधिक पाइनस पेटुला में प्राप्त हुआ इसके अलावा तारपीन पाइनस केसिया 18 % सबसे अधिक मिला । रेजिन के चिकनाई का अध्ययन करने पर जो परिणाम मिले उसमें सबसे ज्यादा चीड़ पाइन चिपकने वाला रेजिन निकला। अब हमने इन वृक्षों से जिनसे रेज़िन निकाला था और उनके घावों को गीली मिट्टी से बंद कर यह देखा की सबसे जल्दी किस वृक्षो में अपनी छाल से घाव को तीव्रता से भरा उसमें चीड़ पाइन > केसिया पाइन > पैटूला पाइन के वृक्षों में घाव भरने की छमता का पता चलता है।

3/3

CHAPTER-I

INTRODUCTION

Forest provides not only natural habitat for wild flora and fauna, but also a source of sustenance and livelihood to the local community due to the available wide varieties of non-timber products from vicinity forest area. Forest and Tree Cover in India has been reported at 24.62 % of the total geographical area with five major categories of forests and these variations are due to variation in climate, soil type, topography, and elevation (FSI,2019). Coniferous Forests, one of the important forest types, naturally found the Himalayan region. These forests have tall straight trees with needle like leaves with downward sloping branches and have cones. During seventies few central Indian States had introduced conifers in the natural forest area owing its economic importance. Conifers are valuable natural resources of India, which contribute substantially to its socio-economic development by providing goods and services to the people and industries (Malik *et al.*, 2012) and Oleoresins occupy a prime place among Non-timber forest products (NTFPs). The production of oleoresins is not only important for oleoresin-based industries but also has an immense potential to generate employment for rural people. The genus Pinus is the most common member of the family Pinaceae. This genus comprises of over 110 species worldwide and divided into two subgenera: Strobus (Haploxylon, soft pines) and Pinus (Diploxylon, hard pines) Richardson and Rundel, 1998). Although more than 100 pine species exist naturally in Europe, Asia, North America and especially in Central America (Lima *et al.*, 1988), few of these species produce resin in a feasible amount to be exploited economically (Santos *et al*.,2016). In the Indian subcontinent, there are six species of pines found naturally in a scattered manner from Jammu to North- East. The classification of Genus Pinus is given in Table 1.1 These species are *Pinus roxburghii* (Chir pine), *Pinus wallichiana* (Blue Pine), *Pinus gerardiana* (Chilgoza /Neoza Pine), *Pinus kesiya (*Khasi Pine), *Pinus merkusii* (Merkus/Teriasserian Pine), and *Pinus armandii* (Armandis Pine) all these pine species are Indigenous to India (Sharma *et* *al*,2018). Out of these *Pinus roxburghii*, *Pinus wallichiana, and Pinus gerardiana are* found in the Himalayan region, whereas *Pinus kesiya*,*Pinus armandi, and Pinus merkusii are* found in the north-eastern parts of India and also distributed in China and Bhutan.

In India, *Pinus roxburghii, P. wallichiana*, and *P. kesiya* are the three common pine species tapped for resin, with Chir pine leading the way (Maheshwari and Konar 1971). *Pinus roxburghii* comes in third place in terms of growing stock in forest status with a total volume of 180.85 m cum (which is 4.12 percent of the total growing stock in the country's forest (FSI,2021).The Blue pine (*Pinus wallichiana*), Khasi pine (*Pinus kesiya*), and Neoza pine (*Pinus gerardiana*) produce a higher grade of turpentine oil with more alpha-pinene, but this could not be commercially exploited due to a variety of factors, such as *Pinus geradiana* provides pine nut called Neoza, which has a high market rate of around Rs 4000-5000/ kg. Whereas, Blue pine and Khasi pine wood, on the other side, are being used for building and high-grade timber. The relative merits of different pine species for tapping, resin yields, and turpentine quality (chemical composition) vary markedly within a species, and according to provenance origin.

Table 1: Classification of Genus Pinus

Kingdom :	Plantae
Division :	Pinophyta
Class :	Pinopsida
Order :	Pinales / Coniferals
Family :	Pinaceae/Abitaceae
Genus :	Pinus

Resins are exudates from plant parts and oozes out from injured part of tree. It is induced mainly by mechanical injury, physiological perturbation, microorganisms, drought, mineral deficiencies, auxins, paraquat, and ethylene, as reported by Fahn *et al.*, (1979). Resin seals the plant's wounds, kills insects and fungi, and allows the plant to eliminate excess metabolites Drocnev, Ja, G, and Toburdanovskij, (1957) discovered that nutrient supply conditions primarily regulate resin yield. The oleoresins exude from trees through resin ducts. The normal resin canals are longitudinal and transverse canals are always included in the fusiform rays. The oleoresin is synthesized in the epithelial cells of the canal and adjoining living parenchymatous cell (Kramer and Kozlowaski,1960). When the tree is injured/tapped, the cells exerts exudation pressure into the lumen of canal and this pressure is responsible for exudation of oleoresin(Murtem,1962).

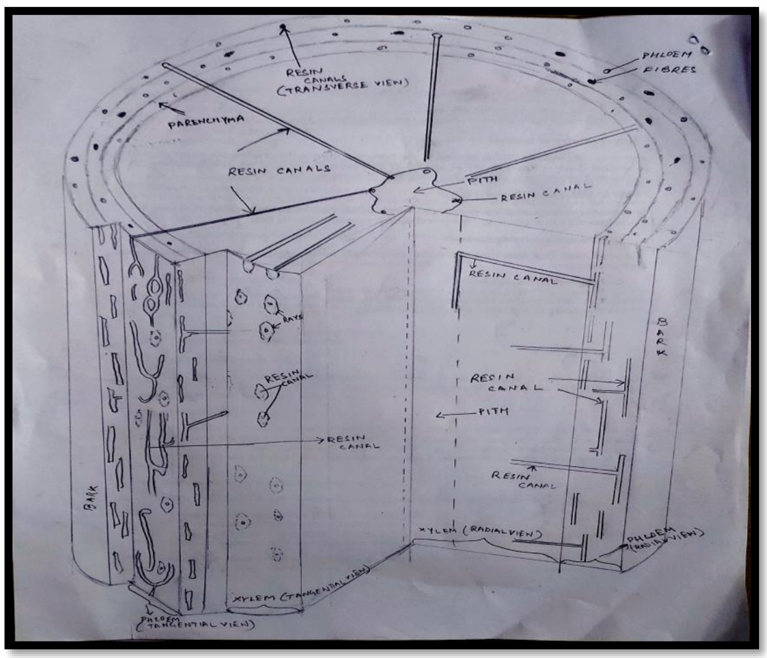


Figure 1.1. T.S. of shoot showing Resin canals

There are several factors which determine the resin yield such as species used for tapping (yield varies from species to species), tree morphology (trees with bigger crown size/crown height and twisted trees yield more resin), method of tapping (example: cup and lip method yields less than rill method whereas in bore hole method yield is much higher), aspect (more resin is secreted on a warmer or sun facing aspect), nature of forest (more yield in open forest as compared to crowded forest), slope of the area (higher yield in slopes as compared to plains), tree diameter (girth), environmental factors and genetic factors, stimulant used and width of blaze etc. (Deshmukh and Dutt, 1967; Kedarnath, 1971; Lohani, 1968)

At global level the resin tapping system was started in the fifteenth century as a naval store industry in America (Chaudhari, 1995). Pierre Hugues (around 1850) developed the first pine resin tapping technique in France. Afterwards, Steele (1869) was granted a US patent for his fish bone tapping technique. Later, this technique was modified by Mazek Fialla in Europe in the 1950s, which came to be known as the Rill Method (which is widely used in India). Presently, there are four tapping techniques used for the production of pine resin. The "Chinese method" is applied in China and South East Asia. The "American method" is used in South America and Europe. The "Hugues method" is used in Indonesia and Mexico, and the "Mazek or Rill method" is mainly used in India.

India has been producing naval stores for a long time. Both natural forests as well as plantations of *Pinus roxburghii have* been used for resin tapping in the northern states of Jammu and Kashmir, Uttarakhand and Himachal Pradesh. Resin tapping was started on an experimental scale in Uttar Pradesh (now Uttarakhand) around 1890 and was commercialized in 1896. It was extended to Himachal Pradesh in 1940 and 1945, respectively (Singh and Asokan, 1984).

In India resin tapping was started with the cup and lip method, and then later replaced by with rill method. Due to these methods considerable damage such as poor growth and casualty was observed in pine trees. Even though the channels were reported to have been completely healed up in about 30 years, but it has been generally found that the timber obtained from such tapped trees deteriorated quality of wood (Kaushal and Khosla, 1984). It has been observed that those tapped trees with such deep channels breakdown during storms (Chaudhari *et al*.,1988). In case of rill method, although the depth of rills is less, the tapped surface area is larger and more open, which results in an increase in the risk of forest fire, disease, and insect pest incidence (Lekha and Sharma, 2010). From the beginning of the early 90s, resin production declined, and the main reasons were the loss of trees for tapping, either because many of them have reached the end of their productive lives and there are no new areas of pine with which to replace them, or because the damage done to trees by the use of inefficient, incorrectly applied methods of tapping, which led to ban by Forest Department on tapping. At present, all the above methods found to be unsustainable and destructive methods have been replaced by new methods in which a bore hole method has been developed and used for the tapping of resin.

Globally, resin tapping is carried out in some selected tree species across various parts of the world. Generally, the species which are tapped at a commercial scale are invariably chosen from those existing within the country either as natural stands or in the form of plantations (Coppen and Hone, 1995). The principal species ofPinus tapped in different countries are presented below (Table 1.2.):

Table -2: Commercially tapped pine trees in different countries

Name of the species	**Producing countries**
Pinus elliottii	Brazil, Argentina, South Africa
Pinus roxburghii	India, Pakistan
Pinus. massoniana and *Pinus kesiya*	People's republic of China
Pinus pinaster	Portugal
Pinus. merkusii	Indonesia,Vietnam
Pinus oocarpa	Mexico, Honduras
Pinus caribaea	Venezuela,Kenya
Pinus. sylvestris	Russia
Pinus halepensis	Greece
Pinus radiate	Kenya

(Source: FAO, 2010)

The Worlds pine resin production 1,114.000 million tons during 2010.China is the world's leader in resin production, with an annual production of 830,000 metric tons. It is followed by Brazil and Indonesia, with production volumes in the order of 180,000 metric tons per year. Whereas other producers of pine resin are India, Argentina, Mexico, Nepal, Russian Federation, Portugal, Spain, Cuba, Vietnam, Madagascar, Fiji, Honduras, South Africa, Colombia, Malaysia, and Uruguay (Cunningham, 2012; Abraf, 2013).

According to Lac, Plant Resins and Gums Statistics 2018, in India, the total export of rosin during the year 2017-18 was 288.42 tons, which was valued ₹294.25 lakh. Similarly, the total import of rosin during the year 2017-18 was 46703.63 tons, which was valued ₹40835.86 lakh. The analysis of EXIM data revealed that the exported quantity of resin increased to 102.2% while the imported quantity of rosin increased by 8.37% in 2017-18 in comparison to 2016- 17. In the international market that year, the export price of rosin decreased by 19.02% and the import price decreased by 4.82% compared to the previous year it was higher than the quantity processed in India. Hence, India depends on Indonesia, Brazil, Nepal, China, and Vietnam to meet out its domestic demand (IINRG, 2018).

The two major products that are obtained from pine resin are rosin (a brittle, transparent, glossy, faintly aromatic solid) and turpentine oil (a clear liquid with a pungent odour and bitter taste). Rosin is used in a wide range of products, including paper size, adhesives, printing inks, rubber compounds, and surface coatings. Whereas, turpentine is a very versatile material and, nowadays, is used mainly as a feedstock by the world's chemical industries. The alpha- and beta-pinene constituents of turpentine, in particular, are the starting materials for the synthesis of a wide range of fragrances, flavours, vitamins, and polyterpene resins, and form the basis of a substantial and growing chemical industry. (Coppen and Honne, 1995).

In the beginning of the 19th century, the absence of pines or coniferous forests in the tropical zones of the Indian subcontinent, Forest Research Institute (FRI) has focused attention and a co-ordinate scheme "Investigation on Fast Growing Tropical Pines and Conifers" initiated during the IV five-year plan (1969–74). As the tropical pines have the ability to grow in a wide range of climates and soils, therefore, many higher plateaus and hill ranges with an elevation of about 1000 meters and an annual rainfall of 1200 mm to 1800 mm are selected for introducing the tropical pines in India. The various states that have been attempting the introduction of tropical pines on a large scale are: Andhra Pradesh, Madhya Pradesh, Odisha, Tamil Nadu, Uttarakhand, and West Bengal (fig 1.2.)

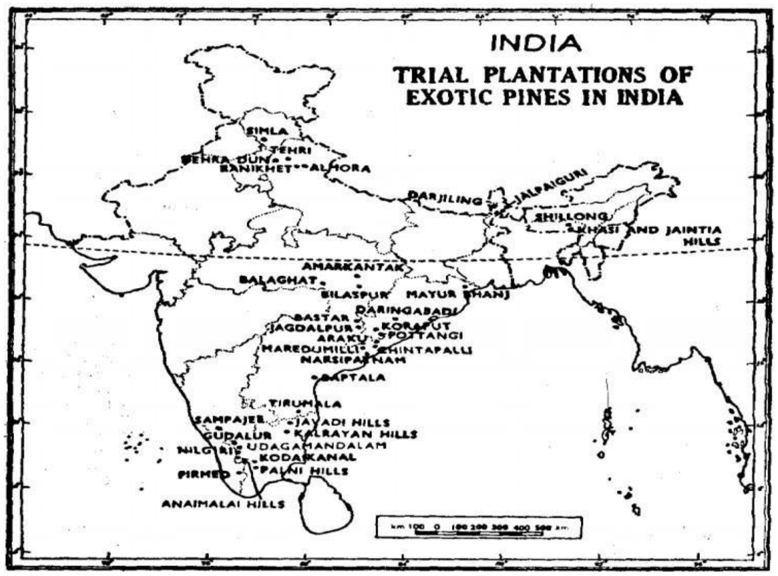


Figure-1.2.: Plantation map of various conifers (Singh *et. al*,1982)

In Madhya Pradesh, the first experimental plantation of tropical pine was done at Jagatpur (Amarkantak) in July,1968 over an area of 0.5 ha, and the species planted was *Pinus caribaea*. Polythene potted plants were planted in 30 cm^3 pits dug after clear-felling operation of Sal (*Shorea robusta*) forest areas (Chaturvedi,1982).

So far, temperate and sub-temperate trees of various pine species have been used for oleoresin tapping in India, but no one has done so in the tropical environment of various pine species that have tremendous growth both in height and diameter and have been planted in tropical forest areas such as Amarkantak.In the present experimental study, three species of pine (including two indigenous and one exotic) were selected for sustainable tapping purposes in the Amarakantak Forest Range. These are; *Pinus roxburghii* Sargent (Chir pine), *Pinus kesiya* Royle ex Gord (Khasi pine), and *Pinus patula* Schlecht. & Cham (Mexican weeping pine).

Details about all the species are mentioned in the Materials and Methods section. Therefore, to meet the increasing requirements of rosin and turpentine for industrial use and to improve the livelihood dependency of tribal people residing in the forest fringes, there is a need to develop a proper sustainable method of resin harvesting in the study area. Hence, two new methods of tapping, like Quaree method and Triangular method along with the much-tested method Borehole method were used for tapping in the present experiment. The present study entitled "**Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar-Amarkantak Biosphere Reserve"** was proposed with the following objectives:

1. To optimize the diameter and depth of incision cut in trees for sustainable tapping.

2. To identify high resin yielding tropical pines between selected species at study area

3. To optimize the concentrations of chemical (Ethephon stimulant) to obtain high yield of oleoresin.

4. To work out on Quality parameters of oleoresin of different Pine species of study area

CHAPTER-II

REVIEW OF LITERATURE

The yield of oleoresin in different pine species depend on the concentration of chemicals available as well morphological, climatic and topographic factors also. A brief review of available literature on different aspects pertaining to present investigation entitled "**Standardization of Resin Tapping Technique of Pinesin Tropical Deciduous Forests of Achanakmar- Amarkantak Biosphere Reserve"** is presented here as under following heads.

2.1 To optimize the diameter and depth of incision cut in trees for sustainable tapping.
2.2 To identify high resin yielding tropical pines between selected species in the study area
2.3 To optimize the concentrations of chemical (Ethephon stimulant) to obtain high yield of oleoresin.
2.4 To work out on Quality parameters of oleoresin of different Pine species of the study area.

2.1 To optimize the diameter and depth of incision cut in trees for sustainable tapping

Murtem (1998) investigated and reported the relationship between morphological and environmental factors and oleoresin yield in order to identify factors that contribute to high oleoresin yield. The correlation coefficients between the morphological parameters such as diameter, height, bark thickness, primary branches, crown length, bole shape, needle colour, grain direction, needle length, and needle diameter with the oleoresin yield were worked out. In his study he observed that the diameter was found to have a significant correlation with the oleoresin yield.

Fahn and Banayour (1976) reported that the Golgi bodies are involved in the dissolution of the middle lamella in the region of the future duct cavity by the secretion of lytic enzymes into the cell walls of *Pinus halepensis.*

Reddy (1985), conducted experiment on resin tapping in Himachal Pradesh and observed that in case of *Pinus wallichiana* resin yield increased significantly with an increase in diameter at breast height (dbh). The trees of 40-45 cm dbh gave significantly higher resin yield than those of 35-40 cm d.b.h trees, in his investigation, data revealed statistically at par with trees of 45 cm d.b.h and above.

Chaudhari (1995) stated that the development of resin tapping in India has been entirely the work of the state forest departments, but the idea of tapping the indigenous pine forests of the Himalaya originally arose after observing that the extraction of crude resin by local people. According to him, in India, commercial tapping of resin from pine trees began in 1896.

Prokazin (1958) conducted studies on *Pinus sylvestris* in various regions of Russia-in-Europe and showed a very wide variation in the resin yield of individual trees. Pines with a high resin yield were said to have shorter in height, more rigid, yellow-green needles, combined with differences in the shape and colour of cone scales, blackish seeds of higher germinative energy, and a more ramified root system than poor resin yielders pine tree.

Sheikh (1979) reported that the diameter of pine trees, crown length, depth, height, periodicity of freshening, ecological factors, fertilization, removal of undergrowth, viscosity of oleo-resin, and other factors can all cause variation in resin yield.

Sheikh (1979) and Chaudhari *et al.* (1992) reported potential sources of variation in resin yield include tree diameter, crown length, depth, height, and frequency of freshening, ecological factors; fertilization; removal of undergrowth, viscosity of oleo-resin, and so on. The yield varies with species to species and also within a species due to the inherited capacity of individuals and seed origin. They elaborated with example, *Pinus roxburghii, P. elliottii, P. merkusii, and P. cariabaea* give a better yield of resin than *Pinus patula, and P. kesiya*

Krishnamurthy *et al.* (1971) and Kedarnath (1971) reported that the variability in resin yield of individuals in a population of pine species has been noticed almost everywhere, which is an inheritance character. According to them the genetic character is also responsible for yield within pine tree species.

Chaudhari (1995) reported that tapping involves causing physical injury to the cambium layer and sapwood of the tree by making a blaze with an adze and collecting the exuded resin in a metal or plastic pot. Various tapping methods have been adopted in response to the advancement of new technology, the availability of labor, and the availability of tapping trees. According to him, there are two general types of tapping:-

(1) light and continuous tapping (applicable to all trees with a g.b.h greater than 0.9 m). Trees between 0.9-1.8 m in girth are tapped in one channel and above 1.8 m in girth in two channels for five years. After five years, a new channel is tapped, leavinga gap of 10 cm between the old channels.

(2) Heavy tapping: This is called "tapping to death, and is common in developed countries. In this method, the maximum amount of resin is exuded by creating as many channels as possible in a 10 cm space. It is generally initiated five years in advance of the main felling. This is destructive harvesting method and now this method is banned.

Coppen and Hone, (1995) &Anonymous, (2009) reported that seasonal changes in climate will largely determine the period of tapping and, accordingly, the resin production was affected with the season to season. During high temperatures are conducive to good resin flow, while prolonged periods of high rainfall cause a decrease in production.

Swain and Patnaik (1998) conducted their resin tapping experiment by rill method of tapping in Koraput and Maliput, Odisha and revealed that average yield of resin per tree at Koraput research station was 3.250 kg, whereas at Maliput it was 4.779 kg/tree.

Chaudhari (1995) also reported other methods of tapping conducted by various researchers. These are the cup and lip method, the Silva Hill Basula method, the Bark chipped method, the Rill method, and the bore hole method. The yield varies with different methods, and the wound to be made on the tree stems is also crucial for determining the suitability of the method. Among these methods, the Rill method has been in vogue for most cases. According him the rill method of tapping has been considered more economical than other methods due to the minimum cutting depth that saves heart wood, fast healing of blaze, stimulant used to make prolonged flow, yields of about 50% more, etc.

Sehgal and Chauhan (1993) studied the relationship between Stomatal density and oleoresin yield in Chirpine and took a step forward in this direction. Dibkon-P3 and Leda-P5 progenies were recorded with the maximum number of stomatal rows on a round surface. Whereas, the maximum number of stomata per mm of a row was obtained in Bagthan-PT-Black Top. Correlation studies between oleoresin yield and number of stomata per mm of a row of progenies projected a significant and positive correlation. Genetic advance (320.28) and genetic gain (35.51%) were found to be the highest for oleoresin yield.

Teshome (2011) conducted resin tapping experiment in *Pinus patula* in Ethiopia and found that trees aged 15 and 20 years produced the highest resin content in the diameter classes (25–30 cm). The experimental results obtained showed that rainfall has no effect on resin production, while temperature shows a positive effect on resin production.

Strange (1958) reported that tree morphology also makes a difference in resin yield. Trees with large crown size, height, and twist yield more resin. In general, the greater the diameter of the tree and the bigger the portion of the live crown, the greater the resin yield. He also discovered that large, fast-growing Chir pine trees with large crowns produce more resin than smaller ones due to the tree's vigor. He also mentioned that early thinning allows the crown to expand will increase resin production.

Tadesse *et al*. (2001) conducted experiment and they selected 51 high resin yielding candidate trees of *Pinus pinaster* Ait. in Central Spain and observed that in comparison to that of the control trees (average production of 7.2 kg/tree/year in selected trees and 3.7 kg/tree/year in control trees) because the candidate trees had slight differences in diameter, height, crown size, and tree stocking when compared to control trees.

Chaudhari *et al.* (1992) reported that the correlation between growth and resin yield showed more yield increases as diameter increases up to 45 cm and then decreases. However, this inference is based on the observation of only 30 Chirpine trees and is not expected to be statistically sound.

Coppen and Hone (1995), reported that humidity and high temperatures are conducive to good resin flow, but prolonged periods of high rainfall are not suitable. It was also noted, on a low level of experimentation resin yield differs with respect to different part of the bole. According to them, yield of resin was greatest in the root column, less in the clean part of the bole and least in the vicinity of the branches.

Flotynski, (1964) observed the effect of soil air temperature, precipitation, and atmospheric pressure on resin yield of Scots pine and reported that soil temperature had the greatest influence on yield; air temperature had a smaller but positive influence; and precipitation did not have a clear influence on resin yield.

Meheta, (1981) conducted experiment on resin tapping in Nepal by making a cut to exposes the surface of the wood. The resin was contained in resin canals, which were either large longitudinal ducts in wood or small ducts in the rays at right angles to the larger ducts. The maximum flow of resin is from the top of the incision, where both the horizontal and vertical ducts are cuts.

Kashio and Johnson (2001) conducted experiment and developed the Indonesian method of tapping *Styrax benzoin* and *S. paralleloneurum* used three tools. A hoop-shaped knife was used to rub and clean off the bark; a wedge is inserted between the bark and wood to make the tapped area into a semi parabola for collecting the resin. After that, the bark around the tapped area is beaten. Resin is collected for about 3–4 months after tapping. A semi-parabola knife is used to cut along the tapped area to open the bark before collecting the resin

Lekha (2002) conducted the resin tapping experiment in *Pinus roxburghii* at Solan and found that the mean yield/tree with 5 cm depth was 450g/tree, 10 cm depth was 692.33 g/tree and with 17.5 cm depth the yield was 1943 g/tree.

Rawat (2001) developed a new tapping technique known as "bore hole technique resin extraction" from *Pinus roxburghii*. In this method, holes were made near the ground level in the sapwood of a tree to open the resin ducts, and the exuding resin is collected in a closed container. The hole in each tree is approximately 1 m above the ground. The holes were drilled straight into the tree stem with a slight slope towards the opening so that resin drains freely.

Brahmi *et al*. (2000) found that the resin yield increased with the increase in diameter class D4 (20–22.5 cm) to D1 (27.5 to 30 cm) and the group of blaze width from B1 (8,10,12, and 14 cm) to B4 (14,16,18, and 20 cm). They found that the maximum resin was obtained in the month of May (the hottest) and the lowest in the month of October (coldest).

Muttoon (1922) and Kalela (1946) observed a close relationship between the diameter of the tree and oleoresin yield. A similar finding was also supported by Kalela further reported that there is a significant effect of d.b.h. and crown ratio in Northern pinewood, between $61^0$3'N latitude.

Grochowski (1951) reported that the simplest and most convenient criterion of resin yield within the limits of a stand is the diameter at breast height, and the best criterion is the total average resin yield from the freshening or the initial efflux. It was further reported that, on an average, an increase of 1" d.b.h. increases the resin yield by 27 barrels per crop and an increase of 0.001" in the mean width of annual rings in the last inch of radial growth increased the yield by 38 barrels per crop (Schopmeyer and Larson, 1954).

Lohani (1968) observed a linear correlation between d.b.h. and resin yield, with some limitations beyond certain higher values of d.b.h. and crown ratio. In another experiment by Lohani (1985), it was stated that there is a marked correlation between resin yield and diameter from Chir pine trees, varying from 30cm to 60cm in diameter tapped by the Cup and Lip method. He reported a 10 per cent increase in yield with an increase of 5 cm in diameter and a diameter range of 37.5–47.5 cm had maximum yield.

Mathauda in 1956 and 1961. carried out experiment on *Pinus roxburghii* Sargent and he revealed that there was a significant influence of d.b.h. and crown ratioon the resin yield.

Chaudhary *et al.* (1992) while studying the correlation between diameter and resin yield by the Rill Method of tapping, they observed that the resin yield increased up to 45 cm and then decreased. Based on this, a model for forecasting the resin yield from trees having a diameter of between 35 and 55 cm was developed.

Vibha (1997) reported a positive and significant correlation of the oleoresin yield with the diameter and height in different provenances of *Pinus roxburghii.*

Mishukov and Kulavov (1970) found that the variation in resin yield of trees with various diameters and generations indicated that the coefficient of correlation between resin yield and stem diameter in *Pinus sibirica* was not more than 0.35, and resin yield in stands of site class II increased up to the age of 200 years and then gradually declined.

Gurgel Filho and Gurgel Garrido (1977) and Filho *et al.* (1967) studied the quantity of resin produced by *Pinus elliotii* in a 15-year-old stand in Brazil and revealed that d.b.h. has a marked effect on the output of resin. Filtho stated the resin yield in *Pinus elliotii var. elliotii* increased with the increase of d.b.h. ranged from 14-30 cm; an increase of 1 cm in d.b.h. increased the resin yield by 10.54g /tree/freshening using the French Method.

Joshi (1972) Conducted a trial and discovered that by reducing the minimum tapping diameter in *P. roxburghii* from 30 cm to 25 cm, the total resin yield could be increased by 25% without causing any damage to the trees or affecting their growth.

Reddy (1985) observed that resin yield increased significantly with the increase in d.b.h. in the case of *Pinus wallichiana*. The trees of 40-45 cm d.b.h. gave a significantly higher yield than those of 35-40 cm d.b.h. However, it was statistically at par with the trees of d.b.h. 45 cm and above.

Khan (1983) studied phenotypic variation in *P.wallichiana* in selected areas of Jammu and Kashmir and Himachal Pradesh. He revealed a positive and significant correlation between height and diameter.

Kaushal and Sharma (1988) reported a significant increase in resin yield with the increase in diameter at breast height in case of blue pine (*Pinus wallichiana*).

Chaudhary *et al.* (1992) observed the highest average yield from the 40–45cm diameter class trees and the lowest yield from the 50cm and above diameter class in Chirpine during 1986 to 1989.

Brahmi (1994) suggested that the trees below 22.5cm in d.b.h. should not be tapped as they registered very low resin yields. He observed that the oleoresin yield increased with an increase in d.b.h. from 20 to 30cm in *Pinus roxburghii*.

Wright (1981) conducted studies on *P. sylvestris* in three provenance trials in Michigan and revealed a strong correlation between height and diameter. Woolastan *et al*. (1990) reported that a strong genetic correlation between diameter and height in *P. caribaea*.

Sehgal and Chauhan (1993) found tree height to be significantly and positively correlated with clean bole in high resin yielders of Chir pine.

Singhal (1997) on the basis of Chi-square test divulged that all needle colors except Yellow-Green gave high resin yield in association with crooked bole form than of straight bole form. However, Yellow-Green color observed higher resin yield in combination with straight bole form. She concluded that association of resin yield with bole form may be either due to the pleiotrophy or linkages between the genes controlling respective traits.

Deshmukh and Payal (1964) revealed from their experiments on the *Pinus roxburghii* that the crown size had no significant effect on the resin yield. Sehgal and Chauhan (1993) found that the height of the tree was significantly correlated with the crown size.

Lohani (1973) reported that the influence of crown ratio (crown height to total height) in Kaligad (U.P) on Chir pine showed a general trend towards an increase in yield with crown ratio indicating a linear relationship. He found that the crown size also has an effect on resin production, with resin yield having a tendency to increase with crown size and crown ratio, while crown density appears to have some effect on resin yielding capacity.

Mathauda (1956) conducted an experiment and revealed that resin producing capacity in all probability is an inherited character and the use of seed from high resin producing tracks is likely to increase resin yield by over 100 per cent in certain localities. However, Barrett also reported that neither total yields nor seasonal trends in yield varied significantly between the seven seed sources in a 24-year-old stand.

2.2. To identify high resin yielding tropical pines between selected species in the study area

Deshmuk *et al.* (1964) reported that both climatic and edaphic factors affect resin yield in Chirpine. According to them, amongst all these factors, evapotranspiration seems to be the most important.

Mathauda (1956) indicated that the Chir resin producing capacity in all probability is an inherited characteristic and that seeds of high yielding trees produce high yields in suitable locations.

Troup (1921) and Schopmeyer (1953) conducted experiment in provenance trial at various locations, and it was discovered that among many stands of Chir pine, Lansdowne and Nainital in Uttrakhand, and Darjeeling in West Bengal, are of poor quality.The quality and quantity of resin being produced by these stands vary due to edaphic, climatic, and genetic factors as these factors govern the tree's growth and, therefore, resin production.

Deshmukh and Payal (1964) reported that climatic factors also influence the tapping of resin, particularly the role of evapo-transpiration, which is a major factor influencing resin yield. Based on the yield of resin from different trees and viscosity values, resin-producing trees were classified into seven classes. These classes directly govern the pattern of tapping.

Upadhyay (1957) reported that the nature of the forest and ground also contribute to the variation of resin yield. More resin is produced in open forest than in crowded forest, and more resin is produced on hilly or sloping land than on level ground. The resin yield of Chir pine trees was 38 to 55 percent higher in ground-clear areas than in trees with dense undergrowth.

Anonymous, (1972) and Bishop and Marckworth (1933) Atmospheric temperature has a definite role to play in the exudation of resin from trees reported that seasonal temperature affects the oleoresin yield, with the yield being high in spring or summer and low in winter.

Chowdhary (1967) has also reported that the resin yield in *Pinus roxburghii* fluctuated with the seasons as it decreased during the cold weather and also during rainy seasons (July and August). However, it increased in September and October due to dry weather.

Kaushal and Sharma (1988) recorded the maximum resin yield in the month of June, the month with the highest temperature. In comparison, low resin yield was obtained in the months with low temperatures and high rainfall in the case of blue pine as well as Chir pine at Himachal Pradesh.

Clements (1961) reported that the effect of tapping months on resin yield of " *Pinus palustris*", he also reported that the warm season (July and August) gave the highest resin yields.

Lohani (1973) worked on the effect of climatic factors on the flow of resin in Chir pine carried out at FRI, Dehradun, Himachal Pradesh and U.P. reported that there was a marked correlation between the temperature and the resin yield. The low humidity increased the resin yield appreciably, provided the temperature is high enough. He further reported that the rainfall and evaporation did not influence the resin yield

Forde and Blight (1964) conducted experiment and revealed that the geographical variation in the turpentine composition of Bishop pine (*P. muricata*) in its northern and southern provenances. The differences in terpene composition were correlated with important morphological differences.

Vibha (1996) conducted rill method of resin tapping on different high resin yielders of *Pinus roxburghii* tree collected from different provenance of Himachal Pradesh. In three months of tapping period, she found that maximum quantity of resin obtained in the Chanina 13 A provenance and the yield was 2103/tree/90 days (25 cm diameter) followed by Majhin 10 A provenance with a yield of 902 gm/tree/90 days (23cm diameter).

Deshmukh and Payal (1964) found that evaporation is an important factor for controlling resin yield. They also found that factors like light intensity, cloudy days, suspended particles in the atmosphere and soil moisture do influence the resin yield, but this is mostly confined to the shorter part of the resin tapping season and, therefore, it is negligible in Chir pine.

Sharma and Kaushal (1992) also studied the influence of some climatic factors on oleoresin yield in *Pinus wallichiana* Jackson. These investigations revealed maximum resin yield in the month of June (the hottest), whereas, lower yields were observed in the coldest months and months with rainfall.

Kulakov (1970) and Betan Court (1981) studied the influence of climatic factors on oleoresin yield in *Pinus sibirica* and in *Pinus caribaea.* These investigations revealed maximum resin yield in the month of June (the hottest), whereas, lower yieldswere observed in the coldest months and months with rainfall.

2.3. To optimize the concentrations of chemical (Ethephon stimulant) to obtain high yield of oleoresin.

Arya (2019) conducted gum tapping experiment on *Commiphora wightii* by using ethephon at various concentration, he made holes angled towards the base of trees to prevent backflow of the solutions. In his experiment he found that highest mean gum

Yield (51.3g/tree by using ethephon (25 mg), followed by 19. 8g/tree by using 175 mgethephon.

Bhatt (1987) reported that the improved gum tapping method involves using ethephon treatment in the trunk by injecting through a syringe into holes made by the increment borer. Gummosis is enhanced by ethephon application and a 466-fold increase in gum yield was recorded in plants treated with 1600 mg of active ethephon substance during April-May, when plants become leafless.

Stephen (1958) while working on *Pinus sylvestris*, they tried to increase the water percentage by covering the wounds with special paper and thus preventing possible evaporation. He used many chemicals that are used as dehydrating agents like H_2SO_4, HCL, and $CaOCl_2$

Nair *et al.* (1985) studied the formation of gum-resin ducts in response to certain chemicals like ethephon (2-chloroethyl phosphonic acid) and parquet in the bark and sapwood of Neem *(Azadirachta indica*). In the controlled samples, the formation of gum resin ducts was observed only after fifteen days, and only a minor amount of gum exudation was observed, while those trees treated with ethephon showed copious gum exudation for prolonged periods. However, the gum-resin ducts developed in response to injury (by making incisions with a chisel) formed only a few ducts and remained active for short periods, while the gum-resin ducts formed in injury immediately followed by fungal infection were active for a longer time and formed several tangential rows of gum ducts.

Hazarika and Bhagat (1984) made studies on *P. wallichiana* resin from Arunachal Pradesh. The yield of rosin and turpentine oil was reached 84 % and 16 g. 0, respectively. The chemical composition of turpentine oil investigated by GLC was 89 % alpha-pinene and 4.4% beta-pinene as major constituents, and the rosin contained 70 % abietic acid as a major component. It was observed that alpha-pinene and beta-pinene were the major components of the turpentine of blue pine (Reddy, 1985).

Prasad and Joshi (1974) conducted a study on *Pinus roxburghii* in which a mixture of H_2SO_4 and HNO_3 at a concentration of 10–30 percent was applied to resin channels every one or two weeks. The results showed that a 20–25 percent acid mixture applied as a spray or paste increased resin yield by 25–33 per cent.

Verma and Payal (1976) investigated the resin yield in *Pinus roxburghii* from various blaze widths as well as the number of untreated and treated faces with a 20% solution of H_2SO_4 and HNO_3 over three tapping seasons. The maximum yield from trees with untreated faces was 13 kg when 48.8 percent of the girth was tapped, whereas from treated faces, a maximum yield of I7 kg was obtained when 61.4 percent of the girth was tapped.

Wolter (1977) reported that deposition of oleoresin can be stimulated by application of an ethylene releasing compound, i.e. 2-chloroethylephosphonicacid.

Snow (1944) reported in *Pinus palustris* and *Pinus elliottii* that 50% water solution of sulfuric acid, applied to fresh wounds every 2 weeks, proved to be the most suitable treatment for resin output. Physiological studies found that the acid did not stimulate the production of oleoresin, but merely facilitated the outflow by prolonging the time during which the resin ducts remained open after wounding.

Gulati et al. (1983) noticed that application of stimulants like 2,4-D, 2,4,5-T and MCPA prolonged the tapping period and, therefore, increased the resin yield.

Kaludin (1983) used yeast extracts alone or in combination with 2-methy 4-chlorophenoxy acetic acid to stimulate resin flow in Scotch pine. Etheral (2-chloroethanephosphonic acid) and sulphite spent, liquor plus 2,4- D have also been tested by him. He noticed that all the treatments increased resin yield. The maximum yield was obtained by ethereal, followed by yeast+2M-4D, sulphite liquor, and 2,4-D and yeast extracts in decreasing order.

McReynolds and Kossuth (1984) reported that the chemical spray treatments of sulphuric acid and 2-chloroethylphosphonic acid applied inside boreholes increased the resin yield.

Wolter and Zinkel (1984) observed that increased ethylene production induced by ethephon treatment also stimulated oleoresin synthesis in red pine and the number of resin ducts increased in wood after treatment and adding to the resin producing capacity of the tree.

Lohani (1984) conducted various experiments on chemical stimulants and concluded that 30 and 50 percent H2SO4, gave 86 percent lower yield to normal one and 25 percent concentration registered similar to conventional method without the use of acid.

Stephan (1985) while studying the effect of camposan (Ethephon) on resin yield in slash pine concluded that to obtain maximum yield, all the freshening should be treated continuously with stimulant.

Mc Reynolds and Kossuth (1985) sprayed chipped faces of slash pine and long-leaf pine with mixtures of liquid sulphuric acid at 12.5, 25.0, and 50% by weight with 0, 2.5, 5.0, 10, and 15% 2-chloroethylphosphonic acid. He reported that maximum yield of 262g /tree was obtained in slash pine with 50 percent H_2SO_4 and 15 percent CEPA. In long leaf pine maximum yield of 297g/cm d.b.h. was obtained with 50% H_2SO_4 +10% CEPA. The addition of CEPA to any acid dose increased yield except for 15% CEPA with 12.5% H_2SO_4, for slash pine and 15% long leaf pine. Increased H_2SO_4 concentration always increased the yield. There was no significant interaction between the effect of $H2SO_4$, and CEPA.

Venkaiah (1991) tested different concentrations of Sulphuric acid (0,10,20%) in combination with 5,10 and 15 percent ethephon for increasing oleoresin yield. Maximum yield was obtained at 20 percent sulphuric acid and 15 percent ethephon mixture.

Sharma and Kaushal (1991) reported that acid mixture of 20 percent sulphuric acid and nitric acid (1:1) has yielded highest amount of resin in *Pinus wallichiana.*

Chaudhari *et al.* (1991) studied the average yield of resin in pines from two methods of preparation, *i.e.,* 1:20 percent acid mixture based on volume by volume and 1:20 percent acid mixture based on weight by weight. The results revealed that a higher yield has been found in the case of a 1: 20 acid mixture based on volume by volume.

Hodges and Johnson (1997) in slash pine observed that the 2·chloroethylphosphonicacid increased resin yield 3 to 4 times greater than with no CEPA treatment. CEPA level of 0.10 ml produced a greater yield. The sulphuric acid had widely variable and mixed effects on the bore hole oleoresin yield. The yields for a high degree of sulphuric acid did not significantly differ, but acid treatments strongly interacted with CEPA treatments. Higher treatment levels of CEPA caused prolonged oleoresin flow.

Anthkowiak (1992) suggested that Flordimex TH (dichloroethanephosphonicacid) sprayed as a 4 percent aqueous solution on to tapping faces in *Pinus sylvestris* of age class III on a poor moist coniferous site increased the seasonal yield by 39 percent.

Pratt and Goeshl (1969) suggested that with very sensitive instruments and very careful technique, it has become possible to show that ethylene is an endogenous growth regulator in plants. Ethylene can regulate ripening, senescence, abscission, epinasty, swelling and elongation, hypertrophy, dormancy, hook closure, leaf expansion, flower induction, sex expression, and exudation. Ethylene is a gaseous effector with a very simple structure is patented as "Ethrer and given the trivial name “Ethephon" the compound is 2-chloroethyl phosphonic acid (CEPA). Ethephon decomposes spontaneously in aqueous solution and in tissues to yield ethylene.

Harrington (1969) experimented with tapping technologies in Slash Pine. He used a 50-percent water solution of sulfuric acid, applied to fresh wounds every 2 weeks, and he found that this was the most suitable treatment for increasing yield. Physiological studies found that the acid did not stimulate the production of oleoresin, but merely facilitated the outflow by prolonging the time during which the resin ducts remained open after wounding.

Hillman (1962) suggested that ethylene acts as an auxin antagonist and thus reduced the auxin level of the tissue, resulting in flowering. Anbazhagan and Shanmugarelu (1982) studied the effect of ethrel and 2-4-D on certain banana cultivars Poovan, Monthan and Nendran.

Mirov *et al*. (1965) studied the chemical composition of *Pinus elliottii* and found that the turpentine oil of *P. elliottii* contained camphene, myrcene, alpha-pinene, betapinene, dipentene, phellandrene, and methyl chavicol. The occurrence of phellandrene was discussed in relation to the geographical distribution and origin of pines.

Rajkhowa and Khan (1962) in *Pinus roxburghii* noticed that 50 percent H_2SO_4 aqueous solution applied in bark chipped faces gave twice the oleoresin yield than unstimulated French faces of 10 cm width. The exudation of oleoresin from resin ducts ceases after sometimes as they get plugged. Many chemicals have been tried to increase the flow rate of resin.

Chawdhary (1967) reported a significant effect of HCI (25%) and Sulphuric acid(25%) spray on resin yield.

Seth and Lohani (1971) discovered that dehydrating chemicals such as acids were the most effective at increasing resin yield (acid stimulation of resin ducts with a 20% mixture of H_2SO_4 and HNO_3 in *Pinus roxburghii* increased resin yield by 50%).

Lekha, 2002 found that in the borehole method of tapping combine dose of $H_2SO_4$20%+10 % Ethephon yielded maximum resin yield of 2031 g/hole/tree recorded in 3 cm diameter and 17.5 cm depth boreholes.

Robert, 1973 studied that the deposition of oleo resin in the wood matrix is a universal phenomenon in *Pinus* species. Increased synthesis and deposition of oleo resin can also be stimulated by systematic application of the bypyridilium salts, paraquate and diaquate.

2.4. To work out on Quality parameters of oleoresin of different Pine species of study area.

Hassan and Amjid (2009) analyzed gas chromatography–mass spectrometric studies on the essential oil of *Pinus roxburghii* and found that the principal component in essential oil was pinene (41.9%) followed by 3-carene (16.3%), caryophyllene (12.3%), p-cymene (1.9%), Terpinenol (1.8%), Limonene (1.7%), Borneol acetate(1.1%), Caryophyllene oxide (1.0%),camphene (0.9%),Tepinyl acetate (0.8%), Phallenderene (0.7%), farnesene (0.6%),o-cymene (0.4%), Butanoic acid, 3-methyl-, 2-phenylethyl ester (0.3%),1-terpinen-4-ol (0.2%), Farnesyle acetate (0.2%) and -terpinene (0.2%).

Dayal (1986) conducted hydrodistillation of resin samples of *Pinus kesiya* and revealed that 312 gm of resin samples contain 21 % turpentine oil and 79 % rosin respectively.

Zajdler (1954) reported that in *Pinus sylvestris,* the turpentine content of crude rosin, when exuded from the tree was 40.7 per cent, but at the lower end of a streak it was 37.3 per cent. The covered faces and cups made of wax paper and tree bark contained 39.1 per cent turpentine, and when both faces and cups were not covered, the turpentine content was 30.0 per cent.

Sharma, 1987 found the turpentine of blue pine has shown about four times more alpha-pinene content as compared to Chir pine. The blue pine rosin contained lesser pimaric acid and neoabietic acid than Chir pine, but an additional acid identified as lambertianic acid.

William (2002) reported that chemical composition of turpentine oils varies from species to species like *Pinus contorta* contain phelladrine, *Pinus pinea* containlimonene, *Pinus ponderosa* contain carene. However, two North American species i.e *Pinus sabiniana* and *Pinus jeffreyi* contain aldehydes instead of terpenes.

Hodges *et al.* (1997) investigated the viscosity of oleoresin and reported that oleoresin of *P. ellioltii* was extremely viscous, Whereas *P. palustris* was of moderately high viscos, and *Pinus taeda* and *P. echinata* oleoresin had lower viscosity.

Verma and Suri (1978) analysed turpentine obtained from *Pinus roxburghii*of difference provenances growing under same conditions. Delta-3-carene was the major constituent (41-63%) in all provenances with alpha-pinene (20-30%) and beta-pinene (4-30%). The studies on *Pinus roxburghii* revealed that there was variation in alphapinene and beta-pinene content in the turpentine oil from oleoresincollected during April and July.

Anonymous,1969 stated that the rosin and turpentine content of crude Chirpine oleoresin was75% and 22%, respectively, with a 3% loss.

Swaleh and Indra (1979.), studied the chemical composition of the turpentine oil extracted from the oleoresin of *Pinus roxburghii,* the delta-3-carene was found to be at its maximum in autumn and decreased gradually towards winter. From June to October, alpha-pinene was found to have increased. It was also revealed that wide variations occurred in alpha-pinene, camphene, beta-pinene, and delta-3-carenecontents.

Kashyap (1978) discovered that samples collected in April had lower levels of alpha-pinene and beta-pinene than samples collected in July.

Zafar *et al*. (2010) used GC-MS to analyze an essential oil of *Pinus roxburghii* needles for antibacterial activity and found that nine components out of forty-one were identified based on their fragmentation pattern. Major components as essential oils of *P*. *roxburghii* needles were α-pinene (29.3%), followed by caryophyllene (21.9%), 3-carene (14.2%), α-terpineol (4.5%), caryophyllene oxide (3.1%), borneol acetate (2.2%), α-longipinene (1.2%), β-myrecene (1.1%), and terpinyl acetate (1.0%).

Singhal (1996) conducted resin tapping experiment in Solan (HP). She collected various resin samples across different places of Himachal Pradesh and found that turpentine oil content in Chirpine varies from 17.33 % to 27.05 %, whereas rosin content varies from 71.72 % to 78.72 %.

Verma and Suri (1978) found that the turpentine oil obtained from *P. roxburghii* lying west of Chakrata contained more β-pinene than those in the east. The maximum (29.67%) content of β-pinene was found in the oil obtained from the trees of Rawalpindi seed.

Bardat and Yazdani (1988) in clones of *P. sylvestris* grown on different sites observed a strong positive correlation between concentrations of delta-3 carene and terpinolene.

Koev *et al.* (1989) found that trees with high content of turpentine had 56–86% pinene and the lowest content of oleoresin of trees with low resin resin yield had high alpha-pinene and betadelta-3 carene). According to them the yield had the greatest content of delta-3 carene.

Bardyshev *et al.* (1973) studied the composition of monoterpenes in turpentine obtained from the oleoresin of *P. sylvestris*, which was studied in Belorussia and West Siberia. The individual trees were distinguished into 4 types: alpha-pinene pines, beta- pinene pines, delta-carene pines, and ordinary pines. They reported that in alpha-pinene pines, the chemical composition of turpentine from oleoresin collected at intervals and collection once at the end of the tapping season did not differ significantly. But in other three types of pine, the amount of alpha-pinene was smaller and the amount of less volatile terpenes was greater in turpentine from oleoresin collected at the end of the tapping season than from collections made at intervals.

Verma and Suri (1978) analysed turpentine derived from *P. roxburghii* of different seed origins but growing under the same conditions. Delta-3-carene was the major constituent (41–63%) in all nine provenances with alpha-pinene (20–30%) and beta-pinene (4–30%), the second and third most abundant constituents, respectively, except in one provenance where there was more beta-pinene than alpha-pinene). On studying the chemical composition of the turpentine oil extracted from the oleoresin of *Pinus roxburghii*, it was revealed that wide variations occurred in alpha-pinene, camphene, beta-pinene, and delta-carene content. Delta canene was found to be highest in autumn and gradually decrease towards winter, whereas alpha-pinene increased from June to October (Swaleh and Indra, 1979).

Afej *et al.* (2013), studied the phenolic components of *P. eldarica* in bark, seed, and needle were investigated by HPLC. The results demonstrate that a significant amount of catechins and epicatechins (subgroup of flavanols) found in the bark, seed, and needle of this pine (0.03%, 0.005%, and 0.019%, respectively, which was based on dry weight.

Ahmad and Jahan (2017) studied the quality parameters in the oleoresins of *Pinus roxburghii.* He obtained resin samples from a drug dealer in Kashmir Valley and discovered that the pH, moisture content, and total ash value were 5.24 0.09, 3 0.00%, and 12 1.73%, respectively.

Sharma (1982) reported that the highest turpentine contents of value 20percent was recorded in the freshly collected resin of *Pinus roxburghii* and lowest of 15 percent in resin analysed after 90 days of storage. The author recommended that resin can be stored upto 40days without loss of turpentine..

Persad (1983) observed more turpentine content in the refrigerated condition of storage as compared to other storage conditions. such as in the open and in a laboratory. The turpentine content decreased with time. The viscosity and specific gravity of turpentine were significantly lower in refrigerated conditions. The specific gravity and ash content of the resin were found to be non-significant.

Coppen *et al.* (1988) studied Chemical constituents present in *Pinus roxburghii* and found that the oleoresin consists α-Pinene (22.8%), camphene (0.4%), β- pinene (14.1), Δ3-carene (50.6%), α-phellandrene (0.1%), α-terpinene (0.4%), limonene (0.9%), β-phellandrene (0.7%), γ-terpinene (0.5%), p-cymene (tr), terpinolene (3.8%), longipinene (0.2%), cyclosativene (tr), longicyclene (0.2%).

Mc Reynolds, (1971), viscosity can be defined as the resistance to change of form that all fluids possess. It is usually expressed in dyne-seconds per square centimeter, or poises. The ratio of viscosity to density is termed kinematic viscosity. The unit of kinematic viscosity, which is expressed in centimeter-gram-seconds, is called the Stoke, after Sir George G. Stokes. Stokes' Law states that the force required to move a sphere through a given viscous fluid at a low uniform velocity is directly proportional to the velocity and radius of the sphere. Higher numerical stokes denote a higher (thicker) viscosity. Schopmeyer *et al*. found that the viscosity of slash pine oleoresin affected the flow rate during the first 24 hours after wounding

Mc Reynolds (1971) studied Oleoresin viscosity was measured in slash pine (*Pinus elliottii* var. elliottii) trees of known genetic origin over a l-year period. A strong broad sense heritability of this trait was found. Seasonal variation followed a definite pattern, with the highest viscosities occurring in early spring and a gradual decline occurring in late spring and summer.

Hodges *et al.* (1977) analysed the physical properties of four major southern pines and found that *Pinus elliottii* oleoresin was extremely viscous, crystallised very slowly, and flowed at a slow rate over a long period. Oleoresin had a moderately high viscosity, a very high yield, and had a high rate of flow. *Pinus taeda* and *Pinus echinata* oleoresins had an average low viscosity, a moderate to low yield, a short duration of flow, and a rapid rate of crystallization.

Gundidza *et al*. (2011) worked on the topic of the rheological, moisture and ash content analyses of a gum resin from *Commiphora africana.* For rheological studies, a rotational viscometer which had the ability to characterise both Newtonian and non-Newtonian systems was used. The gum resins from *C. africana* exhibited low shear stress even at high concentration of the gum resins. The moisture content obtained by them was 10.6 ±0.04%. The ash content was 3.64±0.01%.

CHPATER-III

MATERIALS AND METHODS

The present investigation, entitled, "**Standardization of Resin Tapping Technique of Pines in Tropical Deciduous Forests of Achanakmar-Amarkantak Biosphere Reserve,**" was carried out in Amarkanatk Forest Range (Anuppur forest division) and East Karanjiya Range (Dindori forest division) of, Madhya Pradesh State during the years 2021&2022**.** The oleoresin tapping was carried out during March to May 2021 and 2022, respectively, at different forest stands of aforesaid area. Details of the experimental site, materials, and methodology employed during the course of investigation are described under the following headings:

3.1 Study area
3.2. Description about Pine species selected for resin tapping
3.3. Experimental Methodology
3.4. Details about the treatments
3.5 Morphological Parameters for tree
3.6. Observations recorded in experiment
3.7. Resin Quality parameters
3.8. Statistical Analysis
3.9. Measurement of the Climatological parameters

3.1 Study area:-

3.1.1. General description:

The Achanakmar-Amarkantak Biosphere Reserve was declared in March 2005 which is spread in the lap of the Maikal hills of the Satpuda mountain ranges. The biosphere reserve comprises of three rivers origin: Narmada, Sone, and Amanalla (the supporting river of the Arpa/Mahanadi River). The Biosphere reserve lies at a distance of 60 km from the Bilaspur, CG. The Sal forests of Amarkantak are counted as one of the best Sal forests in the country. The natural glory of the forest is a rare experience on its own. The area lies between 22^0 15" N to 22^0 58" North latitude and 81^0 25" E to 82^0 5" East longitude, and having an area of 3835.51 sq. km, which is partly falling in Madhya Pradesh and Chhattisgarh State. The state-wise distribution of the area shows that 1224.98 sq. km of area comes under Madhya Pradesh and the remaining 2610.53 sq. km. area is in Chhattisgarh. It comprises parts of the Bilaspur district of Chhattisgarh and Dindori and Anuppur districts of Madhya Pradesh falling in the agro-climatic zone of the Central Plateau and Hill Region. District-wise distribution is 68.1% lies in the Bilaspur district, followed by Anuppur (16.2%) and Dindori (15.7%). It includes one protected area (PA), viz., the Achanakmar Sanctuary fallingin Bilaspur district with a total geographical area of 551.15 sq. km. which forms the core zone of the Achanakmar Amarkantak Biosphere Reserve. (Anonymous, 2010)

3.1.2.Zonation: The Achanakmar-Amarkantak Biosphere Reserve has been divided into core, bufferand transition zone. However, the buffer zone area has to be further divided into buffer and restoration zones with the consent of both states governments. (Singh,2008)

3.1.2.1 Core zone: The Achanakmar-Amarkantak Biosphere Reserve has a core zone of 551.15 sq. km constituted by the Achanakmar sanctuary. The entire core zone area falls in Chhattisgarh State.

3.1.2.2 Buffer and Transition Zone: Areas covered by the buffer and transition zone are 1955.875 sq. km. and 1328.09 sq. km., respectively Out of this, 2058.98 sq. km. falls under Bilaspur and Marwahi forest divisions of Chhattisgarh and 1,224.98 sq. km. falls under Dindori and Anuppur forest divisions of Madhya Pradesh. (Van Sangyan, 2016).

The core, buffer and transition zones of the BR are divided into following eleven forest ranges in Chhattisgarh and three in Madhya Pradesh. The entire core zone lies in the

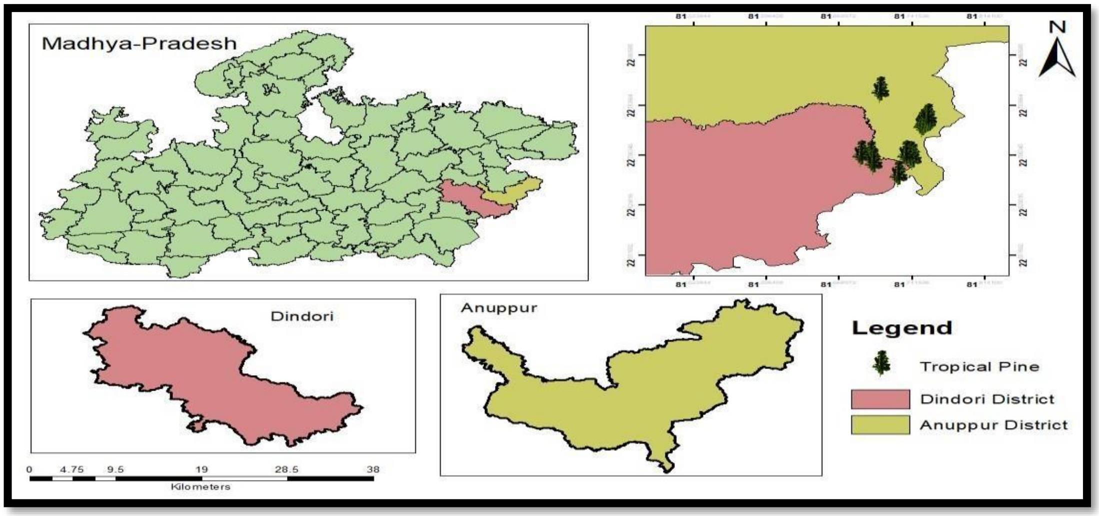
Chhattisgarh state, comprising of the Lamni, Chhaparawa, Achanakmar, and Surhi ranges. The buffer and transition zone partly lie in both the states of Chhattisgarh and Madhya Pradesh, with the major portion falling in Chhattisgarh State. The forest ranges in the buffer zone comprise the Lormi, Kota, Keonchi ranges of Chhattisgarh, whereas, the transition zone comprise Amarkantak, Rajendragram, and East Karanjiya ranges in Madhya Pradesh.

3.1.3. Experimental site

The study was conducted in tropical pine planted in compartment number P-231 of Chakratirath (Sonmuda Beat), R-237 of the Bhundakona beat of Amarkantak Forest range and Kabirchabutra beat of East Karanjiya Range (Figure 3.1). In this range the conifer plantation, was carried out from 1969 to 1982 (Chaturvedi,1982). The total area covered by pine plantations in Amarkantak range was 38.82 ha, and it was plantedin different years till late 90s century.

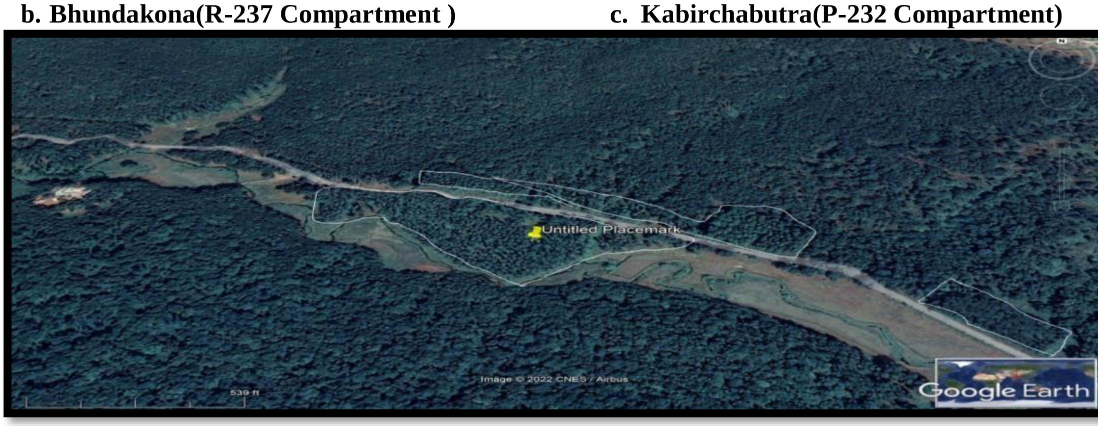
3.1.4. Configuration of the Ground

The topography of the study area varies from plain in the eastern part to plateau and hilly in the south-western part. The areas on both the sides of the rivers Narmada, Son, Johila, and Kewai are prone to soil erosion and have many big and small nallahs drained as their tributaries. The Maikal and lower Vindhyan hills are the main hill ranges of the study area. The Maikal Range, which is a part of the Satpura Mountain Range, is located in the south-western part of the Anuppur forest division. The elevation of the division varies from 500 m to 1175 m above mean sea level (amsl). The hilly terrain in the southern region exhibits a sort of steeping arrangement from the plateau of Amarkantak to the valley of Johilla and then the plains of Son River, with anaverage elevation of 500m.a.m.s.l.



a. (Location map of the study area , Source-Arc GIS)

b. Bhundakona(R-237 Compartment) **c. Kabirchabutra(P-232 Compartment)**



d. Chakratirath(P-231 Compartment)

Fig 3.1. a,b,c,d Pine plantation at different locations((Experimental area, Source-Google earth images)

3.1.5. Geology, rock, and soil

Geological formation found rocks, ranging from 250 million to 60 million years old, belonging to the Archaean group, the Bijawar group, the Vindhyan group, Gondwana group, the Lameta groups and Deccan traps are found in the study area. The Upper Gondwana rocks are mostly found in the form of thick and soft sandstones. However, the soils derived from the above rocks are varied. Lateritic muram soil is the most common soil found on the plateaus as well as in the valleys. Whereas lower areas bear black cotton soil, further the density and quality of forests are mainly dependent on geology and water-holding capacity of the soil. Well-drained soils, such as loams, have goodSal forest stands. The mixed forests occur on trap, quartz, quartzite, and granite rocks due to poor moisture content in the soils, and have high pH.

3.1.6. Climate

The climate of the study area is sub-tropical with three well defined seasons. The rainy season from mid- June to September in this season area receives about 88% of rainfall due to south-west monsoon. However, winter rains are also there due to retreating monsoon. The average rainfall is 1012.6 mm in the study area. During summer, the average maximum temperature ranges from 32.5 ^{0} C to 48. 7 ^{0} C. The highest temperature ever recorded was 48. 7 ^{0} C on 11th June .2009 whereas, lowest temperature ever recorded was 0.3^{0} C on 1 January2013. The overall climatic conditions are suitable for the excellent growth of plants.

3.1.7.Water supply

Due to adequate rainfall, coupled with restricted runoff as most of the areas are covered with good forest canopy, there is no acute shortage of water in the area. The area is the catchment of various perennial rivers such as Narmada, Son and Johilla. Along with this, there are many small tributaries and nallahs such as Kewai, Tipan and Gahirai, etc. which have water in pools even during summer season,

3.1.8. Floral composition

The majority of Amarkantak Forest resources are of Sal and miscellaneous forest, with a few patches of bamboo in plantation areas. As per the working plan report, Sal Forest in Anuppur division consists of 23756.35 ha and other mixed forest covering an area of 25892.06 ha. As per the FSI report (2019) Anuppur district having forest cover 868.68 sq.km**.**

3.1.9. Types of Forest

As per the Champion & Seth (1968), the forests of the division were classified

into:Subtype: 3C/$C_{2e\ (i)}$ - Moist Peninsular High-Level Sal Forest

Subtype: 3C/$C_{2e\ (ii)}$ Moist Peninsular Low level Sal Forest

Subtype: 3C/C_{3a} West Gangetic Moist Mixed Deciduous Forest

Type: 5A/C_3 -Southern dry mixed deciduous forest

Subtype: 5B/C_{1c} -Dry peninsular Sal

3.1.10. Dominating Flora of the Biosphere reserve

The Biosphere Reserve is very rich with a high diversity and density of flora. It comprises of 1527 species of identified flora (Anon, 2010). It has more than 317 species of thallophytes, including 7 species of algae, 179 species of fungi, 130 species of lichen, 44 species of bryophytes, 40 species of ferns, 16 species of gymnosperms (introduced in 1968) , and more than 1, 111 species of angiosperms. .In tropical moist deciduous forests, Sal (*Shorea robusta*) is dominant species, occurring in hilly tracts and low level areas of the Lamni, Game, Marwahi, and Achanakmar ranges, as well as in the valley in the Khudia range. Sal and its associates like Saja (*Terminalia tomentosa*), Bija *(Pterocarpus marsupium*), Dhaora (*Anogeisus latifolia*), Kasai (*Bridelia retusa*), Lendia (*Lagerstroemia parviflora*), Tinsa (*Desmodium oojeinenesis*), Mundi (*Mytragyna parvofolia*) etc. and many species of shrubs like Marorphali (*Helictres isora*), chepti (*Desmodium pulchellum*), Adusa (*Adhatoda*

Plate 3.1. Breathtaking view of AABR

vasica), Baibirang *(Embelica ribes*) etc. Climbers like Mahul *(Bauhinia vahlii*), Keotinar (*Ventilago calyculata*), Malkagani (*Celastrus paniculata*) and herbs like Satavar (*Asparagus racemosus*), Karhata (*Barleria cristata*) exist. The dry mixed deciduous forest consists of dry Sal with associates in the top storey like Saja (*Terminaliatomentosa*), Bija (*Pterocarpus marsupium*), Dhaora *(Anogeisus latifolia*), Kusum *(Schleichera oleosa*), Jamun (*Syzygium cumini*), Mahua (*Madhuca longifolia*), Aonla (*Phyllanthus emblica*), Achar *(Buchanania lanzan*), Baranga (*Kydia calycina*), Bel *(Aegle marmelos*), Khamer (*Gmelina arborea*), Salai *(Boswellia serrata*), Tendu (*Diospyrous melanoxylon*), and a few other thorny species in the middle. The *Isoetes bilaspurensis* (Fam. Isoetaceae) and an angiosperm *Bothrichloa grahamii* (Fam: Poaceae) are endemic to Achanakmar Amarkantak region. (Roychoudhury and Gupta,2016).

3.2. Description about selected tree of Pine for resintapping

3.2.1. **Chir Pine (*Pinus roxburghii*** Sargent***)***

3.2.1.1. Distribution

Pinus roxburghii (family: Pinaceae), commonly known as Chir Pine, is a tall tree with a spreading crown which yields the highest amount of oleoresin in India; named after William Roxburgh and is native to the outer and main valleys of the Himalaya. The Chir Pine forests are found in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, West Bengal and parts of Sikkim, with an estimated total area of 8,90,000 hectares. The major resin producing states are Uttarakhand, Himachal Pradesh, and Jammu and Kashmir in India (Coppen and Hone, 1995). The Chir pines forest are found in elevation ranging from 500–2,500 m a.m.s.l and grows gregariously (Khan *et al*., 2012).

3.2.1.2. Botanical features

Pinus roxburghii is an evergreen tree that can reach 40 m in height and has a trunk that can reach 3 m dbh, but is usually only 1 m dbh.

Crown: Broad, elongated, and more or less pyramidal up to middle age on an older tree, but later becomes spreading, rounded, or umbrella-shaped with a massive branch system.

Branches: self-pruning, long and spreading to ascending, branches occur in the form of whorls up to middle age. **Bark:** Bark becomes thick and divided by long, deep fissures, breaking into large, elongated, scaly plates, weathering grey-brown, with dark brown and purplish hues**. Leaves** near branchlets, persisting 1–2 years, in fascicles of three, held together by persistent, 25–30 mm long basal sheaths, spreading and slightly drooping, 25–30 (–35) cm long, pliant, slender, broadly triangular in cross-section, 1.2–1.7 mm wide; margins minutely serrulate; leaf colour bright green; apex thinly acute-acuminate.

Cones- Pollen cones are clustered near the base of new shoots, spirally arranged, ovoid-oblong, 13–15 mm long. Seed cones are solitary or in whorls of 2–5 on stout branches, short pedunculate, persistent, heavy, broadly ovoid or ovoid-conical when olive green, growing to 10–15 (–20) cm long, 7–12 cm wide when closed, opening only slightly after several years to 13 cm max. width. Apophyses are thick, conical, and strongly developed, with rhombic to irregularly pentagonal bases; umbo triangular, obtuse, and unarmed. (Farjon,2017)

3.2.1.3 Economic importance of Chir Pine:

- It is an important pine species mainly for resin production in the Himalayan region and the seeds are rich in fatty oil, and tannin obtained from its bark is used for curing leather.
- The wood has diaphoretic and stimulant properties. It is useful in treating burns on the body, coughs, and ulcers.

- It has been the basis of the Indian naval stores industry, initiated by Indian Forest Department under British rule during 1888 (Langenheim, 2003). To supply the British Empire with turpentine and related products.
- Rosin finds use in adhesives, printing ink, electric isolation, paper, soldering flux, varnish, and matches. In the printing ink industry, rosin gives adhesiveness, surface smoothness, hardness, anti-blocking and other properties, whereas turpentine oil is commercially important as it is a major component in varnishes, thinners, sealing wax, soaps, and disinfectants.
- The species provides a variety of goods for the communities, such as timber for house construction and packing cases, fuel wood and charcoal, needles for cattle bedding, and leaf litter for manure purposes (Sharma *et al.,* 2006).
- In Europe, especially Norway and Sweden, where pines form the bulk of the vegetation, the wood is used to make very high-quality writing and Kraft paper

3.2.2 General description of Khasi pine (*Pinus kesiya* Royle ex Gord.)

3.2.2.1 Distribution

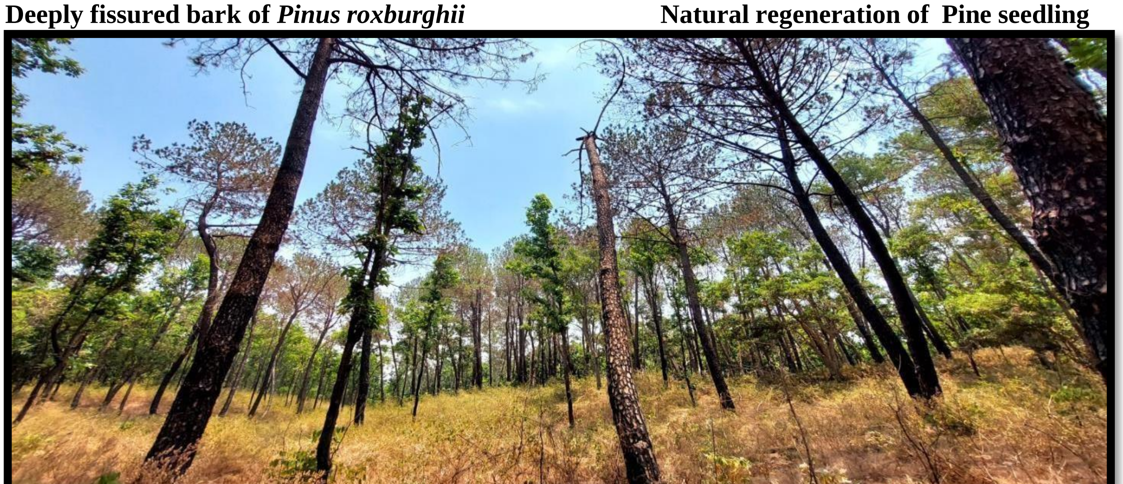
Pinus kesiya, (family: Pinaceae) commonly known as Khasi pine, is an early successional tree species and is an active colonizer of degraded sites. This species is found in the subtropics (800m–2000m) of North-East India (Meghalaya, Manipur, Mizoram, Nagaland, and Arunachal Pradesh), as well as Myanmar and the Philippines in Southeast Asia between 12^0 and 30^0 north latitude. *Pinus kesiya* Royle ex. Gord, which is a dominant forest tree in Meghalaya, constitutes about 30% of the total forest. This species is important in plantations as well as in natural forests in the Philippines, India, Thailand, Vietnam, and other countries in Southeast Asia (Armitage and Burley, 1980). The species epithet refers to the Khasi Hills in NE India, from where it was first reported by J. F. Royle.

Spirally arranged male cones

Broadly ovoid female cones

Deeply fissured bark of *Pinus roxburghii*

Natural regeneration of Pine seedling

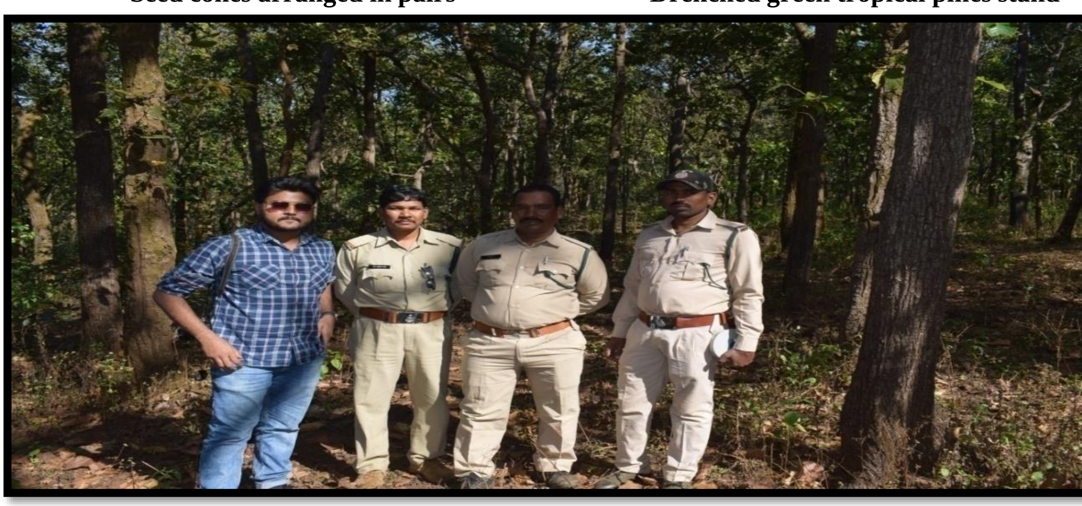


Panoramic view of the *Pinus roxburghii* stands

Plate 3.2. A view of the *Pinus roxburghii* trees in the study area


Grey brown irregular plates like bark of *Pinus kesiya*


Seed cones arranged in pairs **Drenched green tropical pines stand**



Field visit with front line forest staff of Amarkantak Range

Plate -3.3. A view of *Pinus kesiya* trees in the study area

3.2.2.2. Botanical features

Pinus kesiya is a fairly fast-growing evergreen, coniferous tree that can grow up to a height of 20–45 meters and can reach a dbh up to 1 meter.

Crown: Pyramidal or ovoid at first, becoming rounded or umbrella-shaped with age.

Branches: Spreading, crooked branches that self-prune slowly.

Bark: Thick, deeply fissured bark on trunk, forming irregular plates that are rough and flaky, brown, weathering grey-brown**.**

Needles: Arranged in fascicles of 3, 4, or 5, thin, pale green to dark green drooping to pendant, serrulate at the margins, acute apex.

Cones: Pollen cones clustered and spirally arranged at the base of new shoots, short, cylindrical, yellow. Seed cones are solitary or in pairs or threes, with short pedunculate, spreading or reflexes, persistent, 4.5–7 (–8) cm long, narrowly ovoid-conical when closed, Apophysis is prominently raised, more or less pyramidal; Umbo is small, ellipsoid, or at least protruding, armed with a very small, persistent prickle.

3.2.2.3. Economic importance

- Khasi pine is a major source of timber and resin in Meghalaya; the wood of this species is moderately hard, pale brown to red in color, and resinous.

- The timber is used for building houses and other construction purposes, such as making poles and posts, packing boxes, match sticks, match-boxes, and plywood.

- Some genotypes have tremendous biomass potential and oleo-resin prospects.

- Turpentine extracted from *Pinus roxburghii* is devoid of pinene and cannot be used in the camphor industry, whereas, turpentine from *Pinus wallichiana* and *P. kesiya* contains pinene and is useful in the production of synthetic camphor.

3.2.3. General description of *Pinus patula* Schlecht. & Cham

3.2.3.1. Distribution

Pinus patula (Family-Pinaceae) commonly known as Mexican Weeping Pine or Jelecote pine is a straight bole tree with its origins in Mexico (Perry, 1992). It has a wide distribution range, including in Southern and East Africa, where it is commercially planted (Dvorak *et al.,* 2012; Essl *et al*., 2011). *Pinus patula* occurs in the warm to temperate highlands of central and southern Mexico, at altitudes between 1500 and 3000 a.m.s.l. and in areas with abundant precipitation ranging from 1000–2200 mm. The species epithet means 'spreading wide' and refers to the leaves, which are infact drooping or pendulous

3.2.3.2 . Botanical features

Pinus patula is an evergreen tree; it usually grows 35–40 metres tall, and has a g.b.h of upto 1 metre.

Crown- broadly conical, light, and composed of a few more or less ascending branches branching very often from the ground.

Bark: The lower part of the trunk, broken into irregularly shaped plates**,** higher upthin**,** papery reddish brown or orange**,** young shoots more noded, galucous-green, becoming reddish brown or orange.

Needles- In fascicles of 3–4(–5), persisting 2–3 years, thin, lax, drooping to pendant, (11–15or 25–30) cm long, 0.7–0.9(–1) mm wide, serrulate at margins, acute, pale green to dark green.

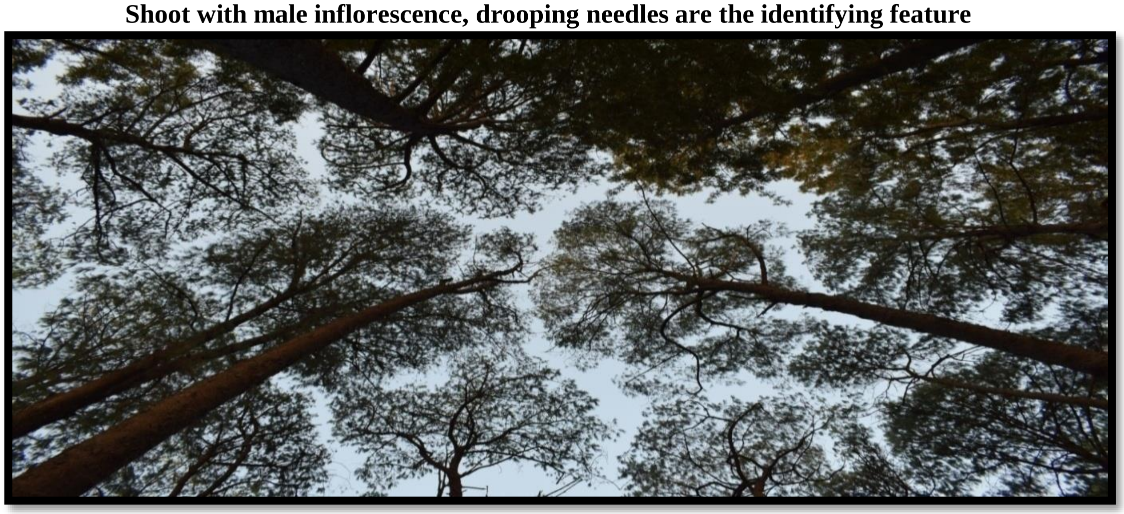
Cones- Pollen cones are ovoid oblong to cylindrical, 1.5–2 cm × 5–6 mm, pinkish yellow. Seed cones are sub terminal or lateral, in whorls of 2–many, rarely solitary, persistent or deciduous, pedunculate. Apophysis is transversely keeled and nearly flat or slightly raised. Umbo dorsal, flat or raised, often sunken into the apophysis, with a minute, deciduous prickle.

3.2.3.3 Economic importance

- This species also been widely introduced in other tropical countries in plantation forestry.
- This species is one of the most important pines for timber in Mexico as it grows fast and produces a long, straight bole, for the most part free of branches.
- The wood is soft and light-colored and easily worked, but can be susceptible to blue stain without treatment.
- It finds applications in flooring and paneling, plywood and particleboard manufacture, veneers, crates and boxes, and, of course, for its softness, pulp for paper; it is therefore, less suitable for high quality furniture and tools**.**
- In Madagascar, the wood is highly appreciated for its glued laminated timber for carpentry and furniture, after the knots have been removed. It is also suitable for hardboard, particle board, and wood-wool. It is an important source of pulpwood in South Africa.
- *Pinus patula is* the most widely planted exotic species in Africa and Ethiopia for timber and pulp production, although their use extends to resin production in Kenya and other parts of Africa.

Rough and scaly bark of *Pinus patula* Seed cones of *Pinus patula*

Shoot with male inflorescence, drooping needles are the identifying feature



Canopy architecture of Pinus patula crown

Plate 3.4.A view of the *Pinus patula*stands in the study area

3.3. Experimental Methodology

Resin tapping methods followed in the present experiment.

3.3.1. Borehole tapping method (Indian method)

The Forest Research Institute, Dehradun, has developed this new tapping technique known as borehole technique of resin extraction from *Pinus roxburghii* (Rawat, 2001). In the present experiment in total, forty-five (45) Borehole shaped cuts were made on each tree species of ***Pinus roxburghii*, *Pinus kesiya* and *Pinus patula*** in each year (March to June) of 2021 and 2022. Details of these incisions are given below.

3.3.1.1. Procedure

- With this method, holes were made at one meter high from ground level with the help of a machine into the tree's sapwood to open the resin ducts, and the exuding resin is collected in a plastic container.
- The hole shapes cut of 2 cm diameter and 3 cm depth were made with a carpenter's wood chisel having diameter class of 25-55 cm.
- The hole in each tree is approximately 1 m above the ground. The holes are drilled straight into the tree stem with a slight slope towards the opening so that resin drains freely.
- Immediately after making the hole, the stimulants/ chemicals in different concentrations of sulfuric acid and ethephon, i.e., Z-chloro-ethyl phosphonic acid and combined dose of both the chemicals sprayed inside each fleshly made hole. A spray volume of 4 ml was applied in each hole.
- After treatment, tin and plastic containers and tin lip were fixed by gently hammering with a mallet or pushing with the palm to achieve compression fitting in the hole.
- Once the plastic container got filled with resin, it was removed from the tree and immediately a new plastic container was fitted for further resin collection.

3.3.2. Quarre method (Indonesian method)

This method is developed by Haldiyane *et al.* (2015) in west Java –Indonesia to extract oleoresin from *Pinus merkusii.* In the current experiment, fourty-five (45) quarre-shaped cuts were made on each tree species of *Pinus roxburghii* , *Pinus kesiya*, and *Pinus patula)* during summer season (March to May) of 2021 and 2022 respectively.

3.3.2.1. Procedure

- The process of the Quarre method is done with the first step being the stem of pine that will be tapped, cleaned of bark, and then wounded with a wood chisel set, with the size of the quarre of 2 cm in width, 10 cm in length, and depth of 3 cm.
- The direction of quarre was vertical so that the resin could flow into plastic glass and a tin lip and a plastic container was fixed to collect the resin.
- Immediately after making the incisions, the stimulants in different concentrations of sulfuric acid and ethephon, and combined dose of both the chemicals are sprayed inside each fleshly made hole. A spray volume of 4 ml was applied to each hole.
- Once the plastic container was filled with resin, it is removed from the tree and immediately a new plastic container was fixed for further collection of resin.

3.3.3.Triangular cut method (Malaysian method)

Kashio and Johnson developed this technique for resin tapping in *Styrax tonkinensi.* This method is used commercially for resin tapping in Malaysia. Certain modifications have been made in this present experiment, like the dimension of incisions and height of tapping. A total of 45 tree species, including *Pinus roxburghii, Pinus kesiya, and Pinus patula*, have been tapped for resin collection in each of the years 2021 and 2022.

3.3.3.1. Procedure

- It entails tapping the trunk at a height of one meter above the ground.
- A chisel is used to make an 8 x 8 x 8 cm long triangular cut with the trianglepointing downwards.
- At the same level, a triangle is sliced into the tree bark to a depth of 3cm. Each incision has its bark and wood removed, and the resin begins to flow.
- Following the cut, a 4 cm × 3 cm piece of Tin sheet is added and bent into a V-shape to direct the flow of resin into a tin affixed to the bottom of the V.

Table 3.1 Study site: - Achanakmar-Amarkantak Biosphere Reserve.(Amarkantak and East Karanjiya Range)

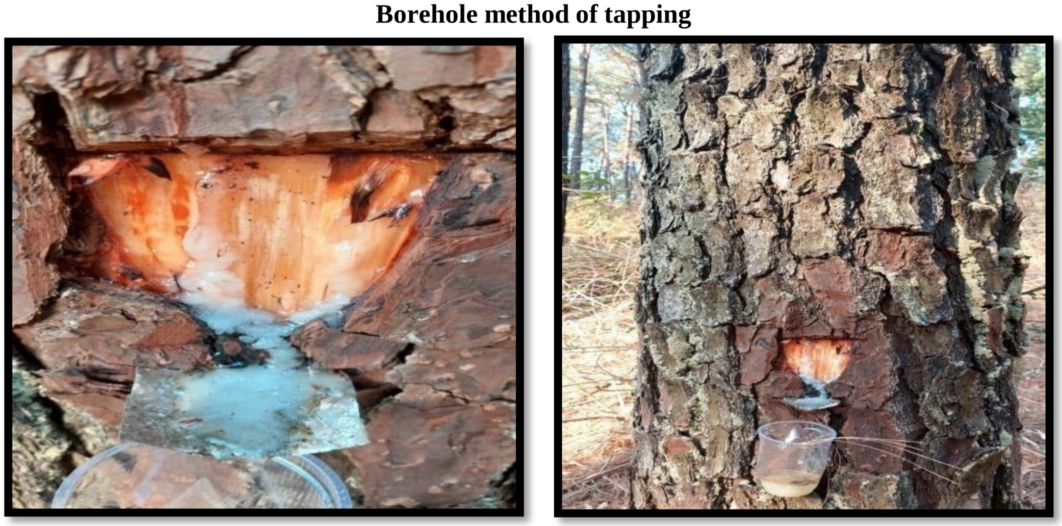
Forest Range	Compartment number
Amaarkantak Range	Bhundakona beat R-237 compartment and Chakratirath (P-231, Sonmuda Beat)
East Karanjiya Range	Kabirchabutra beat, P-232 compartment

Table 3.2. Experimental details:-

Species selected	*Pinus roxburghii*, *Pinus kesiya*, *Pinus patula*
Design	Factorial CRD
Number of Replications	3
Treatment	15
Total number of tree species used for tapping in each shape/method	45 each (total number of trees in each species=135/year)
Season of tapping	Pre-Monsoon: March to May 2021 and 2022.

Quarre method of tapping

Borehole method of tapping



Triangular method of tapping

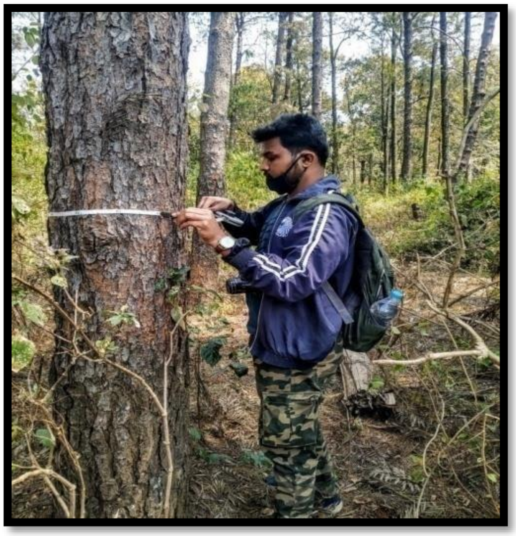
Plate 3.5.Different methods of resin tapping implemented in present experiment

Field inspection at Amarkantak Range by Dr.R.K Prajapati sir

Selection of potential trees for resin tapping

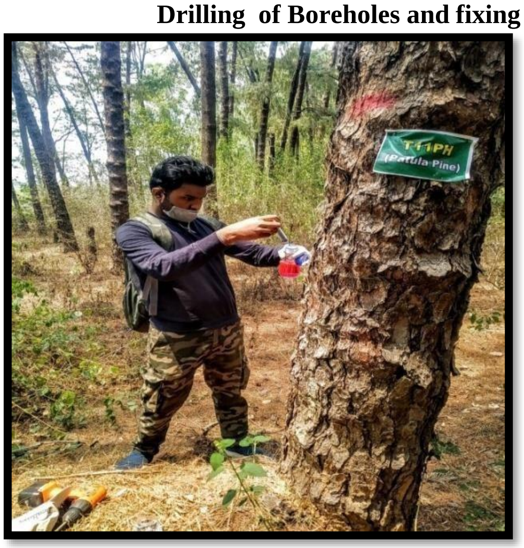
Essential tools required for resin tapping

Plate 3.6. Field selection and other requisites for experiment



Girth measurement of *Pinus patula*   Making triangular shape incision 1 m above the ground

Drilling of Boreholes and fixing tin lip and cup for resin collection



Application of Ethephon stimulant in trees   Resin outflow from Chir pine tree

Plate 3.7. Resin tapping experiment in the field

3.4. Various Treatments used for resin tapping:-

Ethephon, Sulfuric acid and Combine dose of both the chemicals were used in differentconcentrations, all of these are mentioned here.

3.4.1. Only Ethephon at different concentration

Ethephon as a stimulant in 9 numbers of trees in each species of ***Pinus roxburghii*, *Pinus kesiya*** and ***Pinus patula* (Table 3.3)**

Table 3.3. Used of Ethephon at various concentrations

Ethephon	Concentration
T1	10%
T2	20%
T3	30%

3.4.2 Only Sulfuric acid at different concentration

Sulfuric Acid (H_2SO_4) as a refreshing agent in 9 numbers of trees in each shape per species per year in ***Pinus roxburghii*, *Pinus kesiya* and *Pinus patula*** (Table 3.4)

Table 3.4. Used of Sulfuric acid at various conc.

H_2SO_4	Concentration
T4	10%
T5	15%
T6	20%

3.4.3 Combine dose of Ethephon with Sulfuric Acid (H_2SO_4)

Combine treatment of ethephon with Sulfuric acid in 27 numbers of trees in each shape per species of *Pinus roxburghii, Pinus kesiya* and *Pinus patula* (Table 3.5). Details of all the treatments given in following tables 3.6,3.7 and 3.8.

Table 3.5. Use of combine doses of chemicals at different conc.

T7	Ethephon 10 % + 10 % Sulfuric acid
T8	Ethephon 10 % + 15 % Sulfuric acid
T9	Ethephon 10 % + 20 % Sulfuric acid
T10	Ethephon 20% + 10 % Sulfuric acid
T11	Ethephon 20% + 15 % Sulfuric acid
T12	Ethephon 30 % + 20 % Sulfuric acid
T13	Ethephon 30 % + 10 % Sulfuric acid
T14	Ethephon 30 % + 15 % Sulfuric acid
T15	Ethephon 30 % + 20 % Sulfuric acid

Table 3.6. Details of the treatments used in *Pinus roxburghii*.

CHIR PINE		
T1CH=10% E	T1CT=10%	T1CQ=10%
T2CH=20% E	T2CT=20%	T2CQ=20%
T3CH=30% E	T3CT=30%	T3CQ=30%
T4 CH= 10% H	T4 CT= 10%	T4 CQ= 10%
T5CH=15% H	T5CT=15%	T5CQ=15%
T6CH=20% H	T6CT=20%	T6CQ=20%
T7CH= E 10% + H 10%	T7CT= E 10% + H 10%	T7CQ= E 10% + H 10%
T8CH= E 10 %+ H 15%	T8CT= E 10 %+ H 15%	T8CQ= E 10 %+ H 15%
T9CH= E 10% + H 20%	T9CT= E 10% + H 20%	T9CQ= E 10% + H 20%
T10CH= E 20% + H 10%	T10CT= E 20% + H 10%	T10CQ= E 20% + H 10%
T 11 CH= E 20% + H 15%	T 11 CT= E 20% + H 15%	T 11 CQ= E 20% + H 15%
T12CH= E 20% + H 20%	T12CT= E 20% + H 20%	T12CQ= E 20% + H 20%
T13CH= E 30% + H 10%	T13CT= E 30% + H 10%	T13CQ= E 30% + H 10%
T14CH= E 30% + H 15%	T14CT= E 30% + H 15%	T14CQ= E 30% + H 15%
T15CH= E 30% + H 20%	T15CT= E 30% + H 20%	T15CQ= E 30% + H 20%

(E=Ethephon, H= H_2SO_4, CH=Chir pine Bore hole shape method, CT=Chir pineTriangular shape method, CQ= Chir pine Quarre shape method)

Table 3.7. Details of the treatments used in *Pinus kesiya*

Khasi pine		
T1KH=10%	T1KT=10%	T1KQ=10%
T2KH=20%	T2KT=20%	T2KQ=20%
T3KH=30%	T3KT=30%	T3KQ=30%
T4 KH= 10%	T4 KT= 10%	T4 KQ= 10%
T5KH=15%	T5KT=15%	T5KQ=15%
T6KH=20%	T6KT=20%	T6KQ=20%
T7KH= E 10% + H 10%	T7KT= E 10% + H 10%	T7KQ= E 10% + H 10%
T8KH= E 10 %+ H 15%	T8KT= E 10 %+ H 15%	T8KQ= E 10 %+ H 15%
T9KH= E 10% + H 20%	T9KT= E 10% + H 20%	T9KQ= E 10% + H 20%
T10KH= E 20% + H 10%	T10KT= E 20% + H 10%	T1KCQ= E 20% + H 10%
T 11 KH= E 20% + H 15%	T 11 KT= E 20% + H 15%	T 11 KQ= E 20% + H 15%
T12KH= E 20% + H 20%	T12KT= E 20% + H 20%	T12KQ= E 20% + H 20%
T13KH= E 30% + H 10%	T13KT= E 30% + H 10%	T13KQ= E 30% + H 10%
T14KH= E 30% + H 15%	T14KT= E 30% + H 15%	T14KQ= E 30% + H 15%
T15KH= E 30% + H 20%	T15KT= E 30% + H 20%	T15KQ= E 30% + H 20%

(E=Ethephon, H= H_2SO_4, KH=Khasipine Borehole shape method, KT=Khasi pine Triangular shape method, CQ= Khasi pine Quarre shape method)

Table 3.8. Details of the treatments used in *Pinus patula*

Patula pine		
T1PH=10%	T1PT=10%	T1PQ=10%
T2PH=20%	T2PT=20%	T2PQ=20%
T3PH=30%	T3PT=30%	T3PQ=30%
T4 PH= 10%	T4 PT= 10%	T4 PQ= 10%
T5PH=15%	T5PT=15%	T5PQ=15%
T6PH=20%	T6PT=20%	T6PQ=20%
T7PH= E 10% + H 10%	T7PT= E 10% + H 10%	T7PQ= E 10% + H 10%
T8PH= E 10 %+ H 15%	T8PT= E 10 %+ H 15%	T8PQ= E 10 %+ H 15%
T9PH= E 10% + H 20%	T9PT= E 10% + H 20%	T9PQ= E 10% + H 20%
T10PH= E 20% + H 10%	T10PT= E 20% + H 10%	T10PQ= E 20% + H 10%
T 11 PH= E 20% + H 15%	T 11 PT= E 20% + H 15%	T 11 PQ= E 20% + H 15%
T12PH= E 20% + H 20%	T12PT= E 20% + H 20%	T12PQ= E 20% + H 20%
T13PH= E 30% + H 10%	T13PT= E 30% + H 10%	T13PQ= E 30% + H 10%
T14PH= E 30% + H 15%	T14PT= E 30% + H 15%	T14PQ= E 30% + H 15%
T15PH= E 30% + H 20%	T15PT= E 30% + H 20%	T15PQ= E 30% + H 20%

(E=Ethephon, H= H_2SO_4, PH=Patula pine Borehole shape method, PT=Patula pine Triangular shape method, PQ= Patula pine Quarre shape method)

3.5. Measurement of morphological parameters

3.5.1. Diameter of trees

The circumference at breast height (CBH) ranged from 80 to 160 cm of each tree was measured (i.e., 1.37m from the ground level) using measuring tape and furtherit was converted into diameter by using formula ($Girth = \pi \times Diameter$)

3.5.2.Classification of Experimental trees into six diameter classes

Table 3.9- Classification of trees into diameter class

Diameter of tree(cm)	Diameter class
25-30	I
30-35	II
35-40	III
40-45	IV
45-50	V
50-55	VI

3.5.3. Diameter class wise resin tapping

According to the growth status of different Pine species, trees of different diameter classes were selected for resin tapping i.e. For *Pinus roxburghii* (40-55 cm diameter class), *Pinus kesiya* (35-50) and for *Pinus patula* (30-45 cm)..

3.6 Observation recorded include

Reconnaissance of the study area was done during February,2021 and the intensive field work was carried out from March 2021 to May of 2021 and in the next year 2022 field work has been conducted from same March to May. The observations included time of treatment application rate of resin exudation (g/month), time of resin exudation, and quantity of resin exudation (g/tree/year). The details of the observationsare described below.

3.6.1. Rate of resin exudation (g/month)

The rate of resin exudation was measured by application chemical treatment and collection of the resin samples at different time intervals in a month.

3.6.2. Time of resin exudation

The resin exudation was observed after application of treatment in the morning, afternoon after three to four days of the commencement of treatment.

3.6.3 Quantity of resin exudation (g/tree/year)

The quantity of resin exudation was measured by collecting the resin at different time interval in a month and added them to know total resin yield in each season. The yield data per year obtained was compared to check variation in resin exudates per month

3.7. Quality parameter estimation

The study of quality analysis of resin samples was done in the Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants and in Department of Agricultural Processing and Food Engineering of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

3.7 .1 Colour:

The collected resin sample and were analyzed visually for colour determination.

3.7.2 Odour:

The collected resin sample was analyzed by aroma for odor determination.

3.7.3. Moisture content:

Moisture content of resin samples was determined by drying 5g of the resin sample to constant weight at 80 ^{0}C using hot air oven. Dried samples were cooled in desiccators before weighing. Moisture content was expressed as % of mass loss from the original mass as described by Yusuf (2011).

$$\frac{\textbf{Weight of total sample} - \textbf{Weight of dry sample}}{\textbf{Weight of total sample}} \times \mathbf{100}$$

3.7.4. Ash content:

Ash content of the resin samples was determined by burning 1g of resin sample in a muffle furnace at 550 ^{o} C for 4 hours. The ash content was expressed as % ratio of the weight of ash to weight of the sample.

Ash value was designed to measure the total amount of material remaining after ignition. It includes both physiological (derived from plant tissue itself) and non-physiological residue of the extraneous matter like sand that are adhering to plant substances. It was also used to determine the critical levels of foreign matter, acid insoluble matter, salts of calcium, potassium and magnesium (Mocak *et al.*1998).

$$\textbf{Ash content}(\%) = \frac{\mathbf{W3 - W1}}{\mathbf{W2 - W1}} \times \mathbf{100}$$

Where, W_1 = weight of the empty crucible W_2 = weight of crucible + sample and

W_3 =weight of crucible + ash

3.7.5. Turpentine content

Twenty-five grams of oleoresin sample from each tree was taken· in a round bottom flask and sufficient amount of water was added to it. The flask was fixed with clevenger's apparatus and was heated with frequent agitation. Heating was continued for about one and half hour and after cooling for at least five minutes; the volume of turpentine in the graduated portion of the tube was noted. The distillation was continued until successive readings of the volume of turpentine did not differ (Persad, 1983)

Turpentine content (%) was calculated as follows:

$$\textbf{Turpentine}\ (\%) = \frac{\boldsymbol{X}}{\boldsymbol{Sampleweight}\ (\mathbf{25}\boldsymbol{gm})} \times \mathbf{100}$$

Where: x is the volume of turpentine in ml.

3.7.6. Rosin content

The nonvolatile solid material called rosin which remained in the flask after distillation was allowed to cool until it was solidified. The rosin was weighed and the percentage of rosin was calculated as under:

$$\textbf{Rosin}\ (\%) = \frac{\boldsymbol{X}}{\boldsymbol{Sample\ weight}\ (\mathbf{25}\boldsymbol{gm})} \times \mathbf{100}$$

Where: X is the weight of rosin in gram.

3.7.7. Viscosity

The viscosity of a liquid is its resistance to shearing, to stirring in capillary tube. Viscosity was considered as one of the most important analytical and commercial parameters, since it is a factor involving the size and the shape of the macro-molecule. Viscosity can be presented in many terms such as relative viscosity, specific viscosity, reduced viscosity, inherent viscosity and intrinsic viscosity.

The viscosity was determined and calculated for the 4%, concentration of all the resin sample at room temperature and various rotational speed by using spindle 62 and Spindle 63 of digital Brookfield DV-E viscometer (Sinha, 2017)

3.7.8. Determination of solubility

Solubility is defined as the amount of substance that passes into solution to achieve a saturated solution at constant temperature and pressure. Solubility is expressed in terms of maximum volume or mass of the solute that dissolve in a given volume or mass of a solvent. The solubility of the resin was determined in, acetone, chloroform and benzene. 1.0 g sample of the resin was added to 50 ml of each of the above-mentioned solvents and left overnight. 25 ml of the clear supernatants were taken in small pre-weighted evaporating dishes and heated to dryness over a digital thermostatic water bath. The weights of the residue with reference to the volume of the solutions were determined using a digital top loading balance (Model.XP-3000) and expressed as the percentage solubility of the resins in the solvents (Mohsenin,1986).

$$\textbf{Water solubility index}\ (\%) = \frac{\textbf{Weight of dissolve resin sample in solution}(\mathbf{g})}{\textbf{Weight of resin sample}(\mathbf{g})}$$

3.8. Statistical analysis

The CRD statistical design applied in this experiment as the variance technique given by Gomez and Gomez (1985), statistical analysis of the data recorded in various aspects from field and laboratory was carried out as described in the below mentioned Anova table (Table 3.10).

Table 3.10. Table Skeleton of Analysis of Variance (ANOVA)

Source of variation	Degree of freedom	Sum of square	Mean sum of square	Fcal.	Ftab.
Treatment	(t-1)	TrSS	$TrMS = \frac{TrSS}{Df}$	$\frac{TrMS}{EMS}$	
Error	(rt-t)	ESS	$EMS = \frac{ESS}{Df}$		
Total	rt-1	TSS			

t = number of treatment r = number of replications

The ‘f’ test was applied to judge the overall significance of various treatments in general and comparison of individual treatment was made with the help of critical difference at 5 per cent level of significance. This was calculated as given below:

SE (m)± for treatment= J $\frac{\text{ENc}}{\text{Number of replication}}$

SEd for treatment = SEm ×√2

C.D. for treatment = SE(d) × ‘t’ value at 5% error degree freedom

Where,

SE(m) = Standard Error of means, SE(d) = Standard Error of difference, C.D.= Critical difference.

3.9. Measurement of the Climatological parameters

Weather data was recorded on daily basis from (www.worldweatheronline.com) during both years of the tapping period. Temperature and relative humidity data are both crucial in assessing the impact of local climatic factors on resin production.

Table 3.11 Weather data during the resin tapping months of 2021-2022

Year	**2021**				**2022**			
Month	**Temperature (^{0}C)**		**Relative Humidity (%)**		**Temperature (^{0}C)**		**Relative Humidity (%)**	
	Maximum	**minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**minimum**
March	35	22	22	10	39	19	17	11
April	38	25	17	7	45	25	15	9
May	35	25	44	21	41	26	16	10

CHAPTER -IV

RESULTS AND DISCUSSIONS

The results obtained from the present investigation was based on the study carried out during 2021-2022, and it is being presented in this chapter. The main objective of the experiment was to standardize a sustainable resin tapping techniques for *Pinus roxburghii*, *Pinus patula* and *Pinus kesiya* for continuously two years. Pine forest stands provide such a variety of vital economic products like cone, needle and resin, as well as revenue and jobs for those living in the subtropical zone. However, in tropical zones, there is a huge potential for long-term resin harvesting from the tropical pines that are planted there. These pines not only offer resin, but also aid with erosion control, land slip stabilization, carbon sequestration, and other ecosystem services. In this context the study was conducted via using various methods; for the extraction of resin incision like Quarre method, Triangular cut method and Bore hole method with different combinations of resin enhancer (ethephon) to standardize a sustainable resin harvesting technology

The experimental findings of the present investigation have been described under the following heads:

- Effect of chemical treatments on different methods of resin tapping in each pine species
- Effect of climatic factors & year wise resin exudation by using various chemicals
- To optimize the diameter class and chemical concentration on each tree
- Quality parameters analysis for resin samples

.

4.1 Effect of Chemical treatments on different methods and rate of resin exudation (g) in *Pinus roxburghii* during the year 2021

Among three methods used for tapping in *Pinus roxburghii* during the year 2021 borehole method was observed most suitable for tapping the average resin yield per tree yield was recorded highest in T13CH (Ethephon 30% + H_2SO_4 10%) where and the yield was 323.41g/tree followed by T15 CQ (Ethephon 30% + H_2SO_4 20%) where treatment T10 CT (Ethephon 20% + H_2SO_4 10%) the yield were 294.41 g/tree and minimum yield of resin 151.89 g/tree (Table 4.1). According to Lohani (1985) the resin canals systems in Chirpine are made up of vertical and horizontal resin canals with epithelium. The vertical canals are sporadically dispersed and primarily restricted to the ring's central and outer regions. The horizontal canals are very small, solitary, and arranged in fusiform rays, and the surface area was less opened while tapping in borehole method, as a result the solitary regularly arranged resin canals opened up and yielded more resin yield than other methods tried because the surface area was more opened up in other methods. In Chirpine, the resin ducts are primarily responsible for the formation of oleoresin. Ghosh *et al*., (1960), also reported that the majority of horizontal canals in the phloem do not run for long distances and typically end near the cambium region. It was also been noted that the number of horizontal canals varies significantly from outer to inner phloem. Similar observations have been made by Lekha (2002); Nimkar and Sharma (2007) in Chirpine and Kozlowaski (1971) in *P. pseudopsuga*, Larix and Junipers. In the present investigation during 2021 trees with diameter class ranges from 40-55 cm were selected for tapping in Bhundakona area (R-237 compartment) at an elevation of 1120 masl to optimize a specific diameter class for resin tapping in *Pinus roxburghii*. In the present experiment maximum resin yield was obtained in trees having 45-50 cm diameter with a mean yield of 323 .41g/tree/90 days of tapping in a single bore hole. It could be because tree diameter is associated with a greater number of resin canals and a ramified root system, both of which aid in the absorption of nutrients from the soil. The present findings are similar to those of

Muttoon (1922), Grochowski (1951), Mathauda (1961), Lohani (1968), Kaushal *et al.*, (1988) on *Pinus roxburghii*. Singhal (1996) also found a positive and substantial relationship between oleoresin yield and diameter and height of distinct *Pinus roxburghii* provenances. Tree diameter class has a positive and significant relationship with oleoresin yield; trees with diameters greater than 50 cm and less than 40 cm produced less resin, as observed in this study. (Table 13). The trees which are yielding more than 300 g/tree of resin in these 3 months (90 days) tapping period may consider to be viable for resin tapping. Lekha,2000 found that in the borehole method of tapping combined dose of H_2SO_4 20%+20 % HNO_3(1:1) yielded maximum resin 699.67 g/hole/tree recorded in 2.50 cm diameter and 10 cm depth boreholes. Whereas in the present experiment borehole diameter was 2 cm and the depth was also 3 cm and the highest resin yield (323.41 g/tree) was obtained in E 30% +H 10%. The resin yield is less because of the incision comparatively three times less but it won't harm the trees and the incision heals quickly.

Table 4.1. Treatments and diameter class wise resin yield from *Pinus roxburghii* during 2021

Treatments	diameter class	Replications			Total yield(g)	Average yield (g)
		R1	R2	R3		
Quarre shape method						
T1CQ	IV	28.31	37.41	16.96	82.68	27.56
T2CQ	IV	29.19	43.56	39.75	112.5	37.50
T3CQ	V	153.21	136.45	149.56	439.22	146.41
T4CQ	VI	22.12	31.03	48.97	102.12	34.04
T5CQ	IV	56.24	47.56	68.96	172.76	57.59
T6CQ	V	73.13	65.01	54.09	192.23	64.08
T7CQ	VI	49.08	54.01	40.91	144	48.00
T8CQ	VI	44.96	35.67	29.01	109.64	36.55
T9CQ	VI	41.2	49.93	60.34	151.47	50.49
T10 CQ	VI	56.29	62.67	78.03	196.99	65.66
T11CQ	IV	82.33	44.98	61.97	189.28	63.09
T12 CQ	IV	70.23	88.98	53.07	212.28	70.76
T13CQ	V	132.2	149.08	128.09	409.37	136.46
T14CQ	V	144.48	153.97	168.54	466.99	155.66
T15 CQ	**VI**	**291.57**	**302.87**	**288.78**	**883.22**	**294.41**
Triangular shape method						
T1CT	**V**	11.69	18.67	29.67	60.03	20.01
T2CT	IV	41.41	34.67	22.45	98.53	32.84
T3CT	IV	19.89	30.78	24.69	75.36	25.12
T4CT	V	49.76	21.89	35.01	106.66	35.55
T5CT	IV	76.01	88.67	67.09	231.77	77.26
T6CT	VI	38.45	46.66	31.12	116.23	38.74
T7CT	V	84.17	35.09	44.76	164.02	54.67
T8CT	IV	42.77	53.56	49.98	146.31	48.77
T9CT	VI	51.46	59.56	72.22	183.24	61.08
T10 CT	**IV**	**148.24**	**156.21**	**151.23**	**455.68**	**151.89**
T11CT	V	89.02	54.13	43.2	186.35	62.12
T12 CT	VI	33.67	44.89	39.45	118.01	39.34
T13CT	V	121.26	132.34	129.8	383.4	127.80
T14CT	IV	54.97	66.78	59.7	181.45	60.48
T15 C T	VI	72.16	62.17	81.98	216.31	72.10
Borehole shape method						
T1CH	**VI**	36.26	47.78	29.7	113.74	37.91
T2CH	VI	48.69	54.8	69.23	172.72	57.57
T3CH	VI	91.12	82.34	98.45	271.91	90.64
T4CH	IV	53.95	64.67	59.67	178.29	59.43
T5CH	IV	89.54	61.34	72.6	223.48	74.49
T6CH	V	159.15	168.45	174.23	501.83	167.28
T7CH	V	293.86	304.56	315.34	913.76	304.59
T8CH	VI	68.14	75.67	89.02	232.83	77.61
T9CH	V	174.61	184.9	202.23	561.74	187.25
T10 CH	V	238.76	224.56	269.45	732.77	244.26
T11CH	V	207.18	246.34	279.45	732.97	244.32
T12 CH	IV	209.25	233.45	255.49	698.19	232.73
T13CH	**V**	**304.01**	**318.54**	**347.68**	**970.23**	**323.41**
T14CH	IV	225.09	238.56	263.45	727.1	242.37
T15 CH	VI	176.73	163.9	160.45	501.08	167.03
CQ-Chirpine Quaree shape, CT-Chir pine Triangular shape, CH-Chirpine borehole shape						

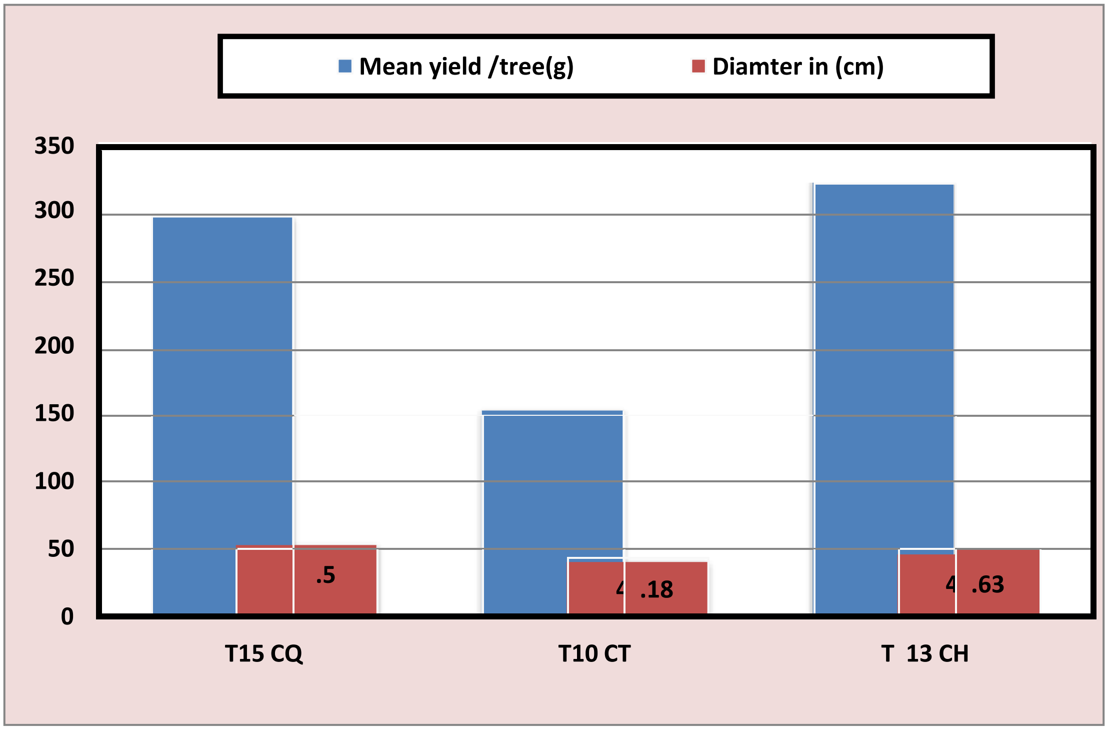


Fig 4.1 ***Pinus roxburghii*** **tree with the highest resin output(g) in 2021 in different methods.**

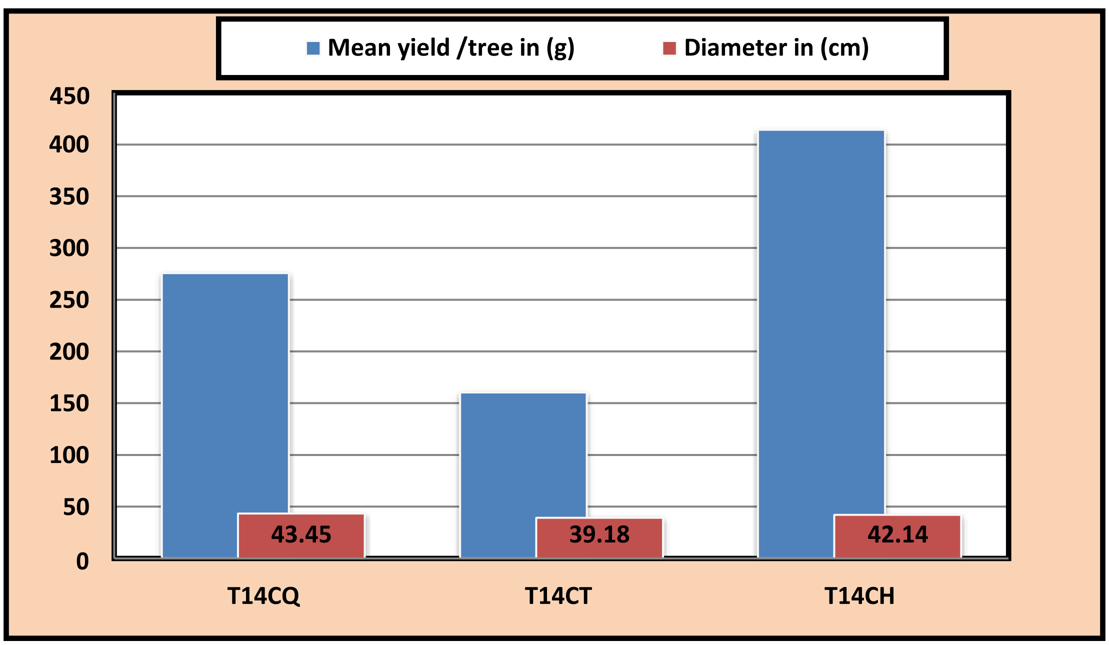


Fig 4.2 ***Pinus roxburghii*** **tree with the highest resin output(g) in 2022 in different methods**

.

4.2 Effect of Chemical treatments on different methods and rate of resin exudation (g) in *Pinus roxburghii* during year 2022

The borehole method (T14CH) observed the highest resin output in 2022, followed by Quarre (T14CQ) and triangle method (T11CT), with average yield of 414.03 g/tree, 275.66 g/tree, and 162.14 g/tree, respectively (Table 4.2). The yield from treatment number T14CH (Ethephon 30% + H_2SO_4 15%) was found to be significantly superior for resin production, with a yield of 414.03 g/tree. This increase in resin yield was due to average temperature from March to May being comparatively higher than 2021. This resulted in a slight uptick in resin yield in the year 2022. Sharma *et al*. (2014) conducted a resin tapping experiment in *Pinus roxburghii* at Nauni(Himachal Pradesh) and reported that trees with a diameter of 40-45 cm yielded the highest resin production, with a mean resin yield of 741.0 g/hole. The present finding (Table 4.2 and figure 4.2**)** also confirms that the tapping of 45-50 cm diameter class trees with Borehole method yielded maximum resin production as with a mean yield of 414.03 g/tree. According to Coppen and Hone (1995), the increase in diameter is thought to enhance the volume of sapwood. The sapwood is made up of cells with physiologically active photosynthesis results, which are created and stored in the tree's phloem and xylem (Papajiannopoulos, 1997; Franceschi *et al.,* 2005). It was observed that bark thickness has a positive and significant relationship with oleoresin yield, with thicker bark producing more resin than thinner bark. In this experiment, it was also found that trees with thicker bark yielded more resin than trees with thinner bark and trees having deep fissured also yielded more resin. The resin yield increases with the increasing fissuring of the bark. In *Pinus sylvestris,* Teresina (1966) observed that trees with high resin yield have thick, deeply furrowed bark. The current findings are consistent with that and confirm the results as reported by earlier scholars. Brahmi *et al.* (2000), have found that resin production increased as dbh increased. In both the 2021 and 2022 year, the highest resin yield was reported in the month of April. Various workers' studies on *Pinus roxburghii* revealed a similar pattern (Lohani,1968; Mathauda,1961;

Verma,1971; Prasad and Joshi,1974). The influence of atmospheric temperature on resin viscosity, which improves resin flow, is likely to be the cause of the rise or decrease in resin yield (Valentini, 1957). The climatological data (Table 4.10) of the present experimental area showed that there is effect of temperature on resin yield. Lekha, C (2002) in borehole method of tapping by using 10% Ethephon+ 20% H_2SO_4 in 3.125 cm borehole diameter and 17.5 cm depth yielded highest resin yield of 2174 g/tree and the minimum yield obtained in 10 cm depth with a yield of 1856 g/tree. Whereas in the present experiment highest resin yield in 3 cm depth borehole was 414.03 g/tree by using 30% Ethephon+ 15 % H_2SO_4. The incision made in the present experiment is in depth was 6 time less therefore the difference in yield of per tree is less but the healing rate of tree was very high and no chances of mortality of trees as compared with above worker, hence clearly indicated that this method will be safer for the trees.

Table 4.2. Treatments and diameter class wise resin yield from *Pinus roxburghii* during2022

Treatments	Diameter class	R1	R2	R3	Total yield (g)	Mean yield /tree (g)
Quarre method						
T1CQ	**IV**	36.04	41.49	30.2	107.73	35.91
T2CQ	VI	31.66	43.78	40.1	115.54	38.51
T3CQ	VI	55.78	64.96	45.22	165.96	55.32
T4CQ	VI	42.19	30.08	46.27	118.54	39.51
T5CQ	V	159.09	147.86	138.76	445.71	148.57
T6CQ	IV	59.1	69.09	74.88	203.07	67.69
T7CQ	V	49.65	57.79	51.91	159.35	53.12
T8CQ	IV	66.77	45.09	59.67	171.53	57.18
T9CQ	V	61.89	40.44	55.89	158.22	52.74
T10 CQ	II	76.64	52.67	68.9	198.21	66.07
T11CQ	II	62.93	44.72	61.19	168.84	56.28
T12 CQ	IV	89.88	68.98	57.06	215.92	71.97
T13CQ	IV	123.18	129.07	148.16	400.41	133.47
T14CQ	**V**	**264.65**	**273.44**	**288.8**	**826.89**	**275.63**
T15 CQ	V	220.48	262.1	297.6	780.18	260.06
Triangular method						
T1CT	**IV**	18.16	22.62	28.94	69.72	23.24
T2CT	VI	32.1	40.69	37.44	110.23	36.74
T3CT	IV	22.87	30.38	25.74	78.99	26.33
T4CT	V	66.15	51.04	45.19	162.38	54.13
T5CT	VI	86.09	78.69	69.32	234.1	78.03
T6CT	VI	28.22	56.29	40.19	124.7	41.57
T7CT	VI	77.7	55.19	64.17	197.06	65.69
T8CT	VI	62.2	43.8	79.96	185.96	61.99
T9CT	V	51.44	65.01	82.19	198.64	66.21
T10 CT	IV	89.45	75.26	51.2	215.91	71.97
T11CT	**IV**	**178.08**	**145**	**163.26**	**486.34**	**162.11**
T12 CT	V	37.98	49.17	69.4	156.55	52.18
T13CT	V	98.77	83.39	79.89	262.05	87.35
T14CT	V	154.18	166.68	159.57	480.43	160.14
T15 C T	IV	122.86	177.67	146.88	447.41	149.14
Borehole method						
T1CH	**VI**	27.36	37.7	42.57	107.63	35.88
T2CH	VI	58.19	68.8	78.27	205.26	68.42
T3CH	IV	87.16	72.44	94.5	254.1	84.70
T4CH	IV	63.95	75.62	68..64	139.57	69.79
T5CH	IV	89.2	61.16	72.69	223.05	74.35
T6CH	IV	65.55	88.69	94.2	248.44	82.81
T7CH	IV	90.46	98.86	75.54	264.86	88.29
T8CH	VI	159.14	177.94	190.44	527.52	175.84
T9CH	V	179.6	224.59	212.29	616.48	205.49
T10 CH	V	278.26	254.5	270.22	802.98	267.66
T11CH	VI	267.19	286.44	279.42	833.05	277.68
T12 CH	VI	219.91	358.89	285.16	863.96	287.99
T13CH	V	404.91	368.45	347.77	1121.13	373.71
T14CH	**V**	**425.17**	**453.07**	**363.85**	**1242.09**	**414.03**
T15 CH	V	376.49	473.9	260.45	1110.84	370.28
CQ-Chirpine Quaree shape, CT-Chir pine Triangular shape, CH-Chirpine borehole shape						

4.3. Methods and Chemical concentration wise Pooled analysis of resin yield during the year 2021 and 2022.

4.3.1 Effect of combine dose of Chemicals

The pooled analysis of effects of chemical tapping by using three different shape of incision and the quantity of resin exudation in *Pinus roxburghii* is presented in Table 4.3 & 4.4. The data showed the effect of different chemical concentration used for tapping. It can be seen that significantly highest yield in borehole method with combine dose of chemical stimulants T13CH (Etthephon 30%+ H_2SO_4 10%) treatment @ 348.56 g/tree and the lowest yield recorded in T8CH treatment @ 126.73 g/tree by using (Ethephon 10%+H_2SO_4 15%). While using Quarre shape tapping method the highest yield was recorded in T15CQ treatment (Ethephon 30%+ H_2SO_4 20%) @ 277.23g/tree and minimum yield was obtained in T8 CQ (Ethephon 10%+ H_2SO_4 15%) treatment @ 46.86g/tree. However, between these three methods of tapping in *Pinus roxburghii* the triangular method of tapping showed lowest resin yield in comparison to other methods. In triangular method of tapping, maximum resin yield was obtained in T11CT (Ethephon 20%+ H_2SO_4 15%) treatment @ 112.11 g/tree and minimum yield was recorded in the case ofT8CT (Ethephon 10%+H_2SO_4 15%) treatment @ 55.38 g/tree. The combine dose of chemical used for tapping in each method resin yield /tree was found to be highest (249.14 g/tree from 54 trees) in borehole method, followed by Quarre method (108.18 g/tree from 54 trees) and minimum yield per tree was collected from triangular method (86.39 g/tree from 54 trees).Lekha (2002)reported that by borehole method ,with borehole depth of 17.5 cm and 3.125cm diameter yielded highest resin yield of 1943 g/hole/tree from April to October 2000 and 2001.Whereas, in the present experiment 2 cm diameter of 3 cm depth yielded highest resin yield of 348.56 g/tree/180 days (March to May), this is comparable looking to the size of the borehole.

4.3.2 Effect of H_2SO_4

The mean resin yield per tree by using Sulfuric acid in three different conc. was found to be highest in Borehole method (84.14 g/tree from 18 trees), followed by Quarre method (68.57 g/tree from 18 trees) and minimum yield (54.21 g/tree from 18 trees) of resin was collected from triangular method of tapping, presented in table 4.4. Further, the Borehole method of tapping, highest resin yield (125.05 g/tree) was obtained by using $H_2SO_4$20% concentration, followed by Quarre method (103.08 g/tree) by using H_2SO_4 15 % concentration and minimum yield (77.65 g/tree) was obtained in triangular method @ H_2SO_4 20% concentration.

4.3.3. Effect of Ethephon

The mean resin yield per tree by using only ethephon chemical in different concentration was found to be highest in Borehole method (62.52 g/tree from 18trees), followed by Quarre method @ 56.86 g/tree from 18 trees and minimum yield (27.38 g/tree from 18 trees) of resin was collected from triangular method of tapping (Table 4.4). Among the single doses of Ethephon used for resin tapping, Quarre method of tapping yielded highest resin yield (100.86 g/tree) by using ethephon 30% concentration, followed by borehole method of tapping (87.67 g/tree) by using ethephon 30% concentration and minimum yield (34.79 g/tree) was obtained in triangular method @ ethephon 20% concentration.

4.4. Diameter class wise resin exudation (g) from *Pinus roxburghii* (mean yield/tree)

It was found that diameter class range from 45-50 cm yielded highest resin in *Pinus roxburghii.* Among all the methods highest (261.95g/tree) was in borehole method with the above-mentioned diameter class, followed by Quarre method (151.43 g/tree) and minimum yield was obtained in triangular shape (108.56g /tree) method shown in Table 4.5. Sharma *et al.* (2014) reported that bore hole method in *Pinus roxburghii*, at an elevation of 1200-1225 m a.m.s.l, the highest yield of oleoresin (2.13 kg/tree) achieved from 45-50 cm diameter classes in the eight-month tapping period. (March to October). In the present experiment, similar 45-50 cm diameter classes yielded resin of (261.95 g/tree) in 6 months of tapping period at an elevation 0f 1025 to 1120 m a.m.s.l. This variation is may be due to depth of tapping, elevation and climatic condition. Similar findings have been reported in *Pinus pinea* and *Pinus pinaster* (Magini,1958), *Pinus palustris* (Schopmayer and Larson, 1954; Gurgel Filho and Gurgel Garrido 1977), *Pinus sylvestris* (Pejoski, 1956-57; Stephan, 1967; Romanovskij and Bestemjannikov, 1968; Koev and Sokolova 1979), *Pinus brutia* (Bad ran, 1963; (Anonymous 1965). Tapping in Uttarakhand, Lohani (1985) revealed that maximum resin yield was obtained in the diameter class ranges of 37.5- 47.5 cm in *Pinus roxburghii.* Therefore, present investigation revealed that for commercial tapping of resin in *Pinus roxburghii* trees in the study site with 45-50cm diameter class shouldbe selected.

Table 4.3 **The effect of chemical concentrations on different methods of resin tapping in *Pinus roxburghii*(g/tree) is shown by a pooled analysis of data.**

Treatments number	**Treatments details**	**Average yield(g) during 2021**	**Average yield (g) during 2022**	**Pooled**
Quaree method				
T1CQ	Ethephon10%	27.56	35.91	31.74
T2CQ	Ethephon 20%	37.5	38.51	38.01
T3CQ	Ethephon 30%	146.4	55.32	100.86
T4CQ	Sulfuric acid10%	34.04	39.51	36.78
T5CQ	Sulfuric acid 15%	57.58	148.57	103.08
T6CQ	Sulfuric acid 20%	64.07	67.69	65.88
T7CQ	Ethephon 10 % + 10 % Sulfuric acid	48	53.11	50.56
T8CQ	Ethephon 10 % + 15 % Sulfuric acid	36.54	57.17	46.86
T9CQ	Ethephon 10 % + 20 % Sulfuric acid	50.49	52.74	51.62
T10 CQ	Ethephon 20% + 10 % Sulfuric acid	65.66	66.07	65.87
T11CQ	Ethephon 20% + 15 % Sulfuric acid	63.09	56.28	59.69
T12 CQ	Ethephon 30 % + 20 % Sulfuric acid	70.76	71.97	71.37
T13CQ	Ethephon 30 % + 10 % Sulfuric acid	136.45	133.47	134.96
T14CQ	Ethephon 30 % + 15 % Sulfuric acid	155.66	**275.63**	215.65
T15 CQ	Ethephon 30 % + 20 % Sulfuric acid	**294.4**	260.06	277.23
Triangular method				
T1CT	Ethephon10%	20.01	23.24	21.63
T2CT	Ethephon 20%	32.84	36.74	34.79
T3CT	Ethephon 30%	25.12	26.33	25.73
T4CT	Sulfuric acid10%	35.55	54.12	44.84
T5CT	Sulfuric acid 15%	77.25	78.03	77.64
T6CT	Sulfuric acid 20%	38.74	41.56	40.15
T7CT	Ethephon 10 % + 10 % Sulfuric acid	54.67	65.68	60.18
T8CT	Ethephon 10 % + 15 % Sulfuric acid	48.77	61.98	55.38
T9CT	Ethephon 10 % + 20 % Sulfuric acid	61.08	66.21	63.65
T10 CT	Ethephon 20% + 10 % Sulfuric acid	**151.89**	71.97	111.93
T11CT	Ethephon 20% + 15 % Sulfuric acid	62.11	162.11	112.11
T12 CT	Ethephon 30 % + 20 % Sulfuric acid	39.33	52.18	45.76
T13CT	Ethephon 30 % + 10 % Sulfuric acid	127.8	87.35	107.58
T14CT	Ethephon 30 % + 15 % Sulfuric acid	60.48	**160.14**	110.31
T15 C T	Ethephon 30 % + 20 % Sulfuric acid	72.1	149.13	110.62
		907.74	1136.77	
Borehole method				
T1CH	Ethephon10%	37.91	35.87	36.89
T2CH	Ethephon 20%	57.57	68.42	63.00
T3CH	Ethephon 30%	90.63	84.7	87.67
T4CH	Sulfuric acid10%	59.43	69.78	64.61
T5CH	Sulfuric acid 15%	74.49	74.35	74.42
T6CH	Sulfuric acid 20%	167.27	82.81	125.04
T7CH	Ethephon 10 % + 10 % Sulfuric acid	304.58	88.28	196.43
T8CH	Ethephon 10 % + 15 % Sulfuric acid	77.61	175.84	126.73
T9CH	Ethephon 10 % + 20 % Sulfuric acid	187.24	205.49	196.37
T10 CH	Ethephon 20% + 10 % Sulfuric acid	244.25	267.66	255.96
T11CH	Ethephon 20% + 15 % Sulfuric acid	244.32	277.68	261.00
T12 CH	Ethephon 30 % + 20 % Sulfuric acid	232.73	287.98	260.36
T13CH	Ethephon 30 % + 10 % Sulfuric acid	**323.41**	373.71	**348.56**
T14CH	Ethephon 30 % + 15 % Sulfuric acid	242.36	**414.03**	328.20
T15 CH	Ethephon 30 % + 20 % Sulfuric acid	167.02	370.28	268.65
		2510.82	2876.88	

Table 4.4- Resin yield (g) per tree by using different chemicals in *Pinus roxburghii*

Methods of tapping	**Only Ethephon**	**Only Sulfuric acid**	**Combine dose of Ethephon and Sulfuric acid**
Quarre method	56.86	68.57	108.19
Triangular method	27.38	54.21	86.39
Borehole method	62.52	84.14	249.14

Table 4.5. Diameter class wise resin yield (g) from *Pinus roxburghii*

Diameter class	**2021**			**2022**			**Mean yield/tree**
Quarre shape method	Number of trees selected	Total yield	Mean yield/tree	Number of trees selected	Total yield	Mean yield/tree	
IV(40-45)	15	1345.78	89.71	15	1209.15	80.61	85.16
V(45-50)	15	2125.78	141.71	15	2477.28	165.15	**153.43**
VI(50-55)	15	393.49	26.23	15	549.1	36.60	31.41
Total	45	3864.75		45	4236.1		
Borehole shape method							
IV(40-45)	15	2245.78	149.71	15	2595.98	173.06	161.39
V(45-50)	15	3647.89	243.19	15	4210.89	280.72	**261.95**
VI(50-55)	15	1638.97	109.26	15	1754.09	116.93	113.10
Total	45	7532.64	Total	45	8560.96		
Triangular shape method							
IV(40-45 cm)	15	772.28	98.59	15	992.18	118.54	58.81
V(45-50 cm)	**15**	**1478.89**	**51.48**	**15**	**1778.15**	**66.14**	**108.56**
VI(50-55 cm)	15	472.18	31.47	15	640.14	42.67	37.07
Total	45	2723.35		45	3410.47		

Table 4.6. Chemical concentrations wise resin yield from *Pinus roxburghii* by different methods during year 2021 -2022

Quarre method Treatments	T1CQ	T2CQ	T3CQ	T4CQ	T5CQ	T6CQ	T7CQ	T8CQ	T9CQ	T10 CQ	T11CQ	T12 CQ	T13CQ	T14CQ	T15 CQ
	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
2021	82.68	112.5	439.22	102.12	172.76	192.23	144	109.64	151.47	196.99	189.28	212.28	409.37	466.99	883.22
2022	107.73	115.54	165.96	118.54	445.71	203.07	159.35	171.53	158.22	198.21	168.84	215.92	400.41	826.89	780.18
Total yield	190.41	228.04	605.18	220.66	618.47	395.3	303.35	281.17	309.69	395.2	358.12	428.2	809.78	1293.88	1663.4
Mean yield/year	95.21	114.02	302.59	110.33	309.24	197.65	151.68	140.59	154.85	197.60	179.06	214.10	404.89	646.94	831.70
Triangular method	T1CT	T2CT	T3CT	T4CT	T5CT	T6CT	T7CT	T8CT	T9CT	T10 CT	T11CT	T12 CT	T13CT	T14CT	T15 C T
Treatments	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
2021	60.03	98.53	75.36	106.66	231.77	116.23	164.02	146.31	183.24	455.68	186.35	118.01	383.4	181.45	216.31
2022	69.72	110.23	78.99	162.38	234.1	124.7	197.06	185.96	198.64	215.91	486.34	156.55	262.05	480.43	447.41
Total yield	129.75	208.76	154.35	269.04	465.87	240.93	361.08	332.27	381.88	671.59	672.69	274.56	645.45	661.88	663.72
Mean yield/year	64.88	104.38	77.18	134.52	232.94	120.47	180.54	166.14	190.94	335.80	336.35	137.28	322.73	330.94	331.86
Bore hole method	T1CH	T2CH	T3CH	T4CH	T5CH	T6CH	T7CH	T8CH	T9CH	T10 CH	T11CH	T12 CH	T13CH	T14CH	T15 CH
Treatments	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
2021	113.74	172.72	271.91	178.29	223.48	501.83	913.76	232.83	561.74	732.77	732.97	698.19	970.23	727.1	501.08
2022	107.63	205.26	254.1	139.57	223.05	248.44	264.86	527.52	616.48	802.98	833.05	863.96	1121.13	1242.09	1110.84
Total yield	221.37	377.98	526.01	317.86	446.53	750.27	1178.62	760.35	1178.22	1535.75	1566.02	1562.15	2091.36	**1969.19**	1611.92
Mean yield/year	110.68	188.99	263	158.93	223.26	375.13	589.31	380.17	589.11	767.87	783.01	781.07	1045.68	**984.59**	805.96

4.5. Total yield of resin by using different tapping methods and chemical treatments during the year 2021 and 2022.

4.5.1. Effect of different chemicals on the resin yield by using Quarre shape method (Mean yield/year)

The total yield obtained from all the treatments in both the years was 8100.85 g, and the total mean yield/Quarre shape/year was 270.02 g. During the year 2022 maximum resin yield was obtained as compared with 2021 this is due to higher temperature. (Table 4.7 & Figure 4.3). Similar observations and findings were made by Deshmukh *et. a*l (1964) that atmospheric temperature plays a significant role in influencing evapotranspiration; any factor that modifies temperature also modifies evapotranspiration rate, and thus the resin yield increases. Ethephon 30 %, (T3CQ) H_2SO_4 concentration of 15%(T5CQ) and both combine dose of treatment Ethephon 30% + H_2SO_4 20 %(T15CQ) yielded maximum resin per year (Table 4.7). The total yield by using Ethephon chemical at various conc. was 1023.63 g from 18 trees (means 511.81 g/year), while, using H_2SO_4 the yield was 1234.43 g from 18 trees (928.42 g/year) and the yield using combine dose was 5842.79 g from 54 trees (2921.39 g /year). The data tabulated in table number 4.7 confirm that the mean yield of resin/year was found highest (831.7 g) in T15 CQ treatment (Ethephon 30%+ H_2SO_4 20%). From the Quarre method of tapping in *Pinus roxburghii*, it was also observed that by combining 30 percent ethephon with various concentrations of Sulfuric acid (T13 CQ, T14 CQ, T15 CQ), more than 400 g of resin/tree/year can be extracted. Drocnev and Toburdanovskij (1957) reveals that nutrient supply primarily regulates the resin yield. While, Massari and Saya (1960) reported that a continuous supply of water all around injured zone is necessary for flow of resin. They further reported that water in the secretory cell plays a significant role in resin yield and they further suggested that a continual supply of water to the tissues surrounding the wound is required to maintain cellular turgescence. These previous studies and the present investigation results demonstrated that temperature and evapotranspiration play an important role in water translocation, and therefore, it is confirmed that resin yield in pines is related to the above mentioned factors.

Table 4.7. Total and Mean yield of resin/year by using Quarre shape incisions by using different treatments during the year 2021 and 2022.

Treatments	Total resin yield during 2021(in gram)	Total resin yield during 2022(in gram)	Total yield	Mean yield/year
T1CQ	82.68	107.73	190.41	95.2
T2CQ	112.5	115.54	228.04	114.02
T3CQ	**439.22**	**165.96**	**605.18**	**302.59**
T4CQ	102.12	118.54	220.66	110.33
T5CQ	**172.76**	**445.71**	**618.47**	**309.23**
T6CQ	192.23	203.07	395.3	197.65
T7CQ	144	159.35	303.35	151.67
T8CQ	109.64	171.53	281.17	140.58
T9CQ	151.47	158.22	309.69	154.84
T10 CQ	196.99	198.21	395.2	197.6
T11CQ	189.28	168.84	358.12	179.06
T12 CQ	212.28	215.92	428.2	214.1
T13CQ	409.37	400.41	809.78	404.89
T14CQ	466.99	826.89	1293.88	646.94
T15 CQ	**883.22**	**780.18**	**1663.4**	**831.7**
Total	3864.75	4236.1	8100.85	270.02

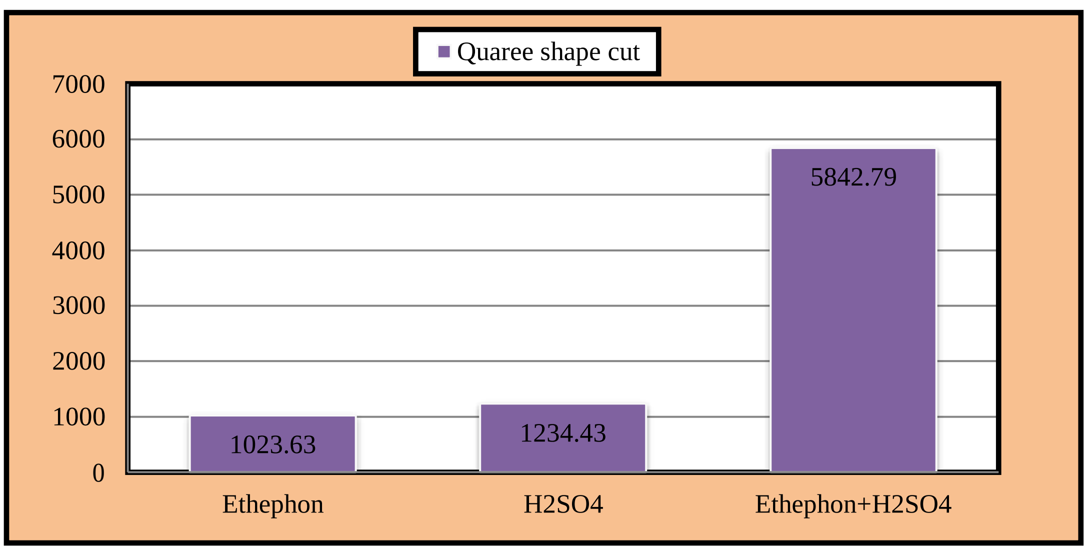


Fig 4.3. Total resin yield by using various chemicals in Quarre method of tapping during 2021-2022.

4.5.2. Effect of different chemicals on resin yield in Triangular shape method (Mean yield/year)

In Triangular shape method of resin tapping the total yield was obtained from various treatments was 6133.82 g and the total mean yield/triangular shape/year was 204.45 g. As indicated in the table 4.8 and Figure 4.4 it is confirmed that the resin yield obtained during the year 2022 was relatively higher than 2021.The maximum resin yield was recorded in the month of April in each year of tapping as shown in table 4.10. The study carried out by Brahmi *et al.*(2000) in Himachal Pradesh revealed that maximum resin output was obtained during the month of May. The Ethephon concentration of 20 %(T2CT), H_2SO_4 concentration of 15%(T5CT) and both combine dose of treatment of Ethephon and Sulfuric acid(T11CT) Ethephon 20% + H_2SO_4 15% yielded maximum resin /year and it was 104.38 g/year, 232.93 g/year,336.34 g/year respectively (Table 4.8). The total yield of resin in two years by using Ethephon chemical was 492.86 g (means 246.43 g/year), while using H_2SO_4 the yield was 975.84 g (487.92 g/year) and the yield obtained whereas, combine dose of treatment it was 4665.12 gm (2332.56 g/year) (Table 4.8). It indicates whenever a single combination of Ethephon and Sulfuric acid has been used, Sulfuric acid yielded a better yield than Ethephon in use of any chemical. From the table it is confirmed that in the combine dose of treatment total resin yield was found highest in T11CT treatment, followed by T15 CT and minimum in T8CT and the yield were 336.34 g, 331.86 g and 55.38 g/year, respectively. Lohani (1985), reported that Nitric acid, Sulfuric acid yielded maximum resin as compared to control blazes. Stephen, G. (1958) concluded that the chemicals used as a refreshing agent/dehydrating agent, such as H_2SO_4, HCL, and $CaOCl_2$, draw water towards the wound, increasing cellular turgescence and thus resin yield increases. The present study findings support the findings of previous researchers that if we use a single dose of chemical like Ethephon and Sulfuric acid for resin tapping, the maximum yield was obtained from Sulfuric acid. The per tree yield by using single concentration of Ethephon and Sulfuric acid was 27.38 g and 54.21 g, respectively, whereas, combine doses of chemical per tree yield was 86.39 g/tree. This shows that combine concentrations of both the chemical was near optimum to obtain maximum yield per triangular cut.Effect of different chemicals on resin yield in Borehole shape method (Mean yield/year)

In borehole method of tapping the total yield was obtained from all the treatment for both the years and it was 16093.6 g and the total mean yield/borehole/year was 536.45 g (table 4.9). The resin yield achieved during the year 2022 was substantially higher than the year 2021, as the average temperature during 2022 was comparatively higher as it indicates in table 4.10 and figure 4.10. It was also noted that the highest resin yield was obtained in April (4666.44g /month), followed by May (2205.64 g/month), and the lowest yield was obtained in March (1174.71 g/month) in the year 2021and 2022 of tapping as shown in table 4.10. The concentration of Ethephon30 %(T3CH), Sulfuric acid (H_2SO_4) concentration of 20% (T6CH) and both combine dose of treatment (T13CH) of Ethephon 30% + $H_2SO_4$10% yielded maximum resin yield per year (Table 4.9). The total yield by using Ethephon chemical was 1125.36 g from 18 trees (means 562.68 g/year), while using H_2SO_4 the yield was 1178.62 g from 18 trees (589.31 g/year) and the yield obtained by using combine dose of treatment was 13453.6 g from 54 trees (6726 g/year) as shown in (Table 4.9). As compared with other methods of tapping, borehole method is most suitable one due to the mean value of 1045.68 g/borehole/year (90 days) was obtained in T13 CH treatment (Ethephon 30% + $H_2SO_4$10%). Sharma *et al.* (2014) reported that maximum value of oleoresin yield was noted in R 11 HRY (3975/year) in 8 month of tapping period with 2.5 cm diameter of boreholes by using Ethephon 10% + H_2SO_4 20% in Himachal Pradesh. Whereas, in the present experiment 2 cm diameter boreholes yielded maximum 6726 g resin/year. It was found that many environmental variabilities also affecting the resin yield. Rawat (2000) also revealed that H_2SO_4 has a highly significant effect on resin yield when mixed with ethephon. He found the borehole method of tapping at depths ranging from 10 to 19.5 cm. The mean yield per hole without H_2SO_4 was only 587 g/tree (35-64 cm dia class), but when H_2SO_4 was added, it increased to 1001 g/tree. The current experiment indicated that the borehole method with combine doses of both the chemicals was superior to the other methods, as the mean yield per borehole by using H_2SO_4 was 84.15 g/tree while, using Combine dose of Ethephon and Sulfuric acid chemical it was increased to 249.14 g/tree which is four times higher (more) with 3 cm depth and 2 cm diameter. In comparison to Rawat's 2000 analysis, this is extremely reasonable. According to True and Schopmeyer (1958), Sulfuric acid aided outflow by extending the time the resin ducts remained open after wounding. This illustrates that combining chemical concentrations is near optimal for obtaining maximum yield per borehole. The total yield of resin obtained by different methods of tapping and different chemicals used for tapping in both the year of 2021-2022 are shown in figure 4.6 to 4.9.

Table 4.8- Total and Mean yield of resin/tree/year by using Triangular shape method with different treatments during year 2021 -2022

Treatments	Total resin yield during 2021(g)	Total resin yield during 2022(g)	Total Yield(g)	Mean yield/year(g)
T1CT	60.03	69.72	129.75	64.87
T2CT	98.53	110.23	208.76	104.38
T3CT	75.36	78.99	154.35	77.17
T4CT	106.66	162.38	269.04	134.52
T5CT	231.77	234.1	465.87	232.93
T6CT	116.23	124.7	240.93	120.46
T7CT	164.02	197.06	361.08	180.54
T8CT	146.31	185.96	332.27	166.13
T9CT	183.24	198.64	381.88	190.94
T10 CT	455.68	215.91	671.59	335.79
T11CT	186.35	486.34	672.69	336.34
T12 CT	118.01	156.55	274.56	137.28
T13CT	383.4	262.05	645.45	322.72
T14CT	181.45	480.43	661.88	330.94
T15 C T	216.31	447.41	663.72	331.86
Total	2723.35	3410.47	6133.82	**204.45**

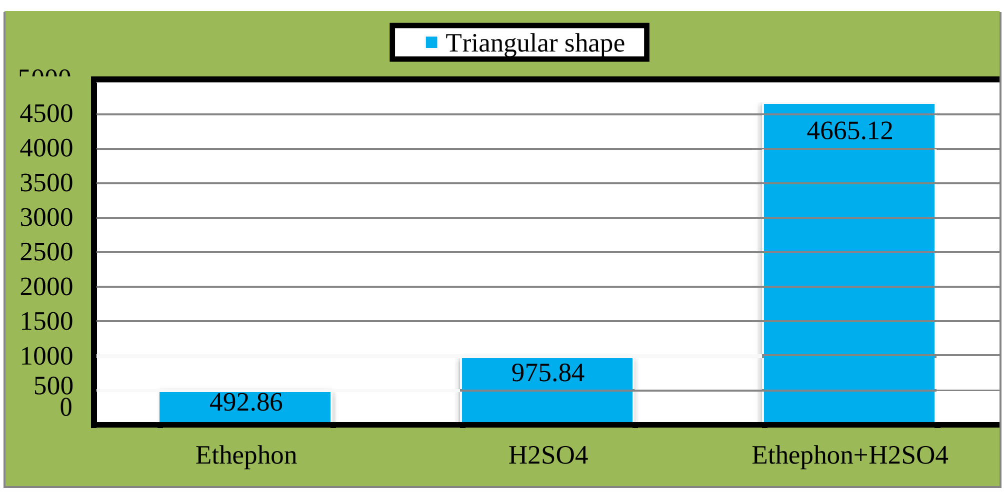


Fig 4.4.Total yield of resin by using various chemical in Triangular method of tapping during 2021 and 2022.

Table 4.9 Total and Mean yield of resin/year in borehole method in different treatments during year 2021 and 2022

Treatments	Total resin yield during 2021(g)	Total resin yield during 2022(g)	Total Yield(g)	Mean yield/year(g)
T1CH	113.74	107.63	221.37	110.68
T2CH	172.72	205.26	377.98	188.99
T3CH	**271.91**	**254.1**	**526.01**	**263**
T4CH	178.29	139.57	317.86	158.93
T5CH	223.48	223.05	446.53	223.26
T6CH	**501.83**	**248.44**	**750.27**	**375.13**
T7CH	913.76	264.86	1178.62	589.31
T8CH	232.83	527.52	760.35	380.17
T9CH	561.74	616.48	1178.22	589.11
T10 CH	732.77	802.98	1535.75	767.87
T11CH	732.97	833.05	1566.02	783.01
T12 CH	698.19	863.96	1562.15	781.07
T13CH	**970.23**	**1121.13**	**2091.36**	**1045.68**
T14CH	727.1	1242.09	1969.19	984.59
T15 CH	501.08	1110.84	1611.92	805.96
Total yield	7532.64	8560.96	16093.6	536.45

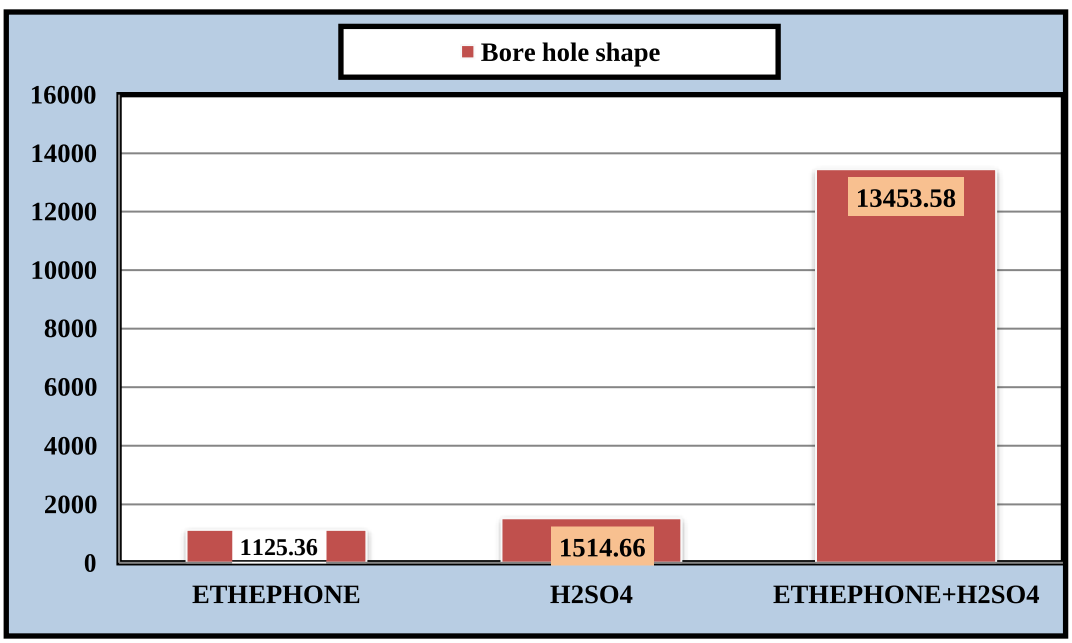


Fig 4.5. Total yield of resin (g) by using various chemical in Borehole method of tapping (2021 and 2022)

Pinus roxburghii **stands in stuidy area**

Canpopy diiferentiation between Pine stand and other broadleaf forest in experrimental sites

Plate 4.1.Lush green pine forest view

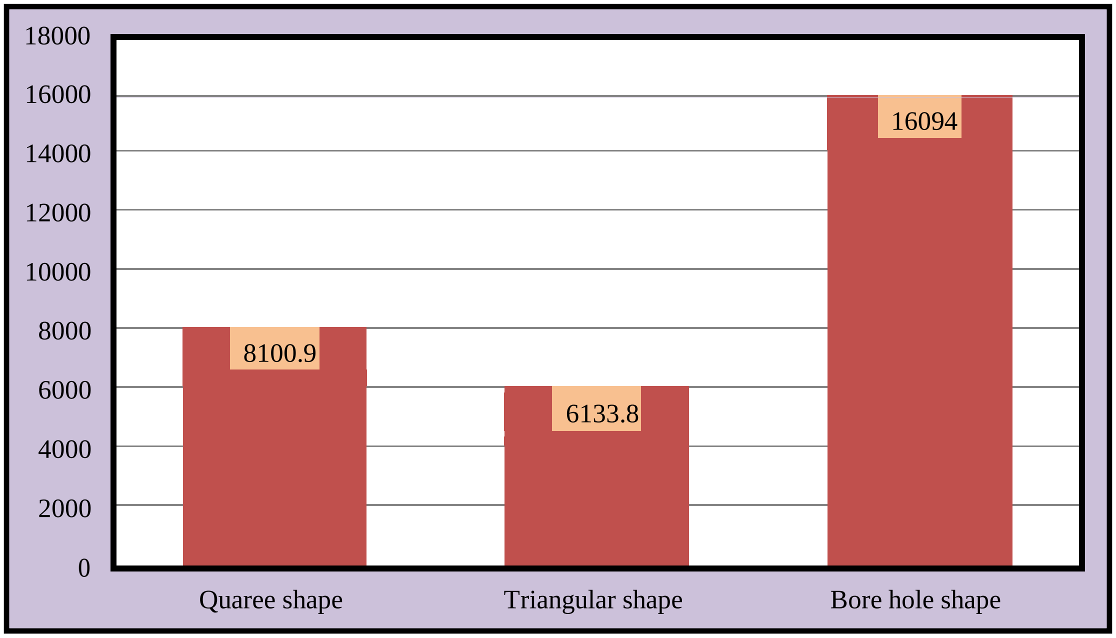


Fig 4.6.Total yield (g) of resin by using different methods of tapping in 2021-22

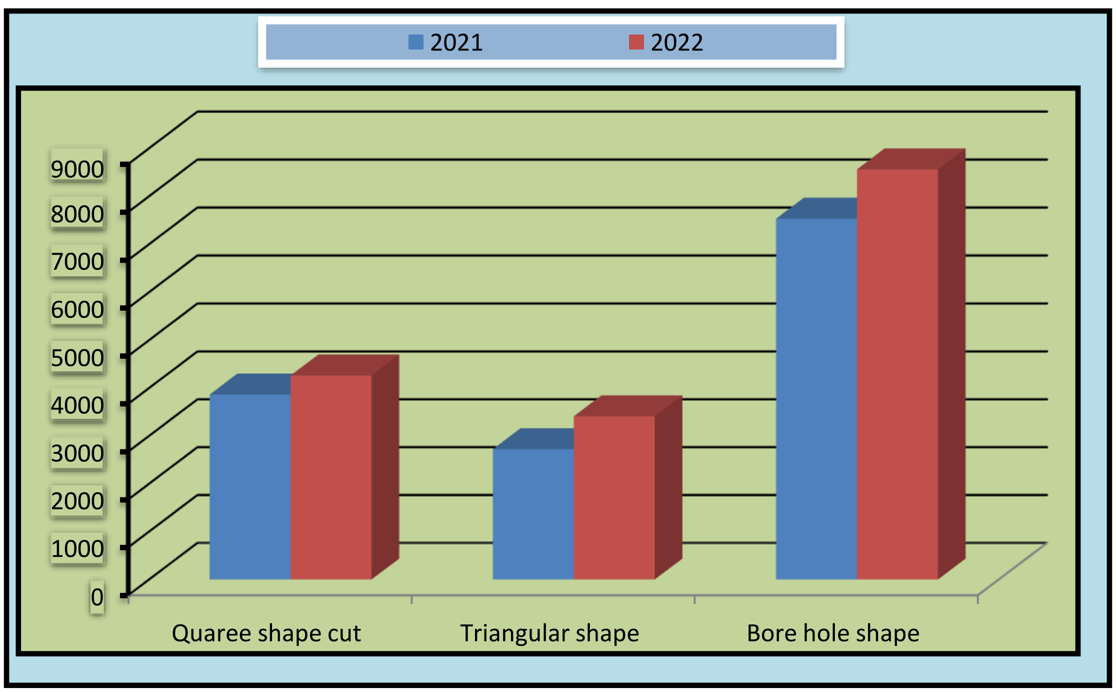


Fig 4.7 Comparison of resin yield (g) by using various methods during the year of 2021 -2022.

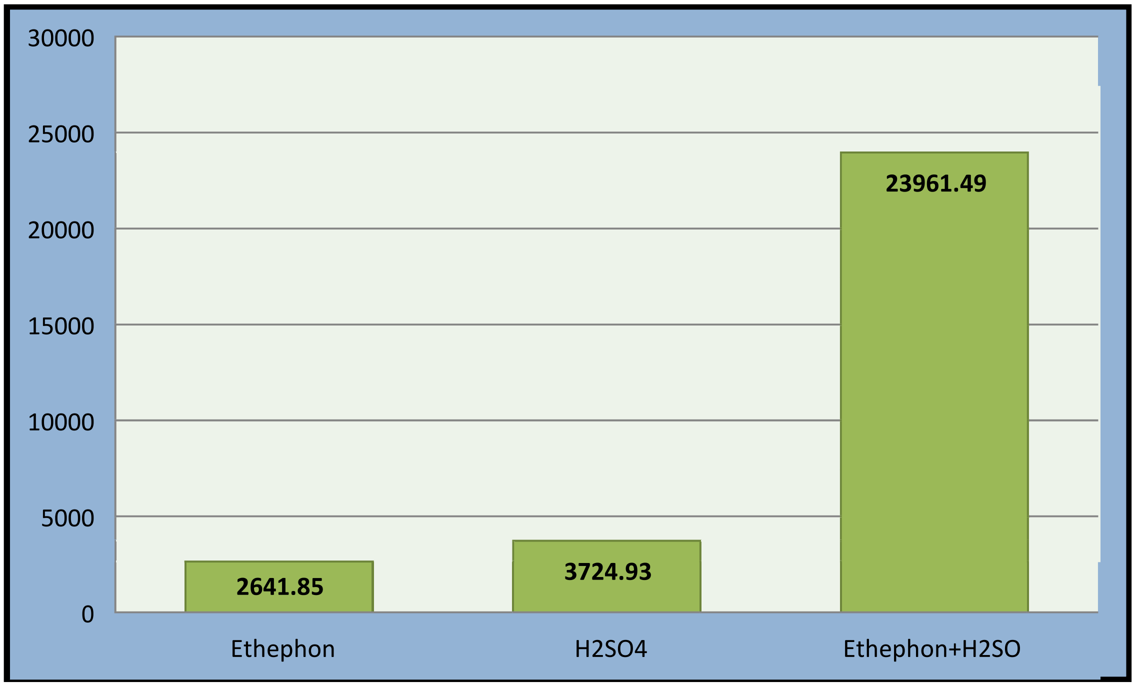


Fig 4.8..Comparison of resin yield(g) by using different Chemicals in both the years

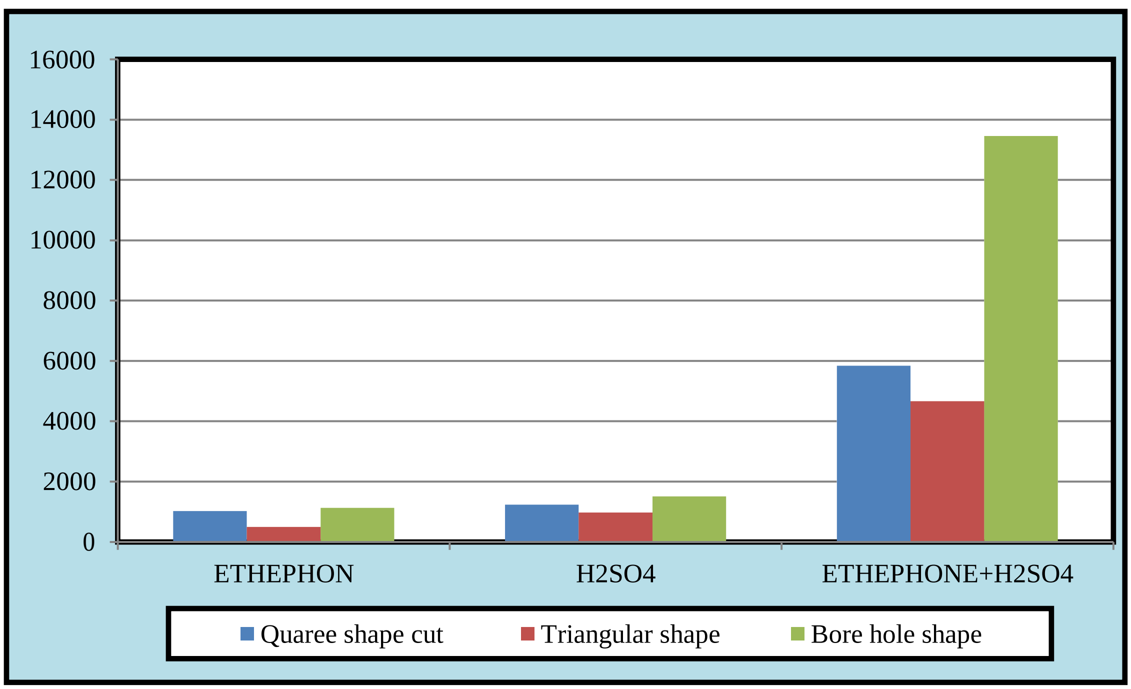


Fig 4.9. Comparison of resin yield (g) with different chemicals and shape 2021-22

Table. 4.10 Monthly resin exudation during 2021 and 2022

	Year of tapping	March	April	May	Total yield (g)
Temperature (^0C)	2021				
Maximum		35	38	35	
Minumum		22	25	25	
Relative Humidity (%)	2021				
Maximum		22	17	44	
Minumum		10	7	21	
Temperature (^0C)	2022				
Maximum		39	45	41	
Minumum		19	25	26	
Rh(%)	2022	17	15	12	
Maximum		11	9	10	
Minumum					
Quarre shape	2021	882.39	1964.09	1018.27	3864.75
	2022	900.42	1828.22	1507.37	4236.01
Triangular shape	2021	508.61	1339.13	875.61	2723.35
	2022	704.48	1701.82	1004.17	3410.47
Borehole shape	2021	1100.47	4431.45	2000.72	7532.64
	2022	1248.96	4901.44	2410.56	8560.96

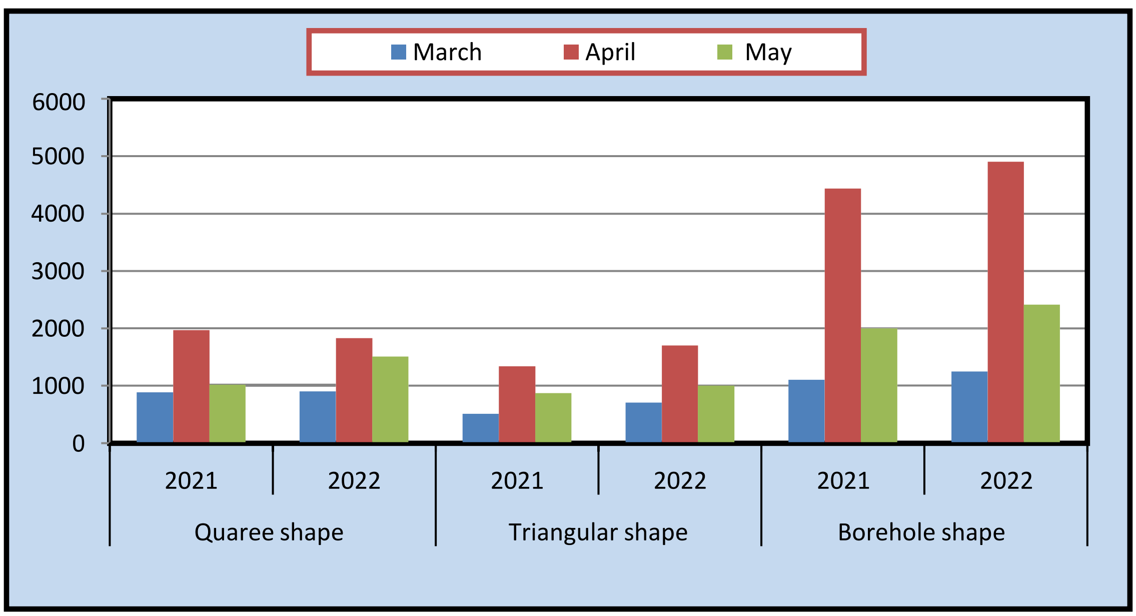


Fig 4.10. Month wise comparison of resin yield during the year 2021 and 2022.

4.6. Statistical analysis

In Quarre method of tapping highest resin yield/tree (277.23 g/tree/90 days) was obtained in T15 CQ (E 30%+H 20%), followed by T14 CQ (E 30%+H 15 %) , T13 CQ treatments (E 30%+H 10%) and the yield was 215.65 g/tree,134.96 g/tree respectively. Whereas in triangular method of tapping highest yield was obtained in T11 CT (E20%+ H15%) treatment with a yield of 112.12 g/tree which was statistically at par with T10 CT treatment (E20%+ H10%) with a yield of 111.93 g/tree, followed by T15 CT treatment (E 30%+H 20%) at a yield of 110.62 g/tree. In Borehole method of tapping highest quantity of resin yield/tree (348.56 g/tree) was obtained withT13 CH treatment (E 30%+H 10 %) which was statistically at par with the T13 CH treatment (E 30%+H 15 %).

Table .4.11 Statistical Analysis of resin yield in *Pinus roxburghii*

Treatments	Mean	Treatments	Mean	Treatments	Mean
T1CQ	31.74	T1CT	21.63	T1CH	36.90
T2CQ	38.01	T2CT	34.79	T2CH	63.00
T3CQ	100.86	T3CT	25.73	T3CH	87.67
T4CQ	36.78	T4CT	44.84	T4CH	62.92
T5CQ	103.08	T5CT	77.65	T5CH	74.42
T6CQ	65.88	T6CT	40.16	T6CH	125.05
T7CQ	50.56	T7CT	60.18	T7CH	196.44
T8CQ	46.86	T8CT	55.38	T8CH	126.73
T9CQ	51.62	T9CT	63.65	T9CH	196.37
T10 CQ	65.87	T10 CT	**111.93**	T10 CH	255.96
T11CQ	59.69	T11CT	**112.12**	T11CH	261.00
T12 CQ	71.37	T12 CT	45.76	T12 CH	260.36
T13CQ	134.96	T13CT	107.58	T13CH	**348.56**
T14CQ	**215.65**	T14CT	110.31	T14CH	**328.20**
T15 CQ	**277.23**	T15 C T	110.62	T15 CH	268.65
SE(m) ±	5.54	SE(m) ±	6.11	SE(m) ±	12.29
SE(d)	7.83	SE(d)	8.64	SE(d)	17.38
CD(p=0.05)	15.99	CD(p=0.05)	17.64	CD(p=0.05)	35.49

4.7. Effect of Chemical treatments on different methods and rate of resin exudation (g) in *Pinus kesiya during* year 2021

Among all three methods used for resin tapping in *Pinus kesiya*, Quarre method was found most suitable because the average resin yield/tree obtained was highest in T14 KQ treatment (Ethephon 30%+ H_2SO_4 15%) and the yield was 129.24 g/tree, followed by T11KT (Ethephon 20 %+ H_2SO_4 15%) and T13 KH (Ethephon 30%+ H_2SO_4 10%) treatments the yield recorded 92.02 g/tree and 48.8 g/tree respectively. The results of experiment confirmed that Quarre shape method of tapping with diameter class of IV (40-45 cm) was much effective for sustainable harvesting of resin in *Pinus kesiya* as shown in table 4.12. Similar finding was reported by Hadiyane *et.al* (2015) while, conducting experiment on *Pinus merkusii* tree at West Java- Indonesia and found that Quarre method of tapping showed maximum resin production (22.76g/Quarre/tree) on the diameter class of 38-40 cm. Although the species is different in the present experiment but the method of tapping is similar to Hadiyane *et.al.*2015 and the yield obtained was 6 times higher than that of above-mentioned worker. According to Li (1991), the influence of tapping method on tree growth is frequently hampered due to cambium damage and would seem to be some kind of tree reaction for the lack of woody tissue in a part of the bole of the tree. Other factors, such as soil (Samanta *et al.*, 2012), climate (Zamski, 1970), applied chemicals (Philippou, 1986), tree age (Buchert et al., 1997), silvicultural regime (Moulalis, 1981), and tree genetics (Papajiannopoulos, 2002), might alter resin production (via wounding).The total yield obtained by various method of tapping the highest yield was found in Quarre method @ 2038.7 g(from 45 trees),followed by Triangular method *i.e* 1413.8 g (from 45 trees) and minimum yield (1280.59 g) was obtained in Borehole method of tapping(from 45 trees) in 2021.

During the present year the highest resin yield was obtained in the month of April in each method of tapping i.e 1030.46 g in Quarre method, 809 g in Triangular method and 927.2 g in Borehole method, respectively. It was observed that low humidity with high atmospheric temperature yielded more resin. The results are in accordance to the findings of Flotynski (1964); Mathauda (1956,1961) ; Deshmukh and Payal (1964;) and Lohani (1973). It is clear from the current findings that as relative humidity increases the oleoresin yield decreases, and when relative humidity percent climbed from June onwards due to heavy rainfall the resin yield decreases in the study area, The oleoresin production is reduced when the temperature is lowered by rain. Therefore, Resin tapping should not be recommended after June in tropical climates because rainfall hinders resin collection as well the rainfall pattern is very high as compared to temperate area.

Table 4.12. Treatments and diameter class wise resin yield in *Pinus kesiya* during 2021

Treatments	Diameter Class	R1	R2	R3	Total yield	Mean yield/tree (g)
Quarre shape method						
T1KQ	III	18.39	16.56	20.95	55.9	18.63
T2KQ	V	20.46	18.44	24.76	63.66	21.22
T3KQ	III	27.3	30.43	24.56	82.29	27.43
T4KQ	III	28.97	28.01	30.26	87.24	29.08
T5KQ	III	29.92	26.79	32.78	89.49	29.83
T6KQ	V	31.22	28.98	37.35	97.55	32.52
T7KQ	IV	48.42	47.89	50.22	146.53	48.84
T8KQ	V	22.65	24.55	20.19	67.39	22.46
T9KQ	IV	27.42	25.44	27.46	80.32	26.77
T10 KQ	V	30.96	29.32	31.98	92.26	30.75
T11KQ	V	34.42	39.5	33.08	107	35.67
T12 KQ	IV	35.09	45.78	38.12	118.99	39.66
T13KQ	IV	125.17	128.54	121.32	375.03	125.01
T14KQ	**IV**	**129.3**	**124.06**	**134.37**	**387.73**	**129.24**
T15 KQ	IV	60.09	66.89	60.01	186.99	62.33
Triangular shape method						
T1KT	III	16.78	19.08	22.07	57.93	19.31
T2KT	III	23.21	20.09	25.66	68.96	22.99
T3KT	IV	25.61	19.98	27.76	73.35	24.45
T4KT	IV	14.85	18.86	11.54	45.25	15.08
T5KT	III	12.96	9.72	16.24	38.92	12.97
T6KT	III	23.39	19.77	26.55	69.71	23.24
T7KT	IV	17.39	16.91	20.51	54.81	18.27
T8KT	IV	78.06	72.9	83.65	234.61	78.20
T9KT	V	16.46	12.09	21.34	49.89	16.63
T10 KT	V	24.23	20.9	26.87	72	24.00
T11KT	**V**	**90.32**	**94.73**	**91.01**	**276.06**	**92.02**
T12 KT	IV	25.21	28.74	25.01	78.96	26.32
T13KT	III	17.01	15.55	20.31	52.87	17.62
T14KT	V	46.04	42.98	50.69	139.71	46.57
T15 KT	V	31.35	32.98	36.44	100.77	33.59
T1KH	III	14.76	11.09	19.45	45.3	15.10
Borehole shape method						
T2KH	III	21.04	25.58`	22.15	43.19	21.60
T3KH	III	33.8	29.09	37.04	99.93	33.31
T4KH	IV	27.97	31.98	32.78	92.73	30.91
T5KH	III	19.23	16.54	25.76	61.53	20.51
T6KH	V	26.74	19.75	24.12	70.61	23.54
T7KH	III	28.9	34.09	27.22	90.21	30.07
T8KH	IV	17.35	19.65	22.04	59.04	19.68
T9KH	IV	24.23	20.78	28.12	73.13	24.38
T10 KH	V	52.14	48.9	56.88	157.92	52.64
T11KH	V	22.6	29.88	20.72	73.2	24.40
T12 KH	V	19.07	17.65	24.67	61.39	20.46
T13KH	**IV**	**48.35**	**43.99**	**54.08**	**146.42**	**48.81**
T14KH	IV	39.36	36.98	44.45	120.79	40.26
T15 KH	V	25.79	28.44	30.97	85.2	28.40
KQ-Khasipine Quaree shape, KT-Khasi pine Triangular shape, KH-Khasipine borehole shape						

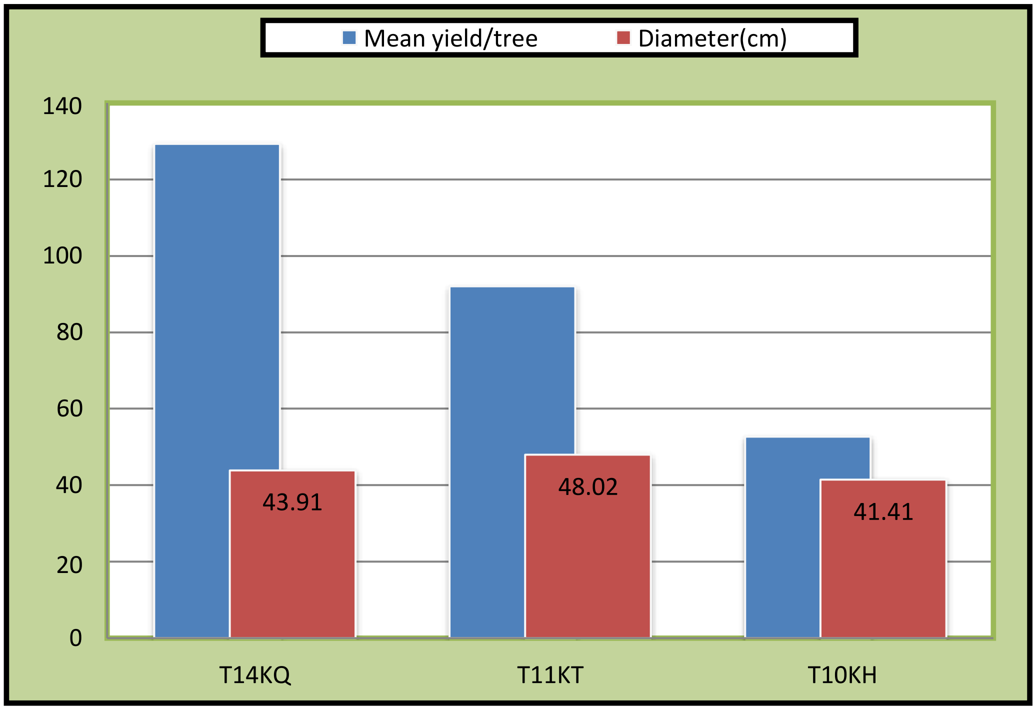


Fig-4.11 Highest resin output in 2021 by using different methods in *Pinus kesiya*

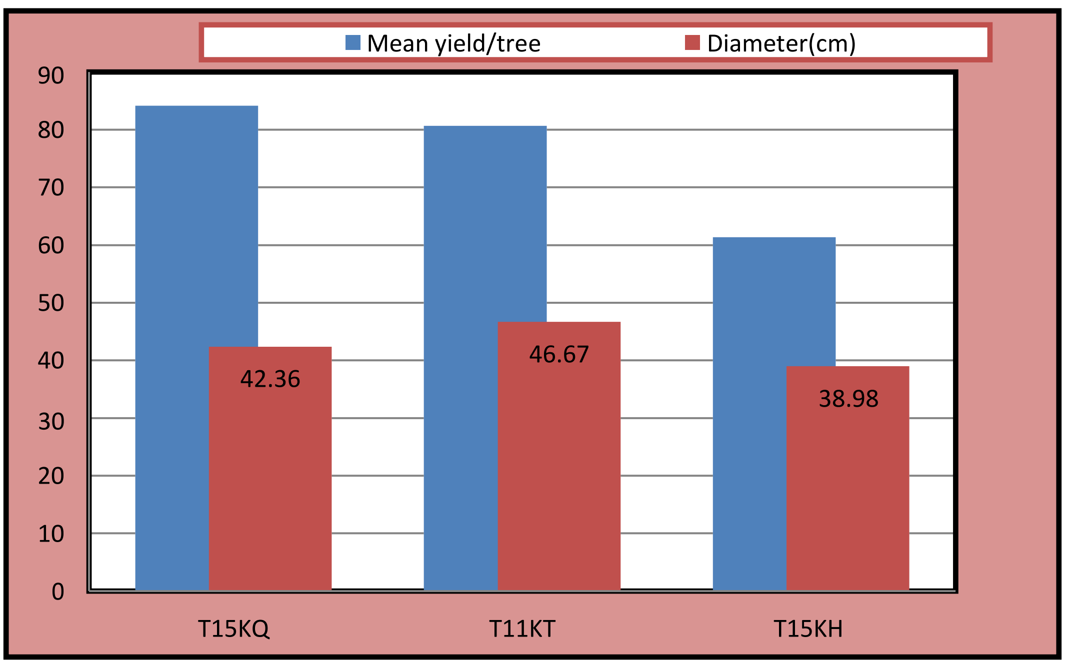


Fig- 4.12. Highest resin output in 2022 by using different methods in*Pinus kesiya*

4.8. Effect of Chemical treatments of on different methods and rate of resin exudation (g) in *Pinus kesiya during* year 2022

The observation recorded in the year 2022 among all three-method used for resin tapping the highest yield was obtained from Quarre method in T15KQ treatment (Ethephon 30%+ H_2SO_4 20%) followed by Triangular method in T11KT treatment (Ethephon 20%+H_2SO_4 15%) and in borehole method of tapping in T15KH treatment (Ethephon 30%+ H_2SO_4 20%) the average yield was recorded 84.18 g/tree ,80.68 g/tree, 61.39 g/tree, respectively. It was noticed that diameter class of 40-45 cm yielded highest resin in *Pinus kesiya* presented in table 4.13. From many experimental findings it was confirmed that diameter has shown positive and significant correlation with the oleoresin yield. Similar, findings have been reported in *Pinus pinea* and *P. Pinaster* (Magini,1958), on *Pinus sylvestris* (Pejoski, 1956). The resin tapping in *Pinus kesiya* has still not been done on a big scale commercially in its native habitat (Meghalaya), because its timber is usually utilized for building of houses, as pole, and in plywood industry. The bark thickness in *Pinus kesiya* is 1-1.5 cm, as compare to *Pinus roxburghii* therefore, bark thickness doesn't regulate the resin outflow in this species. In the present study year in 2022 of total resin yield obtained from Quarre method was comparatively lower than the year of 2021 this is because of the location of stand changed for tapping. In the year of 2022 tapping in Quarre shape method was done at Kabirchabutra (P-232 compartment) which comes under East Karanjia Range (Part of the Buffer zone of Biosphere reserve); the altitude of the place was 1019 m amsl and it faces south -west aspects, whereas, in the first year of tapping was conducted at Bhundakona (Amarkantak range) having an elevation of 1110 m amsl and this place faces North- Eastern aspect. The resin yield was significantly found more in higher elevation as compared with the lower elevation. It can be said that while selection of site for pine plantation higher elevation sites would be selected.

Table 4.13. Treatments and diameter class wise resin yield from *Pinus kesiya* during 2022

Treatments	Dia-classes	R1	R2	R3	Total yield per tree (g)	Mean yield per tree (g)
Quarre shape method						
T1KQ	III	18.49	16.8	20.22	55.51	18.50
T2KQ	IV	19.13	28.64	22.16	69.93	23.31
T3KQ	III	29.92	23.89	28.06	81.87	27.29
T4KQ	III	31.77	26.11	22.86	80.74	26.91
T5KQ	III	25.77	38.79	32.38	96.94	32.31
T6KQ	V	45.49	54.9	61.22	161.61	53.87
T7KQ	V	67.09	47.12	54.02	168.23	56.08
T8KQ	V	60.78	54.18	50.36	165.32	55.11
T9KQ	IV	37.92	30.55	25.9	94.37	31.46
T10 KQ	IV	39.89	20.37	30.77	91.03	30.34
T11KQ	III	34.5	39.81	33.22	107.53	35.84
T12 KQ	IV	35.19	45.39	50.79	131.37	43.79
T13KQ	IV	51.42	59.58	39.95	150.95	50.32
T14KQ	V	66.09	49.11	39.71	154.91	51.64
T15 KQ	**IV**	**98.88**	**66.19**	**87.46**	**252.53**	**84.18**
Triangular shape method						
T1KT	**III**	18.35	22.08	27.45	67.93	22.63
T2KT	III	26.16	21.69	29.76	77.61	25.87
T3KT	III	27.09	19.22	30.55	76.86	25.62
T4KT	IV	17.11	21.56	11.99	50.66	16.89
T5KT	V	12.13	19.36	20.44	51.93	17.31
T6KT	III	28.33	9.66	22.58	60.57	20.19
T7KT	IV	20.2	16.12	24.51	60.83	20.28
T8KT	IV	38.86	32.9	34.95	106.71	35.57
T9KT	V	89.9	68.65	76.84	235.39	78.46
T10 KT	IV	44.53	39.12	49.17	132.82	44.27
T11KT	**V**	80.12	70.9	91.02	242.04	**80.68**
T12 KT	IV	35.11	28.14	20.19	83.44	27.81
T13KT	III	27.49	20.25	29.21	76.95	25.65
T14KT	V	46.93	49.09	55.69	151.71	50.57
T15 KT	V	38.35	30.78	44.44	113.57	37.86
Bore hole shape method						
T1KH	III	26.66	20.49	19.29	66.44	22.15
T2KH	V	31.04	45.58	62.17	138.79	46.26
T3KH	III	53.91	39.68	46.79	140.38	46.79
T4KH	IV	37.69	31.72	40.08	109.49	36.50
T5KH	IV	29.73	22.84	29.56	82.13	27.38
T6KH	III	36.05	39.25	44.82	120.12	40.04
T7KH	V	34.56	50.49	27.72	112.77	37.59
T8KH	IV	19.75	24.65	22.84	67.24	22.41
T9KH	V	24.23	20.78	17.15	62.16	20.72
T10 KH	III	45.14	38.97	55.98	140.09	46.70
T11KH	V	36.26	29.48	28.72	94.46	31.49
T12 KH	IV	29.97	17.35	24.57	71.89	23.96
T13KH	IV	29.42	22.66	31.88	83.96	27.99
T14KH	V	43.43	39.58	44.45	127.46	42.49
T15 KH	**III**	68.88	54.9	60.38	184.16	**61.39**
KQ-Khasipine Quaree shape, KT-Khasi pine Triangular shape, KH-Khasipine borehole shape						

4.9. Method and Chemical concentration wise Pooled analysis data per tree yield of resin during the year 2021 and 2022.

4.9.1. Effect of Combine dose of Chemical concentrations

The pooled analysis of effects of chemical tapping by using three different shape of incision and the quantity of resin exudation in *Pinus kesiya* is presented in Table 4.14. The pooled data showed the effect different combine dose of chemical concentration used for tapping. It was revealed that among all the combine dose of chemical used for tapping highest resin yield (53.31 g/tree from 54 trees) was obtained from Quarre method, followed by triangular method (42.08 g/tree from 54 trees) and minimum yield (33.55 g/tree from 54 trees) recorded from borehole method shown in table 4.15. It was confirmed from table 4.14 that significantly highest yield/tree was obtained in Quarre method with combine dose of chemical stimulants T14KQ (Ethephon 30%+H_2SO_4 15%) treatment 90.44 g/tree and lowest yield obtained in T9KQ treatment @ 29.11 g/tree by using (Ethephon 10%+H_2SO_4 20%).While, using Triangular shape method highest yield was recorded in T11KT treatment (Ethephon 20%+ H_2SO_4 15%) @ 86.85 g/tree and minimum yield was obtained in T7 KT (Ethephon 10%+ H_2SO_4 10%) treatment @ 19.27 g/tree. However, among all the three methods of tapping in *Pinus kesiya, the* Borehole method yielded lowest resin yield as compare with other methods. In Borehole method of tapping maximum resin yield was obtained in T10 KH (Ethephon 20%+ H_2SO_4 10%) treatment @ 49.67 g/tree and minimum yield was recorded from T8KH (Ethephon 10%+H_2SO_4 15%) treatment @ 21.05 g/tree. As per *Pinus kesiya* project launched by ICAR in North Eastern Hill region, (IINRG,2020) the mean resin yield /tree was found to be highest in Borehole method (41.6 to115.8 g/tree). However, in the present experiment highest resin yield was observed in Quarre method of tapping with combine dose of chemicals and the yield rangefrom 30.54 g to 90.44 g/tree.

Swain and Patnaik (1998) conducted resin tapping experiment on *Pinus kesiya* by using Rill method at Koraput and Maliput Research station, Odisha. They found that mean yield of resin/year/tree in Koraput was 62.65 g and in Maliput it was 91.91 g/tree/year (52 weeks). In total of 52 weeks of tapping period starting from January to December, resin production was significantly highest in the month of April at Maliput and in the month of August at Koraput. In the present experiment highest resin yield was obtained by using Quarre shape of incision in T14 KQ treatment (E 30%+ H 15 %) and the yield of 90.43 g/tree/year which was higher than the work done by Swain and Patnaik (1998) in the tropical environment. The present method of tapping is non-destructive and sustainable in nature as the incision made on trees create less injuries in comparison to rill method of tapping and the yield obtained was much higher in the short period of time.

4.9.2. Effect of H_2SO_4

Among the single doses of Sulfuric acid used for resin tapping in various shape highest resin yield (34.09 g/tree) obtained in Quarre method, followed by borehole method (29.81g /tree) and minimum yield was observed in triangular method (17.61 g/tree) shown in table 4.15. The Quarre method of tapping yielded highest resin (89.44 g/tree) by using H_2SO_4 20% concentration, followed by borehole method of tapping (33.70 g/tree) by using H_2SO_4 10 % concentration, and minimum (21.71 g/tree) was obtained in triangular method using H_2SO_4 20% concentration as shown in table 4.14.

4.9.3. Effect of Ethephon

Among the single doses of Ethephon used for resin tapping in various shape significantly highest yield (29.67 g/tree) obtained in borehole method followed by triangular method (23.48 g/tree) and minimum yield (22.73 g/tree) was observed in Quarre method of tapping (Table 4.15). The borehole method of tapping yielded highest resin yield (40.05 g/tree) by using ethephon 30% concentration followed by Quarre method of tapping (27.36 g/tree) by using ethephon 30% concentration and minimum yield (25.04 g/tree) was obtained in triangular method by using ethephon 30% concentration.

4.10. Diameter class wise resin exudation (g) in *Pinus kesiya* (mean yield/tree)

It was found that diameter class ranging from 40-45 cm yielded highest resin in *Pinus kesiya.* Among all three methods tried the mean yield per tree was found highest (62.01 g/tree) in Quarre method with the above mentioned diameter class, followed by triangular method (47.82 g/tree) and minimum yield was obtained in borehole shape (45.13 g/tree) mentioned in table 4.16. Swain and Patnaik (1998) also reported in their experiment in *Pinus kesiya* by using rill method at Koraput and Maliput Research station,Odisha they reported that diameter class of 30- 32 cm yielded 62.65 g/tree at Koraput and diameter class of 33-37 cm yielded 91.01 g/tree at Maliput. As per ICAR, *Pinus kesiya* project in NEH region diameter class of 35-50 cm yielded highest resin by using borehole method of tapping. (IINRG,2020)

Table 4.14. The effect of chemical concentrations on different methods of resin tapping in *Pinus kesiya* (gram/tree) is shown by a pooled analysis of data.

Treatments	Treatments details	Mean yield /tree during 2021	Mean yield /tree during 2022	Pooled
Quarre method				
T1KQ	Ethephon10%	18.63	18.5	18.56
T2KQ	Ethephon 20%	21.22	23.31	22.26
T3KQ	Ethephon 30%	27.43	27.29	27.36
T4KQ	Sulfuric acid10%	29.08	26.91	27.99
T5KQ	Sulfuric acid 15%	29.83	32.31	31.07
T6KQ	Sulfuric acid 20%	32.52	53.87	89.44
T7KQ	Ethephon 10 % + 10 % Sulfuric acid	48.84	56.07	52.45
T8KQ	Ethephon 10 % + 15 % Sulfuric acid	22.46	55.1	38.78
T9KQ	Ethephon 10 % + 20 % Sulfuric acid	26.77	31.45	29.11
T10 KQ	Ethephon 20% + 10 % Sulfuric acid	30.75	30.34	30.54
T11KQ	Ethephon 20% + 15 % Sulfuric acid	35.67	35.84	35.75
T12 KQ	Ethephon 30 % + 20 % Sulfuric acid	39.66	43.79	41.72
T13KQ	Ethephon 30 % + 10 % Sulfuric acid	125.01	50.32	41.41
T14KQ	Ethephon 30 % + 15 % Sulfuric acid	129.24	51.64	90.44
T15 KQ	Ethephon 30 % + 20 % Sulfuric acid	62.33	84.17	73.25
Triangular method				
T1KT	Ethephon10%	19.31	22.62	20.96
T2KT	Ethephon 20%	22.98	25.87	24.42
T3KT	Ethephon 30%	24.45	25.62	25.03
T4KT	Sulfuric acid10%	15.08	16.88	15.98
T5KT	Sulfuric acid 15%	12.97	17.31	15.14
T6KT	Sulfuric acid 20%	23.23	20.19	21.71
T7KT	Ethephon 10 % + 10 % Sulfuric acid	18.27	20.27	19.27
T8KT	Ethephon 10 % + 15 % Sulfuric acid	78.2	35.57	56.88
T9KT	Ethephon 10 % + 20 % Sulfuric acid	16.63	78.46	47.54
T10 KT	Ethephon 20% + 10 % Sulfuric acid	24	44.27	34.13
T11KT	Ethephon 20% + 15 % Sulfuric acid	92.02	80.68	86.35
T12 KT	Ethephon 30 % + 20 % Sulfuric acid	26.32	27.81	27.06
T13KT	Ethephon 30 % + 10 % Sulfuric acid	17.62	25.65	21.63
T14KT	Ethephon 30 % + 15 % Sulfuric acid	46.57	50.57	48.57
T15 KT	Ethephon 30 % + 20 % Sulfuric acid	33.59	37.85	35.72
Borehole method				
T1KH	Ethephon10%	15.1	22.14	18.62
T2KH	Ethephon 20%	21.59	46.26	33.92
T3KH	Ethephon 30%	33.31	46.79	40.05
T4KH	Sulfuric acid10%	30.91	36.49	33.7
T5KH	Sulfuric acid 15%	20.51	27.37	23.94
T6KH	Sulfuric acid 20%	23.53	40.04	31.78
T7KH	Ethephon 10 % + 10 % Sulfuric acid	30.07	37.59	33.83
T8KH	Ethephon 10 % + 15 % Sulfuric acid	19.68	22.41	21.04
T9KH	Ethephon 10 % + 20 % Sulfuric acid	24.37	20.72	22.54
T10 KH	Ethephon 20% + 10 % Sulfuric acid	52.64	46.69	49.66
T11KH	Ethephon 20% + 15 % Sulfuric acid	24.4	31.48	27.94
T12 KH	Ethephon 30 % + 20 % Sulfuric acid	20.46	23.96	22.21
T13KH	Ethephon 30 % + 10 % Sulfuric acid	48.8	27.98	38.39
T14KH	Ethephon 30 % + 15 % Sulfuric acid	40.26	42.48	41.37
T15 KH	Ethephon 30 % + 20 % Sulfuric acid	28.4	61.38	44.89

Table 4.15. Resin yield per tree by using various chemicals and methods in *Pinus kesiya*

Methods of tapping	Ethephon	H_2SO_4	Ethephon + H_2SO_4
Quarre shape	22.73	34.09	53.31
Triangular shape	23.48	17.61	42.08
Bore hole shape	29.67	29.81	33.55

Table 4.16. Diameter class wise resin yield (g) from *Pinus kesiya*

Diameter class	2021			2022			Mean yield/tree
Quarre shape cut	Number of trees selected	Total yield	Mean yield in 2021	Number of trees selected	Total yield	Mean yield in 2022	
III (35-40)	15	435.71	29.04	15	344.18	22.94	25.99
IV (40-45)	**15**	**974.18**	**64.94**	**15**	**886.20**	**59.08**	**62.01**
V (45-50)	15	628.48	41.89	15	632.46	42.16	42.03
Total yield(g)		2038.37			1862.84		
Borehole method							
III (35-40)	15	253.05	16.87	15	304.73	20.31	18.59
IV (40-45)	**15**	**569.48**	**37.96**	**15**	**784.45**	**52.29**	**45.13**
V (45-50)	15	458.06	30.53	15	512.36	34.15	32.34
Total yield(g)		1280.59			1601.54		
Triangular method							
III (35-40)	15	305.42	20.36	15	358.02	23.86	22.11
IV (40-45)	**15**	**689.06**	**45.93**	**15**	**745.69**	**49.71**	**47.82**
V (45-50)	15	419.32	27.95	15	485.31	32.35	30.15
Total yield (g)		1413.8			1589.02		

Table 4.17 Chemical concentrations wise resin yield in *Pinus kesiya* by different methods during year 2021 -2022

Quarre shape method	**T1KQ**	**T2KQ**	**T3KQ**	**T4KQ**	**T5KQ**	**T6KQ**	**T7KQ**	**T8KQ**	**T9KQ**	**T10 KQ**	**T11KQ**	**T12 KQ**	**T13KQ**	**T14KQ**	**T15 KQ**
Treatments	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20%	E 10 % +H 10 %	E 10 % +H 15 %	E 10% +H 20 %	E 20 % +H 10 %	E 20 % +H 15 %	E 20% +H 20	E 30 %+H 10	E 30 % E+H 15	E 30 % +H 20
2021	55.9	63.66	82.29	87.24	89.49	97.55	146.53	67.39	80.32	92.26	107	118.99	375.03	387.73	186.99
2022	55.51	69.93	81.87	80.74	96.94	161.61	168.23	165.32	94.37	91.03	107.53	131.37	150.95	154.91	252.53
Total yield	111.41	133.59	164.16	167.98	186.43	259.16	314.76	232.71	174.69	183.29	214.53	250.36	525.98	542.64	439.52
Mean yield/year	74.27	89.06	109.44	111.99	124.29	172.77	209.84	155.14	116.46	122.19	143.02	166.91	350.65	361.76	293.01
Borehole shape method	**T1 KH**	**T2 KH**	**T3K H**	**T4 KH**	**T5 KH**	**T6K H**	**T7KH**	**T8KH**	**T9KH**	**T10 KH**	**T11KH**	**T12 KH**	**T13KH**	**T14KH**	**T15 KH**
Treatments	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20%	E 10 % +H 10 %	E 10 % +H 15 %	E 10% +H 20 %	E 20 % +H 10 %	E 20 % +H 15 %	E 20% +H 20	E 30 %+H 10	E 30 % E+H 15	E 30 % +H 20
2021	45.3	43.19	99.93	92.73	61.53	70.61	90.21	59.04	73.13	157.92	73.2	61.39	146.42	120.79	85.2
2022	66.44	138.79	140.38	109.49	82.13	120.12	112.77	67.24	62.16	140.09	94.46	71.89	83.96	127.46	184.16
Total yield	111.74	181.98	240.31	202.22	143.66	190.73	202.98	126.28	135.29	298.01	167.66	133.28	230.38	248.25	269.36
Mean yield/year	55.87	90.99	120.155	101.11	71.83	95.365	101.49	63.14	67.645	149.005	83.83	66.64	115.19	124.125	134.68
Traingular Shape method	**T1KT**	**T2KT**	**T3KT**	**T4KT**	**T5KT**	**T6KT**	**T7KT**	**T8KT**	**T9KT**	**T10 KT**	**T11KT**	**T12 KT**	**T13KT**	**T14KT**	**T15 KT**
Treatments	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20%	E 10 % +H 10 %	E 10 % +H 15 %	E 10% +H 20 %	E 20 % +H 10 %	E 20 % +H 15 %	E 20% +H 20	E 30 %+H 10	E 30 % E+H 15	E 30 % +H 20
2021	57.93	68.96	73.35	45.25	38.92	69.71	54.81	234.61	49.89	72	276.06	78.96	52.87	139.71	100.77
2022	67.93	77.61	76.86	50.66	51.93	60.57	60.83	106.71	235.39	132.82	242.04	83.44	76.95	151.71	113.57
Total yield	125.86	146.57	150.21	95.91	90.85	130.28	115.64	341.32	285.28	204.82	518.1	162.4	129.82	291.42	214.34
Mean yield/year	62.93	73.285	75.105	47.955	45.425	65.14	57.82	170.66	142.64	102.41	259.05	81.2	64.91	145.71	107.17

4.11. Total resin yield by using different methods and Chemical treatments during year 2021 and 2022.

4.11.1. Effect of different chemical stimulants on the resin yield by using Quarre shape method. (Mean yield/year)

In the Quarre method of tapping the total resin yield was obtained highest (3901.21 g) during two years of the study as compared to other method tried and the total mean yield per year was 130.04 g/Quarre/ year. The total yield of resin by using Ethephon chemical was 409.16 g, while using H_2SO_4 the yield was 613.57 g and the yield obtained by using combine dose of Ethephon and Sulfuric acid was 2878.48 g as shown in table 4.18. From (Table 4.18) it has been confirmed that in the combine dose of treatment total yield of resin was found to be highest in T14KQ (Ethephon 30% + H_2 $SO_4$15%) treatment, followed by T13 KQ (Ethephon 30% + H_2 SO_4 10%) and minimum in T9KQ (Ethephon 10% + H_2 $SO_4$20%) and the yield were 271.32 g/year,262.99 g/year and 87.34 /year, respectively. In both the year of chemical treatment ethephon concentration of 30% yielded maximum resin yield. The Ethephon chemical is also used to stimulate latex flow in *Hevea brasiliensis*, resin enhancement in Pines reported by (Peters 1971) and also in *Commiphora wightii* (Bhatt and Shah,1985). Higher gum exudation at high concentration of ethephon could be due to the developmental response of plants to dehydration stress induced by ethephon (ethylene) application. As it is well known that whenever ethephon (consisting of ethylene, phosphate and chloride ions) is injected into the plants, it metabolizes and converts in ethylene gas which triggers various developmental responses in plants (Hall and Smith, 1995). Our results corroborate with the results of Bhatt and Ram (1990). They reported increased gum yield with increased ethephon concentration in *Acacia Senegal* and similar observation had been observed that with increasing conc. of ethephon resin yield increases. In *Anogeissus latifolia*, similar increase in gum yield with the increase in concentration of ethephon was reported by Kuruwanshi and Katiyar (2017). While by using various concentration of Ethephon and Sulfuric acid, the mean yield/ year was 204.58 g and 306.78 g respectively. whereas, in combine doses of chemicals the value was 1439.24 g/ year (Table 4.18). In the month of April in each year highest average resin yield (1056.78g) was obtained followed by May (577.03 g) and minimum average yield was obtained in the month of March (316.79 g)

Table 4.18. Total and Mean yield of resin/year by using Quarre shape incisions by using different treatments during the year 2021 and 2022

Treatments	Total resin yield during 2021(g)	Total resin yield during 2022(g)	Total Yield (g)	Mean yield/year(g)
T1KQ	55.9	55.51	111.41	55.7
T2KQ	63.66	69.93	133.59	66.79
T3KQ	**82.29**	**81.87**	**164.16**	**82.08**
T4KQ	87.24	80.74	167.98	83.99
T5KQ	89.49	96.94	186.43	93.21
T6KQ	**97.55**	**161.61**	**259.16**	**129.58**
T7KQ	146.53	168.23	314.76	157.38
T8KQ	67.39	165.32	232.71	116.35
T9KQ	80.32	94.37	174.69	87.34
T10 KQ	92.26	91.03	183.29	91.64
T11KQ	107	107.53	214.53	107.26
T12 KQ	118.99	131.37	250.36	125.18
T13KQ	375.03	150.95	525.98	262.99
T14KQ	**387.73**	**154.91**	**542.64**	**271.32**
T15 KQ	186.99	252.53	439.52	219.76
	2038.37	1862.84	3901.21	130.04

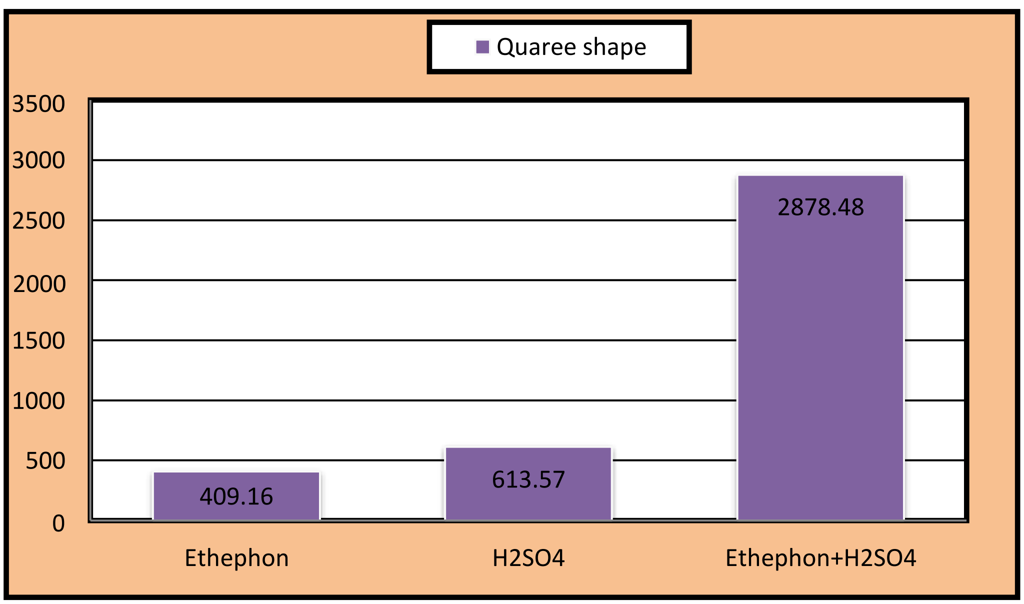


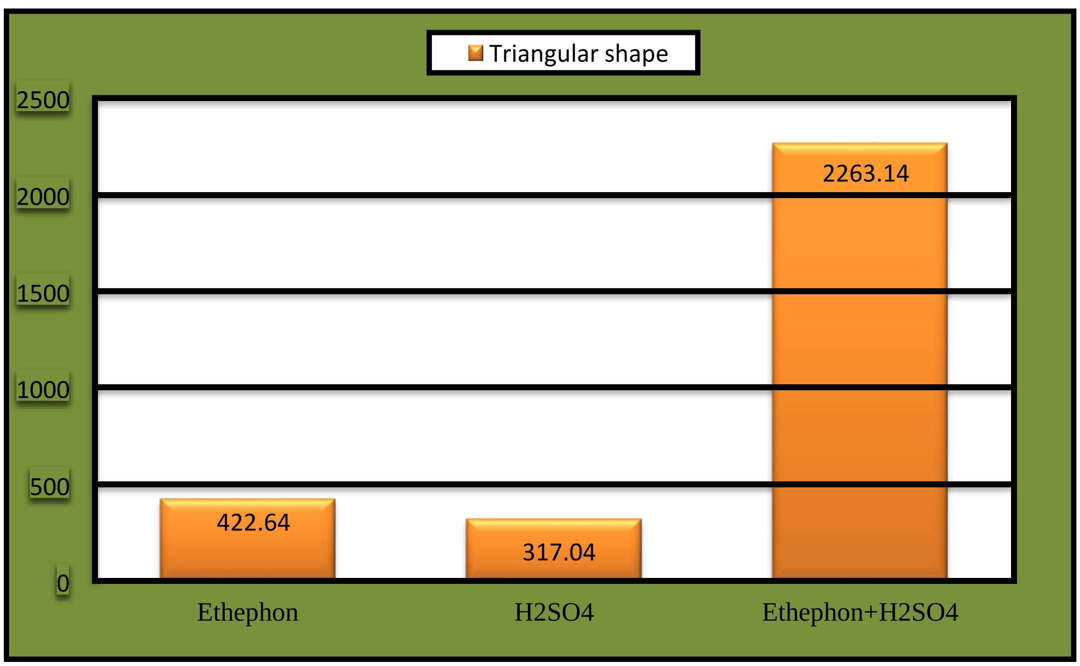
Figure- 4.13. Total yield of resin by using various chemical in Quarre method of tapping during the year2021-22

4.12.2. Effect of different chemical concentration on the resin yield by using triangular shape method. (Mean yield/year)

In the present experiment triangular method of tapping the total yield was obtained from all the treatment in both the years was 3002.82 g and the total mean yield per triangular shape/year was 100.09 g. From the result table 4.19 it is confirmed that the resin yield obtained during the month 2022 is relatively higher than the yield of 2021. Ethephon concentration of 30 %, H_2SO_4 concentration of 30% and both combine dose of treatment of Ethephon 20% + H_2SO_4 15% treatment yielded highest mean resin yield in both the years of 2021 and 2022 (Table 4.19). In combine dose highest resin yield(259.05g/year) was obtained in T11 KT (Ethephon 20% +H $_2SO_4$ 15%) ,followed by T8KT (Ethephon 10% + H_2SO_4 15%) @ 170.66 g/year and minimum yield obtained in T7 KT treatment (Ethephon 10% +H 10%) @ 57.82 g/year. Abib *et al*., (2013) also reported that high yield with lower concentration of ethephon in *Acacia senegal* tree and the similar results was found in the present study method of tapping that by using lower concentration ethephon i.e 20% yielded maximum quantity of resin in this triangular method. The total yield by using Ethephon chemical was 422.64 g (211.32 g/year), while using H_2SO_4 the yield was 317.04 g(158.53 g/year) and the yield obtained by using combine dose of treatment was 2263.14 g (1131.57 g/year) as presented in figure 4.14. It was also reported in the present experiment that the yield increases with increase in chemical concentration of Ethephon. It was observed that Ethephon at various conc, yielded more resin (70.43 g/year) as compared to Sulfuric acid (52.83 g/year) in three different concentrations. Ethephon application leads to schizolysigenous formation of gum cavities in the axial parenchyma of sapwood associated with the formation of cavities and many vessels of secondary xylem become clogged with gummy material. Nair *et al*., (1995), Bhatt et al., (1987), Nayak and Prajapati (2020), observed that the use of ethephon as a gum inducer enhance gum production in tropical trees like *Boswellia serrata* and *Lannea coromandelica* and hasproved to be effective for sustainable gum tapping

Table 4.19. Total and Mean yield of resin/year by using Triangular shape method by using different treatments during 2021 and 2022

Triangular shape	Total resin yield during 2021 (g)	Total resin yield during 2022 (g)	Total yield	Mean yield/year
T1KT	57.93	67.93	125.86	62.93
T2KT	68.96	77.61	146.57	73.28
T3KT	**73.35**	**76.86**	**150.21**	**75.10**
T4KT	45.25	50.66	95.91	47.95
T5KT	38.92	51.93	90.85	45.42
T6KT	**69.71**	**60.57**	**130.28**	**65.14**
T7KT	54.81	60.83	115.64	57.82
T8KT	234.61	106.71	341.32	170.66
T9KT	49.89	235.39	285.28	142.64
T10 KT	72	132.82	204.82	102.41
T11KT	**276.06**	**242.04**	**518.1**	**259.05**
T12 KT	78.96	83.44	162.4	81.2
T13KT	52.87	76.95	129.82	64.91
T14KT	139.71	151.71	291.42	145.71
Total yield (g)	1413.8	1589.02	3002.82	100.09



4.14 Total yield of resin by using various chemical concentrations in Triangular method of tapping during the year 2021-2022

4.11.3. Effect of different chemical concentration on resin yield by using borehole shape method (Mean yield/year)

In borehole method of tapping the total yield obtained from all the treatment in both the years was 2882.13 g and the mean yield per year by using this method was 96.07 g per borehole/year. Atmospheric temperature has a definite role to play in exudation of oleoresin from tree. The optimum yields being obtained at a critical temperature of 26.5°C and above; below it the yield falls off significantly (Anonymous, 1972). It is evident from the experimental results of the present study that the highest average resin yield (727.61 g/month) obtained in the month of April, followed by May (472.2 g/month) and minimum yield (241.26 g/month) was obtained in March each year respectively (Table 4.21). Ethephon concentration of 30% (T3KH treatment) @ 120.16 g/year, H_2SO_4 concentration of 10% (T4KH) @ 101.11 g /year and with the combine dose of treatment (Ethephon 20%+ H_2SO_4 10%) it oozed out maximum resin yield (149.01 g/year) shown in table 4.20. The total yield of resin in both the years by using Ethephon chemical was 534.03 g from 18 trees (means 267.01 g/year), while in H_2SO_4 the yield obtained was 536.61 g from 18 trees (268.30 g/year) and the combine dose of chemical yielded resin of 1811.49 g from 54 trees (905.74 g/year) as shown in figure 4.15. The yield obtained by using Ethephon chemical was near about equal to the yield obtained in H_2SO_4 treatment. In Maliput, Odisha resin tapping experiment conducted by Swain and Patnaik (1998) by using Rill method and found that diameter class of 30-32 cm give a average yield of 58 g to 69 g /year. As per ICAR-*Pinus kesiya* project (2018-2019) the mean resin yield per borehole varied from 41.36 g to 115 g/tree in 10 months of tapping period. Whereas, in present experiment mean resin yield/tree by using Borehole method varies from 18.62 g to 49.66 g/tree in 3 months of tapping shown in table 4.14. hence it is comparable. Elevation and aspect influence the temperature hence it plays a vital role in yield of resin from any locality. The earlier studies carried out on *Pinus roxburghii* have showed a similar pattern too (Verma,1971;

Prasad and Joshi,1974; Kaushal *et al*., (1984), Persad (1983). The yearly variation in resin yield may be attributed to the difference in temperature and other climatic factors as the period from April to June was found to be hot and dry in Himalayan landscape and from July to September there was a fall in temperature. The total yield of resin by using different methods and chemicals in both the year of tapping are presented in figure 4.16 to 4.19.

Table 4.20. Total and Mean yield of resin/year by using Borehole shape method by using different treatments during the year 2021 and 2022

Treatments	**Total resin yield during 2021 (g)**	**Total resin yield during 2022 (g)**	**Total Yield (g)**	**Mean yield/year (g)**
T1KH	45.3	66.44	111.74	55.87
T2KH	43.19	138.79	181.98	90.99
T3KH	**99.93**	**140.38**	**240.31**	**120.16**
T4KH	**92.73**	**109.49**	**202.22**	**101.11**
T5KH	61.53	82.13	143.66	71.83
T6KH	70.61	120.12	190.73	95.37
T7KH	90.21	112.77	202.98	101.49
T8KH	59.04	67.24	126.28	63.14
T9KH	73.13	62.16	135.29	67.65
T10 KH	**157.92**	**140.09**	**298.01**	**149.01**
T11KH	73.2	94.46	167.66	83.83
T12 KH	61.39	71.89	133.28	66.64
T13KH	146.42	83.96	230.38	115.19
T14KH	120.79	127.46	248.25	124.13
T15 KH	85.2	184.16	269.36	134.68
	1280.59	1601.54	2882.13	96.07

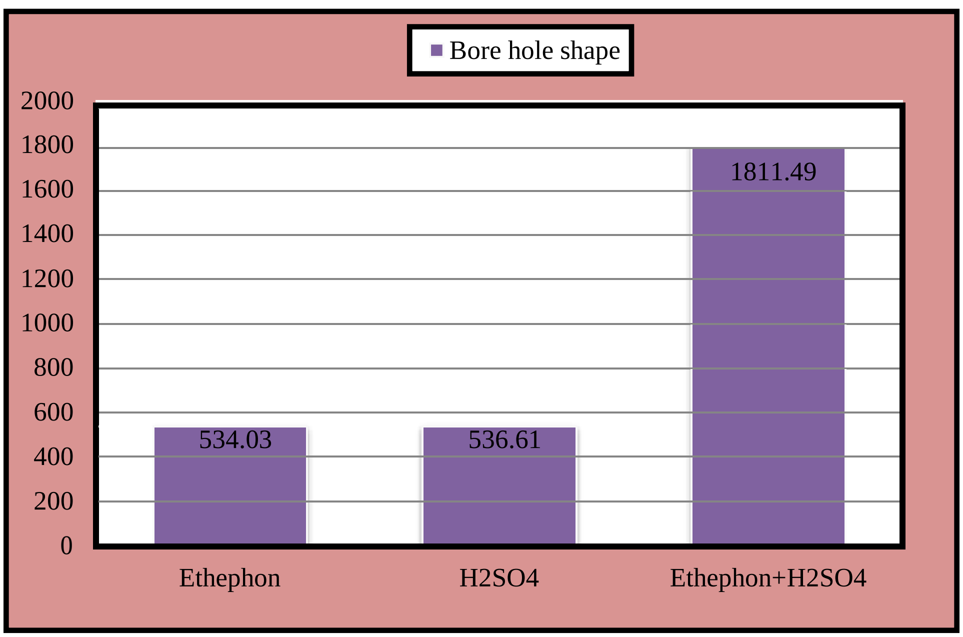


Fig- 4.15.Total yield of resin by using various chemical in Borehole method of tapping during the year 2021-2022

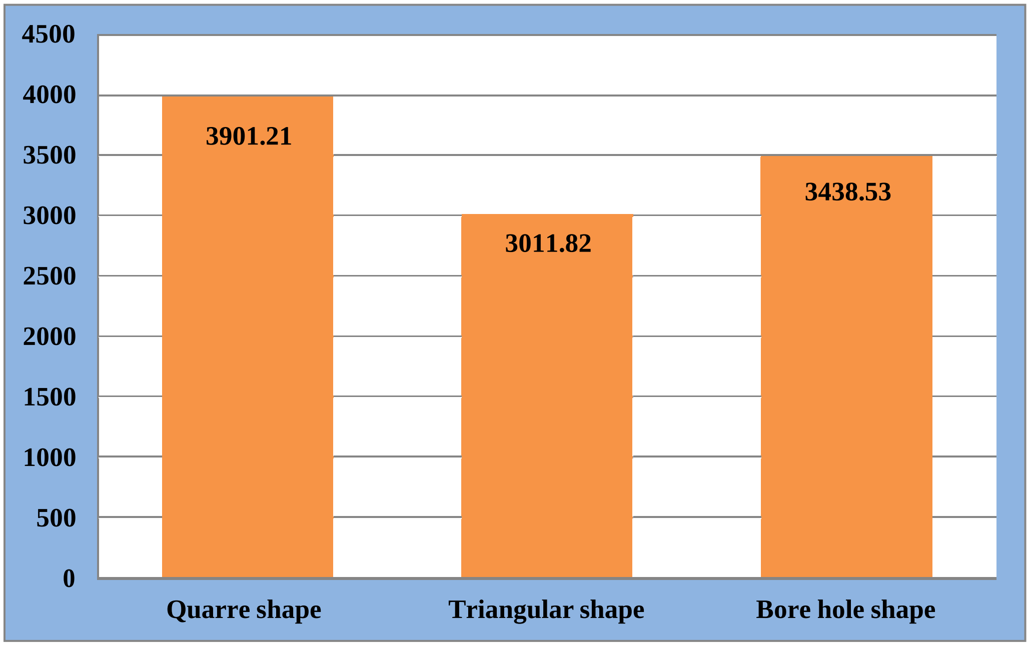


Figure 4.16 Total yield of resin (g) by using different methods of tapping in both the year

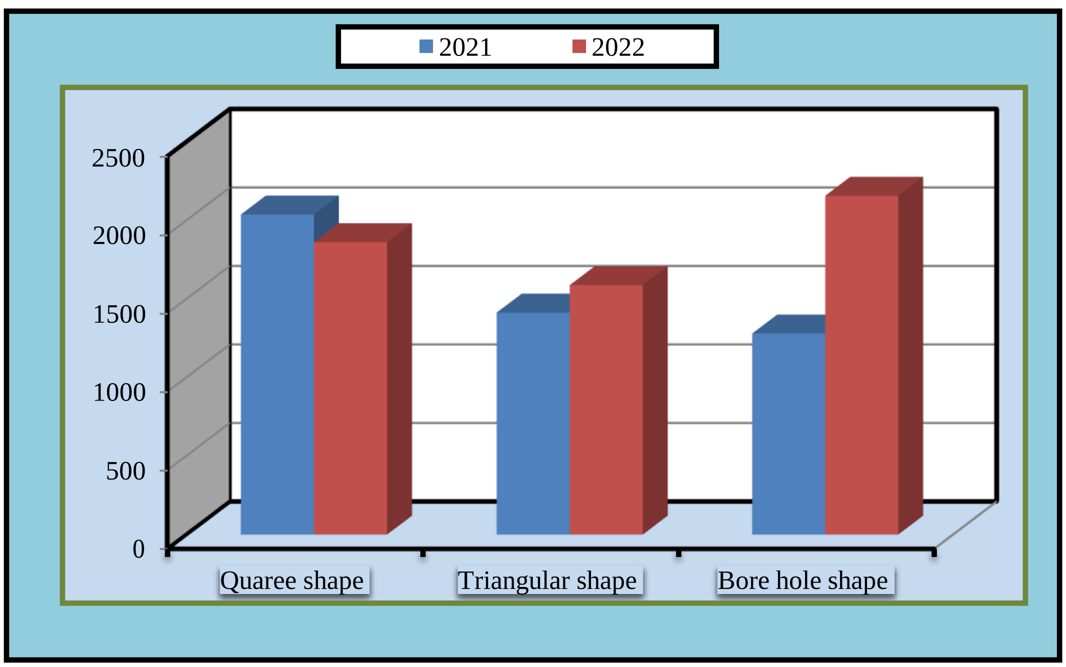


Figure 4.17. Comparison of resin yield by using different chemicals in different shape in both the years

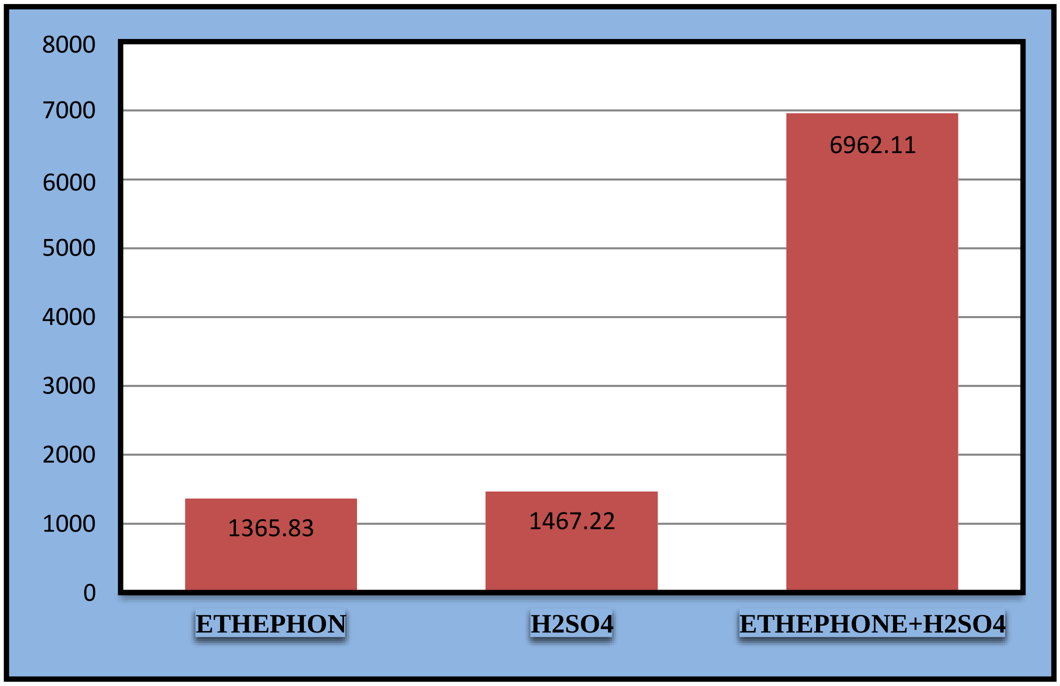


Figure 4.18. Comparison of resin yield(g) by using different Chemicals in both the years

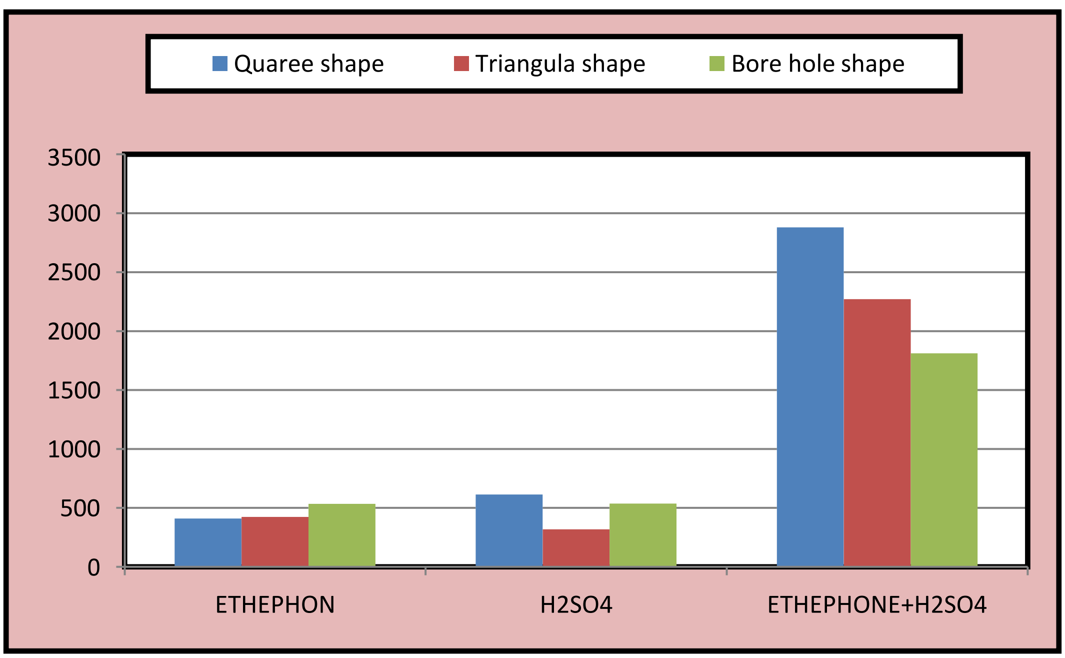


Figure 4.19 Comparison of resin yield by using different chemicals in different shape in both the years

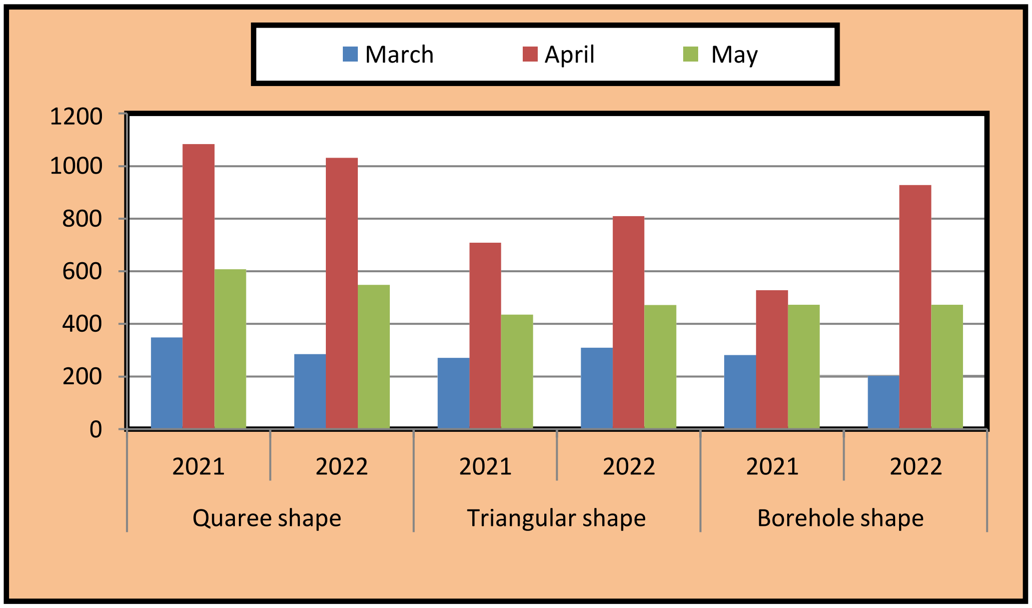


Figure 4.20. Comparison of month wise resin exudation from *Pinus kesiya* in both the yearTable 4.21. - Month wise resin exudation from *Pinus kesiya* in each year

	Year of tapping	March	April	May	Total yield (g)
Temperature	**2021**				
Maximum		**35**	**38**	**35**	
Minimum		**22**	**25**	**25**	
Rh (%)	**2021**				
Maximum		**22**	**17**	**44**	
Minimum		**10**	**7**	**21**	
Temperature	**2022**				
Maximum		**39**	**45**	**41**	
Minimum		**19**	**25**	**26**	
Rh (%)	**2022**				
Maximum		**17**	**15**	**16**	
Minimum		**11**	**9**	**10**	
Quarre shape	**2021**	**348.49**	**1083.1**	**606.78**	**2038.37**
	2022	**285.1**	**1030.46**	**547.28**	**1862.84**
Triangular shape	**2021**	**270.48**	**708.74**	**434.58**	**1413.8**
	2022	**308.78**	**809**	**471.24**	**1589.02**
Borehole shape	**2021**	**280.77**	**528.02**	**471.81**	**1280.59**
	2022	**201.75**	**927.2**	**472.59**	**1601.54**

4.12. Statistical analysis

All the methods used for resin tapping in *Pinus kesiya* having significant difference at 5 % level. In Quarre method of tapping highest resin yield/tree (90.44 g/tree/90 days) was obtained in T14 KQ treatment (Ethephon 30%+H_2SO_4 15%) which was statistically at par with T13 KQ (Ethephon 30% + H_2 SO_4 10%) with the yield of 87.66 g/tree. Whereas, in triangular method of tapping highest yield (86.35 g/tree) was obtained in T11KT treatment which is statistically different from T14KT treatment (Ethephon 30%+ H_2SO_4 15%) @ 48.57 g/tree. Similarly in Borehole method of tapping highest resin yield /tree was obtained in T10 KH treatment (Ethephon 20%+ H_2SO_4 10%) which was statistically at par with T15 KH (Ethephon 30% + H_2SO_4 20%) @ 44.89 g/tree, followed by T14 KH @ 41.38 g/tree.

.

Table4.22. Statistical analysis of resin yield in *Pinus kesiya*

Treatments	**Mean yield(g)**	**Treatments**	**Mean yield(g)**	**Treatments**	**Mean yield(g)**
T1KQ	18.57	T1KT	20.97	T1KH	18.62
T2KQ	22.27	T2KT	24.43	T2KH	37.93
T3KQ	27.36	T3KT	25.04	T3KH	40.05
T4KQ	28.00	T4KT	15.99	T4KH	33.70
T5KQ	31.07	T5KT	15.14	T5KH	23.94
T6KQ	43.19	T6KT	21.71	T6KH	31.79
T7KQ	52.46	T7KT	19.27	T7KH	33.83
T8KQ	38.79	T8KT	56.89	T8KH	21.05
T9KQ	29.12	T9KT	47.55	T9KH	22.55
T10 KQ	30.55	T10 KT	34.14	T10 KH	49.67
T11KQ	35.76	T11KT	86.35	T11KH	27.94
T12 KQ	41.73	T12 KT	27.07	T12 KH	22.21
T13KQ	87.66	T13KT	21.64	T13KH	38.40
T14KQ	90.44	T14KT	48.57	T14KH	41.38
T15 KQ	73.25	T15 KT	35.72	T15 KH	44.89
SE(m) ±	2.58	SE(m) ±	2.46	SE(m) ±	2.75
SE(d)	3.65	SE(d)	3.48	SE(d)	3.89
CD(p=0.05)	7.46	CD(p=0.05)	7.12	CD(p=0.05)	7.94

4.13. Effect of Chemical treatments of on different methods and rate of resin exudation (g) in *Pinus patula* during year 2021.

Trees with a diameter of 30-45 cm were chosen for resin tapping in this species, with 15 trees selected in each of the diameter classes of 30-35 cm, 35-40 cm, and 40-45 cm respectively. Among all three methods used for resin tapping in *Pinus patula* triangular method was found most suitable due to the average resin yield per tree in first year obtained was highest in T5 PT (H_2SO_4 15%) treatment and the yield was 162.56 g/tree, whereas, in Quarre method of tapping maximum yield was obtained in T8PQ (Ethephon 10%+ $H_2SO_4$15%) treatment @ 48.29 g/tree and in Borehole method of tapping maximum yield was obtained in T14PH (Ethephon 30%+ H_2SO_4 15%) treatment @ 44.64 g/tree shown in table 4.23. From this observation it was confirmed that triangular method of tapping with the use of sulfuric acid yielded much effective quantity of resin in this above species. While in other species tried for resin tapping in the current experiment the maximum yield was obtained in combined dose of Ethephon and Sulfuric acid, but in the *Pinus patula* tree maximum yield was obtained by using only Sulfuric acid with 15% concentration. In the year of 2021 tapping was done in Chakratiarth area (P-231 compartment) which was more exposed to sunlight as compared to other areas where more *Pinus patula* trees were present and those trees selected for tapping with 15 % concentration of Sulfuric acid are more vigor in shape and size. Similar kind of finding was also reported by Tadessee*et al.* (2001) in Central Spain where they selected both superior candidate trees and control trees of *Pinus pinaster* for resin tapping. In their two years of experiment, they found that average resin production of 7.2 kg/tree/year in candidate trees where as in control trees it was only 3.7 kg/tree/year. In triangular method of tapping tapped surface area is increases, many researchers also reported that resin yield increases if greater volume of resinous woody tissue affected,thus more number of resin canals are opened for oleoresin flow therefore resin yield increases. Nebeker *et al*. (1995) in Lodgepole pine and Hodges (1995) in slash pine also reported the increase in oleoresin yield in size of surface area tapped. Similarly, Sharma (1982) reported that oleoresin yield has increased up to 10 cm width of blaze in Chir pine. The total resin yield obtained in *Pinus patula* in the year 2021 was 4008.55 g (4.0 kg) in three different methods of tapping.

Table. 4.23 Treatments and diameter class wise resin yield from *Pinus patula* during 2021

Treatments	Diameter classes	R1	R2	R3	total yield(g)	Mean yield/Tree(g)
Quarre shape method						
T1PQ	II	15.79	16.57	17.98	50.34	16.78
T2PQ	II	20.42	22.92	27.8	71.14	23.71
T3PQ	III	29.86	30.98	26.81	87.65	29.22
T4PQ	III	16.39	18.07	20.41	54.87	18.29
T5PQ	II	18.42	18.76	19.09	56.27	18.76
T6PQ	IV	17.93	16.43	18.97	53.33	17.78
T7PQ	II	16.28	19.05	18.89	54.22	18.07
T8PQ	**III**	**47.92**	**49.09**	**47.87**	**144.88**	**48.29**
T9PQ	III	27.09	26.23	29.8	83.12	27.71
T10 PQ	III	26.67	24.23	28.4	79.3	26.43
T11PQ	IV	32.98	33.09	35.67	101.74	33.91
T12 PQ	IV	22.72	25.98	24.89	73.59	24.53
T13PQ	IV	38.89	41.64	48.9	129.43	43.14
T14PQ	III	47.09	49.34	47.98	144.41	48.14
T15 PQ	IV	28.08	27.28	29.69	85.05	28.35
Triangular shape method						
T1PT	**IV**	16.92	18.78	15.32	51.02	17.01
T2PT	II	34.21	30.89	32.76	97.86	32.62
T3PT	III	36.42	37.90	35.66	109.98	36.66
T4PT	II	17.32	16.03	19.08	52.43	17.48
T5PT	**IV**	**168.85**	**158.12**	**160.71**	**487.68**	**162.56**
T6PT	III	16.39	19.06	21.87	57.32	19.11
T7PT	IV	23.20	25.76	24.55	73.51	24.50
T8CPT	II	25.36	28.87	25.09	79.32	26.44
T9PT	IV	16.78	18.56	15.09	50.43	16.81
T10 PT	IV	24.85	25.01	26.92	76.78	25.59
T11PT	II	26.78	29.89	27.45	84.12	28.04
T12 PT	II	38.58	40.87	37.89	117.34	39.11
T13PT	III	24.36	26.66	26.34	77.36	25.79
T14PT	IV	40.57	47.65	38.44	126.66	42.22
T15 PT	III	24.96	19.78	31.97	76.71	25.57
Borehole shape method						
T1PH	III	18.39	22.98	20.32	61.69	20.56
T2PH	III	25.58	20.22	29.03	74.83	24.94
T3PH	III	18.75	20.45	22.36	61.56	20.52
T4PH	V	22.69	24.9	21.67	69.26	23.09
T5PH	II	26.66	29.97	27.99	84.62	28.21
T6PH	VI	37.84	39.45	37.22	114.51	38.17
T7PH	I	16.75	18.56	16.22	51.53	17.18
T8PH	III	16.89	15.02	19.78	51.69	17.23
T9PH	IV	16.92	18.55	20.16	55.63	18.54
T10 PH	II	17.09	20.11	17.9	55.1	18.37
T11PH	IV	17.28	20.43	18.44	56.15	18.72
T12 PH	V	17.95	19.56	18.99	56.5	18.83
T13PH	IV	20.86	21.26	22.67	64.79	21.60
T14PH	**III**	**43.72**	**45.98**	**44.23**	**133.93**	**44.64**
T15 PH	IV	40.96	45.78	42.16	128.9	42.97
PQ-Patula Quaree shape, PT-Patula Triangular shape, PH-Patula borehole shape						

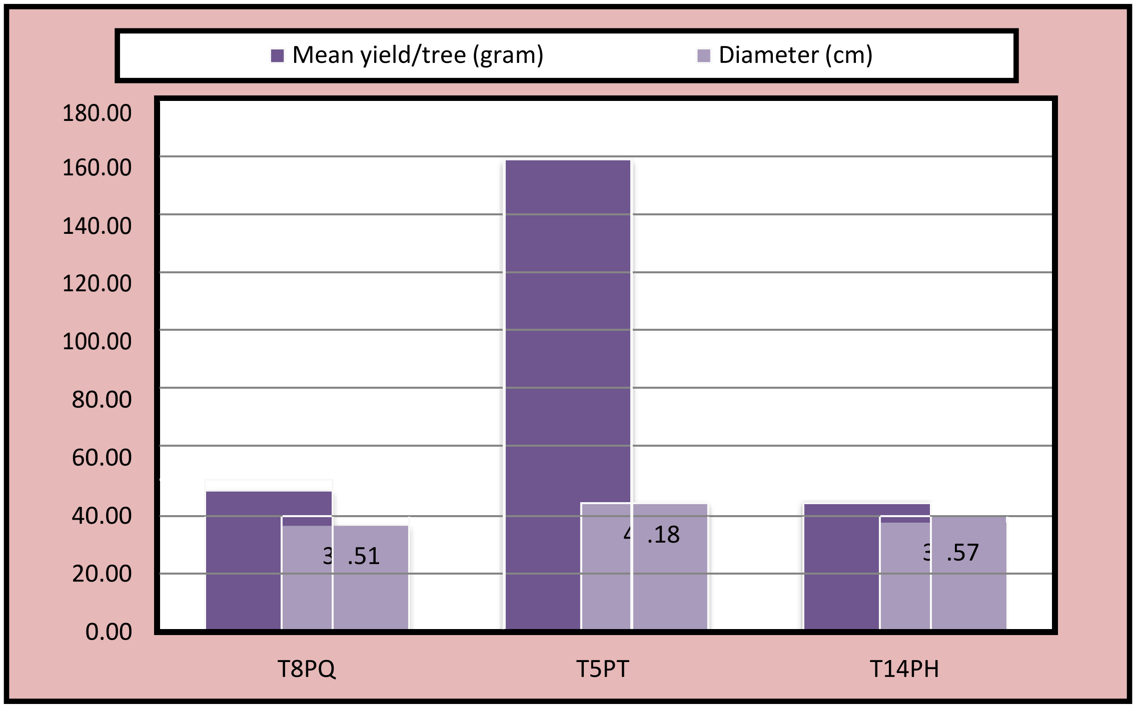


Figure 4.21. ***Pinus patula*** **tree with the highest resin output in 2021 by using different method.**

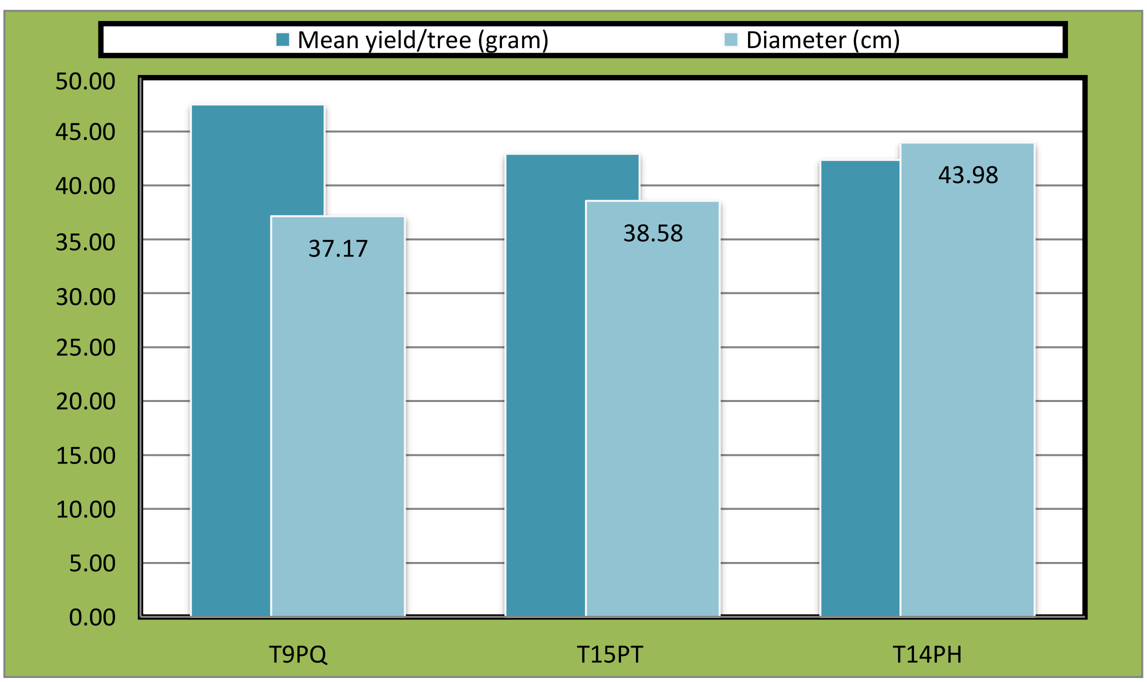


Figure 4.22. ***Pinus patula*** **tree with the highest resin output in 2022 by using different method.**

4.14. Effect of Chemical treatments of on different methods and rate of resin exudation (g) in *Pinus patula* during year 2022

During the resin taping in the year 2022, Quarre method of tapping yielded highest resin yield /tree as compared to other method used. Out of three methods of tapping resin yield /tree was found to be highest in Quarre method i.e. 47.52 g/tree by using T9PQ treatment, followed by 42.95 g/tree by using T15 PT treatment, while in Borehole method of tapping highest yield was obtained in T15PH treatment with highest yield/tree which was 42.38g presented in table 4.24. The total yield obtained during the year 2022 was 3731.44 g (3.7 kg). From this observation it was confirmed that Quarre method of tapping with diameter class of III (35-40 cm) was much effective for sustainable harvesting of resin in this species. While in previous year (2021) of tapping the highest yield was obtained in 35- 40 cm diameter classes trees and in the present year (2022) highest yield /tree was obtained in the similar diameter class trees. Similarly, in Previous year of tapping highest yield was obtained by using only 15% concentration of Sulfuric acid but in 2022 the highest yield was found in combine dose of Ethephon and Sulfuric acid (Ethephon 10%+ H_2SO4 15%). It was observed that trees having longitudinal fissures yielded lesser resin, whereas trees having clear and straight bole yielded more resin yield. The resin production rises when the bark fissures and the crown branching become denser (Konovalov and Machalov, 1978). It is clear from the Table 4.32 that the maximum temperature in the month of April is positively and highly correlated with the evapo-transpiration which suggests that if there is increase in temperature then there will be increase in evapotranspiration thus enhancing resin yield. The total resin yield obtained in the second year of tapping in three different methods was 3731.44 g.

Table 4.24. Treatments and diameter class wise resin yield in *Pinus patula* during 2022

Treatments	Dia classes	R1	R2	R3	Total Yield(g)	Mean Yield(g)
Quarre shape method						
T1PQ	II	12.88	16.9	17.78	47.56	15.85
T2PQ	II	24.47	19	26.45	69.92	23.3
T3PQ	III	39.67	20.17	25.14	84.98	28.32
T4PQ	III	19.94	28.84	23.54	72.32	24.1
T5PQ	II	14.39	20.47	18.45	53.31	17.77
T6PQ	IV	19.66	22.35	27.79	69.8	23.26
T7PQ	II	20.77	29.09	25.69	75.55	25.18
T8PQ	II	21.39	19.55	27.43	68.37	22.79
T9PQ	**III**	**57.17**	**45.95**	**39.44**	**142.56**	**47.52**
T10 PQ	III	24.57	19.57	18.4	62.54	20.84
T11PQ	IV	31.33	16.08	45.08	92.49	30.83
T12 PQ	IV	26.22	28.69	18.19	73.1	24.36
T13PQ	IV	48.6	21.45	28.34	98.39	32.79
T14PQ	III	35.69	39.64	27.18	102.51	34.17
T15 PQ	IV	20.66	37.42	42.19	100.27	33.42
Triangular shape method						
T1PT	**IV**	9.22	16.12	11.49	36.83	12.27
T2PT	II	29.06	27.19	36.26	92.51	30.83
T3PT	III	39.89	27.7	30.16	97.75	32.58
T4PT	II	27.11	17.78	12.29	57.18	19.06
T5PT	III	45.46	32.09	43.32	120.87	40.29
T6PT	III	13.39	22.06	25.87	61.32	20.44
T7PT	IV	29.87	19.44	27.69	77	25.67
T8PT	II	25.22	22.56	21.98	69.76	23.25
T9PT	IV	21.43	23.67	18.55	63.65	21.21
T10 PT	IV	24.85	25.11	26.92	76.88	25.62
T11PT	II	18.36	23.78	25.26	67.4	22.46
T12 PT	II	34.55	17.94	21.28	73.77	24.59
T13PT	III	20.66	17.89	29.23	67.78	22.59
T14PT	IV	45.57	39.55	28.44	113.56	37.85
T15PT	**III**	**32.58**	**56.48**	**39.79**	**128.85**	**42.95**
Borehole shape method						
T1PH	III	28.05	16.75	19.54	64.34	21.44
T2PH	IV	43.28	26.66	34.43	104.37	34.79
T3PH	II	22.15	28.95	24.16	75.26	25.08
T4PH	III	42.97	34.8	25.92	103.69	34.56
T5PH	IV	34.77	25.05	37.78	97.6	32.53
T6PH	II	34.87	49.26	32.16	116.29	38.76
T7PH	II	26.79	28.9	22.44	78.13	26.04
T8PH	III	19.67	17.66	29.45	66.78	22.26
T9PH	IV	34.92	28.15	30.19	93.26	31.08
T10 PH	IV	17.51	20.9	27.98	66.39	22.13
T11PH	III	17.18	29.73	18.04	64.95	21.65
T12 PH	II	37.68	29.18	18.69	85.55	28.51
T13PH	II	20.06	29.99	24.07	74.12	24.7
T14PH	III	23.97	55.08	24.73	103.78	34.59
T15 PH	**IV**	**38.79**	**49.8**	**38.56**	**118.15**	**42.38**
PQ-Patula Quaree shape, PT-Patula Triangular shape, PH-Patula borehole shape						

4.15. Different Methods and Chemical concentration wise Pooled analysis of data per tree yield of resin during 2021 and 2022

4.15.1 Effect of Combined dose of Chemicals concentration

The pooled analysis of effects of chemical tapping by using three different shape of incision and the quantity of resin exudation in *Pinus patula* is presented in Table number 4.25 and 4.26 The pooled data showed the effects of combine dose of chemical concentration used for tapping, which was significantly higher andwas obtained in Quarre (31.69 g/tree) followed by Triangular (27.79 g/tree) and minimum yield was obtained in borehole method (26.02 g/tree). Among the Quarre method of tapping chemical stimulants of T14 PQ (Ethephon 30%+$H_2SO_4$15%) treatment the yield was 41.15g/tree and lowest yield obtained in T7PQ treatment @ 21.63 g/tree by using Ethephon 10%+H_2SO_4 10%. While, using Triangular method of tapping the highest yield was recorded in T14 PT (Ethephon 30%+ H_2SO_4 20%) treatment @ 40.04 g/tree and minimum yield was obtained in T9 PT (Ethephon 10%+ H_2SO_4 20%) treatment @ 19.01 g/tree. However, among all the three methods of tapping in *Pinus patula*, the Borehole method of tapping yielded lowest resin than other methods. Among the borehole method of tapping in *Pinus patula* maximum resin yield was obtained in T15 PH (Ethephon 30%+ H_2SO_4 20 %) treatment @ 42.68 g/tree and minimum yield was collected from T8PT (Ethephon 10%+H_2SO_4 15%) treatment @ 19.75 g/tree. In both the year of tapping by using all three method of tapping highest resin yield was obtained in Triangular method (31.37 g/tree) followed by Quarre (27.58 g/tree) a minimum yield obtained in borehole method (27.03 g/tree) as shown in figure4.26.This figure depicted resin yield from 90 trees in each method of tapping.

4.15.2 Effect of H_2SO_4:

Among the single doses of Sulfuric acid used for resin tapping, the Triangular method of tapping yielded highest resin yield of (46.49 g/tree), which is followed by borehole method (32.55 g/tree) and minimum yield (19.99 g/tree) was obtained in by Quarre method presented in table 4.26. The mean yield /tree by using H_2SO_4 in all three shapes used for tapping from 54 trees was 33.01 g/tree shown in figure 4.28.

4.15.3 Effect of Ethephon

Among the single doses of Ethephon used for resin tapping, the Triangular method of tapping yielded highest resin 27 g/tree, followed by borehole (24.56 g/tree) and minimum (22.87 g/tree) was observed in Quarre method of tapping. The mean yield/tree (total 54 trees) by using ethephon was 24.81 g/tree, shown in figure 4.28.

4.16. Diameter class wise resin exudation (in gram) in *Pinus patula* (mean yield/tree)

It was found that diameter class ranges from 35-40 cm yielded highest resin yield in *Pinus patula* shown in table 4.27. Trees having diameter less than 35 cm and more than 45 cm doesnot produced significant quantity of resin. Among all the method tried the mean yield per tree was found highest (47.96 g/tree) tin triangular method of tapping with the above mentioned diameter class, followed by Quarre method of tapping (43.27 g/tree) and minimum yield was obtained in borehole (38.58 g /tree). Tehsome (2011) reported that diameter class of 25-30 cm yielded maximum resin for *Pinus patula* in Ethipoia. The growth pattern (diameter and height) of *Pinus patula* trees was considerably lower in the present study sites as compared to the other two species. This could be because this species is not native to India and cannot achieve better growth due to various local conditions.

Table 4.25. Pooled average data on effect of Chemical treatments on tapping and quantity of resin exudation in *Pinus patula* (gram/tree)

Treatments number	Treatments details	Average resin yield (in gram) during 2021	Average resin yield(g) during 2022	Mean yield/tree
T1PQ	Ethephon10%	16.78	15.85	16.32
T2PQ	Ethephon 20%	23.71	23.31	23.51
T3PQ	Ethephon 30%	29.22	28.33	28.77
T4PQ	Sulfuric acid10%	18.29	24.11	21.20
T5PQ	Sulfuric acid 15%	18.76	17.77	18.26
T6PQ	Sulfuric acid 20%	17.78	23.27	20.52
T7PQ	Ethephon 10 % + 10 % Sulfuric acid	18.07	25.18	21.63
T8PQ	Ethephon 10 % + 15 % Sulfuric acid	48.29	22.79	35.54
T9PQ	Ethephon 10 % + 20 % Sulfuric acid	27.71	47.52	37.61
T10 PQ	Ethephon 20% + 10 % Sulfuric acid	26.43	20.85	23.64
T11PQ	Ethephon 20% + 15 % Sulfuric acid	33.91	30.83	32.37
T12 PQ	Ethephon 30 % + 20 % Sulfuric acid	24.53	24.37	24.45
T13PQ	Ethephon 30 % + 10 % Sulfuric acid	43.14	32.80	37.97
T14PQ	**Ethephon 30 % + 15 % Sulfuric acid**	**48.14**	**34.17**	**41.15**
T15 PQ	Ethephon 30 % + 20 % Sulfuric acid	28.35	33.42	30.89
Triangular method				
T1PT	Ethephon10%	17.01	12.28	14.64
T2PT	Ethephon 20%	32.62	30.84	31.73
T3PT	Ethephon 30%	36.66	32.58	34.62
T4PT	Sulfuric acid10%	17.48	19.06	18.27
T5PT	**Sulfuric acid 15%**	**162.56**	**40.29**	**101.43**
T6PT	Sulfuric acid 20%	19.11	20.44	19.77
T7PT	Ethephon 10 % + 10 % Sulfuric acid	24.50	25.67	25.09
T8PT	Ethephon 10 % + 15 % Sulfuric acid	26.44	23.25	24.85
T9PT	Ethephon 10 % + 20 % Sulfuric acid	16.81	21.22	19.01
T10 PT	Ethephon 20% + 10 % Sulfuric acid	25.59	25.63	25.61
T11PT	Ethephon 20% + 15 % Sulfuric acid	28.04	22.47	25.25
T12 PT	Ethephon 30 % + 20 % Sulfuric acid	39.11	24.59	31.85
T13PT	Ethephon 30 % + 10 % Sulfuric acid	25.79	22.59	24.19
T14PT	Ethephon 30 % + 15 % Sulfuric acid	42.22	37.85	40.04
T15PT	Ethephon 30 % + 20 % Sulfuric acid	25.57	42.95	34.26
Borehole method				
T1PH	Ethephon10%	20.56	21.45	21.01
T2PH	Ethephon 20%	24.94	34.79	29.87
T3PH	Ethephon 30%	20.52	25.09	22.80
T4PH	Sulfuric acid10%	23.09	34.56	28.83
T5PH	Sulfuric acid 15%	28.21	32.53	30.37
T6PH	Sulfuric acid 20%	38.17	38.76	38.47
T7PH	Ethephon 10 % + 10 % Sulfuric acid	17.18	26.04	21.61
T8PH	Ethephon 10 % + 15 % Sulfuric acid	17.23	22.26	19.75
T9PH	Ethephon 10 % + 20 % Sulfuric acid	18.54	31.09	24.82
T10 PH	Ethephon 20% + 10 % Sulfuric acid	18.37	22.13	20.25
T11PH	Ethephon 20% + 15 % Sulfuric acid	18.72	21.65	20.18
T12 PH	Ethephon 30 % + 20 % Sulfuric acid	18.83	28.52	23.68
T13PH	Ethephon 30 % + 10 % Sulfuric acid	21.60	24.71	23.15
T14PH	Ethephon 30 % + 15 % Sulfuric acid	44.64	34.59	39.62
T15 PH	Ethephon 30 % + 20 % Sulfuric acid	42.97	42.38	42.68

Table 4.26 Resin yield per tree (g) by using various chemicals and methods in *Pinus patula*

Methods of tapping	Ethephone	H_2SO_4	Ethephone+ H_2SO_4
Quarre shape	22.87	19.99	31.69
Triangular shape	27	**46.49**	27.79
Bore hole shape	24.56	32.55	26.02

Table 4.27. Diameter class wise resin exudation (g) in *Pinus patula*

Diameter class and methods	2021			2022			Mean yield/tree(g)
Quarre shape method	Number of trees selected	Total yield(g)	Mean yield/tree	Number of trees selected	Total yield(g)	Mean yield/tree	
II(30-35)	15	185.09	12.33	15	231.11	15.40	13.87
III(35-40)	15	695.29	46.35	15	602.98	40.19	43.27
IV(40-45)	15	388.96	25.93	15	379.58	25.30	25.61
Total yield(g)		1269.34			1213.67		
Triangular shape method							
II(30-35)	15	316.05	21.07	15	254.75	16.98	19.02
III(35-40)	15	824.48	54.96	15	587.47	39.16	47.06
IV(40-45)	15	477.59	31.83	15	362.89	24.19	28.01
Total yield(g)		1618.12			1205.11		
Borehole shape method							
II(30-35)	15	202.02	13.46	15	298.73	19.91	16.69
III(35-40)	15	529.29	35.28	15	628.35	41.89	38.58
IV(40-45)	15	389.38	25.95	15	385.58	25.70	25.83
Total yield(g)		1120.69			1312.66		

Table 4.28. Chemical concentrations and resin yield in *Pinus patula* in different methods during 2021 -2022

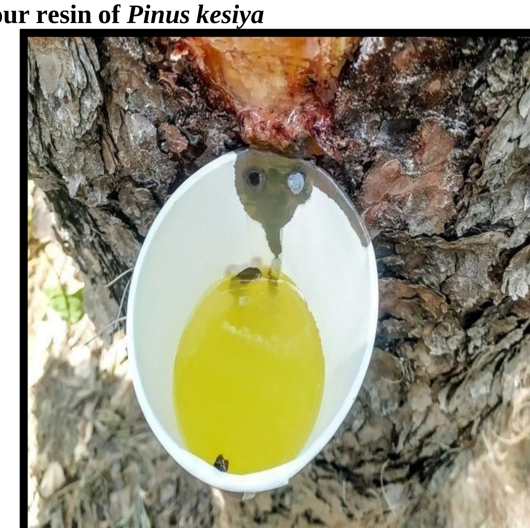
Quarre methods	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
Treatments	T1PQ	T2PQ	T3PQ	T4PQ	T5PQ	T6PQ	T7PQ	T8PQ	T9PQ	T10 PQ	T11PQ	T12 PQ	T13PQ	T14PQ	T15 PQ
2021	50.34	71.14	87.65	54.87	56.27	53.33	54.22	144.88	83.12	79.3	101.74	73.59	129.43	144.41	85.05
2022	47.56	69.92	84.98	72.32	53.31	69.8	75.55	68.37	142.56	62.54	92.49	73.1	98.39	102.51	100.27
total	97.9	141.06	172.63	127.19	109.58	123.13	129.77	213.25	225.68	141.84	194.23	146.69	227.82	246.92	185.32
mean	48.95	70.53	86.315	63.595	54.79	61.565	64.885	106.625	112.84	70.92	97.115	73.345	113.91	123.46	92.66

Triangular method	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
Treatments	T1PT	T2PT	T3PT	T4PT	T5PT	T6PT	T7PT	T8CPT	T9PT	T10 PT	T11PT	T12 PT	T13PT	T14PT	T15 PT
2021	51.02	97.86	109.98	52.43	487.68	57.32	73.51	79.32	50.43	76.78	84.12	117.34	77.36	126.66	76.71
2022	36.83	92.51	97.75	57.18	120.87	61.32	77	69.76	63.65	76.88	67.4	73.77	67.78	113.56	128.85
Total	87.85	190.37	207.73	109.61	608.55	118.64	150.51	149.08	114.08	153.66	151.52	191.11	145.14	240.22	205.56
Mean	43.93	95.19	103.87	54.81	304.28	59.32	75.26	74.54	57.04	76.83	75.76	95.56	72.57	120.11	102.78

Borehole method	E 10 %	E 20 %	E 30 %	H 10 %	H 15 %	H 20 %	E 10 % +H 10 %	E 10 % +H 15 %	E 10 %+H 20 %	E 20 %+H 10 %	E 20 %+ H 15 %	E 20 %+H 20 %	E 30 %+H 10 %	E 30 % +H 15 %	E 30 % +H 20 %
Treatments	T1PH	T2PH	T3PH	T4PH	T5PH	T6PH	T7PH	T8PH	T9PH	T10 PH	T11PH	T12 PH	T13PH	T14PH	T15 PH
2021	61.69	74.83	61.56	69.26	84.62	114.51	51.53	51.69	55.63	55.1	56.15	56.5	64.79	133.93	128.9
2022	64.34	104.37	75.26	103.69	97.6	116.29	78.13	66.78	93.26	66.39	64.95	85.55	74.12	103.78	118.15
Total	126.03	179.2	136.82	172.95	182.22	230.8	129.66	118.47	148.89	121.49	121.1	142.05	138.91	237.71	247.05
mean	63.015	89.6	68.41	86.475	91.11	115.4	64.83	59.235	74.445	60.745	60.55	71.025	69.455	118.855	123.525


Yellow colour resin of *Pinus roxburghii*


Creamy white colour resin of *Pinus kesiya*

Yellowish white color resin of *Pinus patula*

Plate 4.2. Variation in resin colors in different pine

4.17. Total yield of resin by using different incisions and chemical treatments during the year 2021 and 2022.

4.17.1. Effect of different chemicals stimulants on resin yield by using Quarre shape method. (Mean yield/year)

In Quarre shape method of tapping the total yield was obtained from all treatment in both the years was 2483.01 g and total mean yield/Quarre shape/year was 82.76g it was quite interesting to note that the total yield during 2021 was comparatively higher than 2022 as shown in table 4.29. Whereas , in other species it was just opposite. Although average temperature during the year of 2022 was higher than 2021 but the location of trees tapped in 2021 was changed therefore, the aspects was also changed and this causes little bit lesser yield as compared to first year of tapping. The year wise resin yield was found to be highest in Ethephon concentration of 30 % (86.31 g/year), followed by T2 PQ (Ethephon 15%) and minimum yield (48.95 g) was observed in Ethephon 10% concentration. While using H_2SO_4 10% concentration yielded highest resin (63.59 g/year) followed by Ethephon 20 % and minimum yield (54.79 g/year) was observed in 15 % conc of Sulfuric acid. In Quarre method of tapping it was observed that lower conc of Sulfuric acid yielded highest resin as compared to higher conc. The combined doses of chemical concentration (Ethephon 30% + $H_2SO_4$15%) yielded maximum resin yield 123.46 g/year (Table 4.29). The total yield by using Ethephon chemical was 411.59 g from 18 trees (205.79 g/year) while using H_2SO_4 the yield was 359.9 g from 18 trees (179.95 g/year) and the yield obtained by using combine dose was 1711.52 g from 54 trees (855.76 g/year) shown in figure 4.23. From the table number 4.29 it was confirmed that the total yield of resin was found highest in T14PQ treatment (Ethephon 30% + H_2SO_4 15%) the yield was 246.92 g. which is followed by T14 PQ treatment with a yield of 227.282 g and minimum yield was obtained in T7 PQ (Ethephon 10% + H_2SO_4 10 %) treatment having yield of 129.77g.

Table 4.29 Total and mean yield of resin/year in Quarre method in different treatments during 2021 and 2022

Quarre method of tapping	Total resin yield during 2021(g)	Total resin yield during 2022(g)	Total yield(g)	Mean yield/year(g)
T1PQ	50.34	47.56	97.9	48.95
T2PQ	71.14	69.92	141.06	70.53
T3PQ	**87.65**	**84.98**	**172.63**	**86.31**
T4PQ	**54.87**	**72.32**	**127.19**	**63.59**
T5PQ	56.27	53.31	109.58	54.79
T6PQ	53.33	69.8	123.13	61.56
T7PQ	54.22	75.55	129.77	64.88
T8PQ	144.88	68.37	213.25	106.62
T9PQ	83.12	142.56	225.68	112.84
T10 PQ	79.3	62.54	141.84	70.92
T11PQ	101.74	92.49	194.23	97.115
T12 PQ	73.59	73.1	146.69	73.345
T13PQ	129.43	98.39	227.82	113.91
T14PQ	**144.41**	**102.51**	**246.92**	**123.46**
T15 PQ	85.05	100.27	185.32	92.66
	1269.34	1213.67	2483.01	82.76

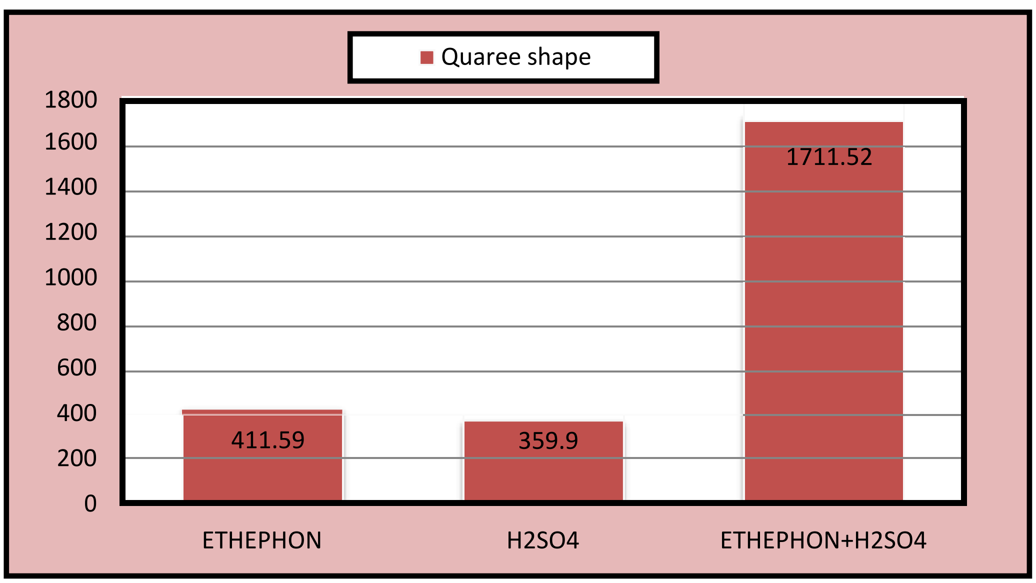


Figure 4.23 Total yield of resin (g) by using various chemicals in Quarre method

4.17.2. Effect of different chemicals on resin yield by using Triangular shape method (Mean yield/year)

In Triangular shape method of tapping the total yield obtained from all the treatment in both the years was 2823.63 g and the total mean yield/Triangular shape/year was 94.12 g. It was quite interesting to note that the total output in 2021 was higher than in 2022, whereas, in other species it was just opposite. Although the average temperature in 2022 was substantially higher than in 2021, the location of trees tapped in 2021 was changed, therefore the aspects also modified, resulting in a slightly lower yield than in the first year of tapping. The total yield in all the treatments by using Ethephon chemical was 485.95g (242.99 g/year), while using $H_2SO_4$the yield was 836.8 g(418.4 g/year) and the yield obtained by using combine dose was 1500.88 g(750.4 g/year) shown in figure 4.24. In Table 4.30 it was confirmed that the total yield of resin was found to be highest in T5PT (15% H_2SO_4) treatment in both the years 2021 and 2022; the mean yield per year was 304.28 g/year, whereas in combine dose of treatment it was maximum in T14 PT (Ethephon 30%+ HSO4 15%) with average yield/year was 120.11g/year; while by using single concentration of Ethephon it found to be maximum in T3 PT with a yield of 103.87 g/year. Resin yield per year by using Ethephon and Sulfuric acid was 242.97 g/year and 418.4 g/year. Snow (1944) found that 50-percent water solution of Sulfuric acid, applied to fresh wounds every two weeks, was most effective treatment for maximizing resin yield in *Pinus palustris* and *Pinus elliottii*. However, in the present experiment Sulfuric acid 15 % conc. was found to be more effective for resin tapping in *Pinus patula* .According to a report published by the United States Patent Office in 1966, sulfuric acid paste was proposed as a generally safe chemical stimulant for extending gum flow up to 28 days. After a while,oleoresin exudation from ducts stops as they become clogged

Water is vital in cellular turgescence, which leads to resin canal obstruction by expanding epithelial cells. Chemical stimulants are sprayed to keep the ducts open for longer periods of time, enabling resins to flow freely. Kossuth (1984), reported that increase in Sulfuric acid concentrations prolonged the resin flow by reducing the turgescence, of epithelial cells due to tapping injury. Increase in resin yield by Sulfuric acid concentration has also been reported by Rajkhowa and Khan (1962), Seth and Lohani (1971), Sheikh (1978). As sulfuric acid is act as a freshner it opens the blocked resin canals therefore the use of both ethephon and sulfuric acid in different concentration species wise concentration changes due to specific species having different anatomical features.

Table 4.30. Total and mean yield of resin/year in Triangular method in different treatments during 2021 and 2022.

Treatments	Total resin yield during 2021(g)	Total resin yield during 2022(in gram	Total yield(g)	Mean yield/year(g)
T1PT	51.02	36.83	87.85	43.93
T2PT	97.86	92.51	190.37	95.19
T3PT	**109.98**	**97.75**	**207.73**	**103.87**
T4PT	52.43	57.18	109.61	54.81
T5PT	**487.68**	**120.87**	**608.55**	**304.28**
T6PT	57.32	61.32	118.64	59.32
T7PT	73.51	77	150.51	75.26
T8CPT	79.32	69.76	149.08	74.54
T9PT	50.43	63.65	114.08	57.04
T10 PT	76.78	76.88	153.66	76.83
T11PT	84.12	67.4	151.52	75.76
T12 PT	117.34	73.77	191.11	95.56
T13PT	77.36	67.78	145.14	72.57
T14PT	**126.66**	**113.56**	**240.22**	**120.11**
T15 PT	76.71	128.85	205.56	102.78
Total yield(g)	1618.52	1205.11	2823.63	94.12

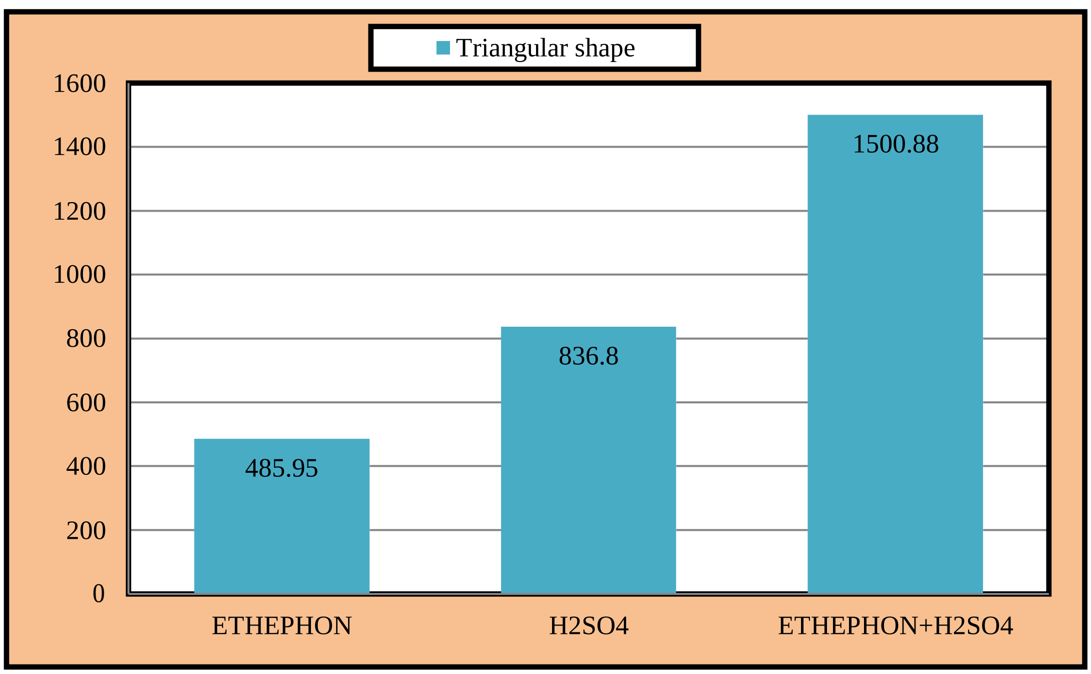


Figure 4.24. Total yield of resin (g) by using various chemicals in Triangular method

4.17.3. Effect of different chemicals on the resin yield by using Borehole shape method (Mean yield/year).

In borehole method of tapping the total yield was obtained from all the treatment in both the years was 2433.35 g and the total mean yield/borehole shape/year was 81.11g. In this method of tapping the resin yield during 2022 was higher than 2021, whereas in other two methods of tapping, resin yield was much higher in 2021. The total yield in all the treatments by using Ethephon chemical was 442.05g(from 18 trees), while using H_2SO_4 the yield was 585.97 g (from 18 trees) and the yield obtained by using combine dose was 1405.33 g(from 54 trees) shown in figure 4.25. From the table number 4.30 it was confirmed by using combine dose of treatment total resin yield per year was found to be highest in T15PH (Ethephon 30% + H_2SO_4 20%) treatment @ 123.53 g/year, followed by T14PH @ 118.86 g/year and minimum quantity off resin yielded in T8PH (Ethephon 10% + H_2SO_4 15%) treatment @ 118.47 g. However, by using single concentration of Ethephon and Sulfuric acid it was found maximum in T2 PH (20% Ethephon) @ 89.60 g/year and T5PH (H_2SO_4 15%) @ 91.11 g/year respectively. Rawat (2000) for *Pinus roxburghii*, Hodges and Johanson (1997) for *Pinus elliottii* reported that 20% Sulfuric acid concentration with Ethephon 10 % concentration yielded highest resin yield. The per year yield of resin by using ethephon and Sulfuric acid was 221.02 g /year and 292.98 g/year, respectively. Whereas, the combine dose of both the chemicals yielded 702.66 g /year. It represents that in Borehole method of tapping both single concentration of ethephon and Sulfuric acid yielded at par resin, while using combine doses of chemicals the yield increases three times. Several workers (Miyamoto *et al.*, 2010; Harsh *et al.*, 2013; Li *et al.*, 2014) also reported that Ethephon (2-chloroethylphosphonic acid) is the most promising compound among gum/resin inducers. The total resin yield during both the year of tapping by using different methods and chemical were shown in figure 4.26 to 4.28, respectively.

Table 4.31. Total and mean yield of resin/year in Borehole method in different treatments during 2021 and 2022

Treatments	Total resin yield during 2021(g)	Total resin yield during 2022(g)	Total yield	Mean yield/year
T1PH	61.69	64.34	126.03	63.02
T2PH	74.83	104.37	179.2	89.60
T3PH	61.56	75.26	136.82	68.41
T4PH	69.26	103.69	172.95	86.48
T5PH	84.62	97.6	182.22	91.11
T6PH	114.51	116.29	230.8	115.40
T7PH	51.53	78.13	129.66	64.83
T8PH	51.69	66.78	118.47	59.24
T9PH	55.63	93.26	148.89	74.45
T10 PH	55.1	66.39	121.49	60.75
T11PH	56.15	64.95	121.1	60.55
T12 PH	56.5	85.55	142.05	71.03
T13PH	64.79	74.12	138.91	69.46
T14PH	133.93	103.78	237.71	118.86
T15 PH	128.9	118.15	247.05	123.53
Total	1120.69	1312.66	2433.35	81.11

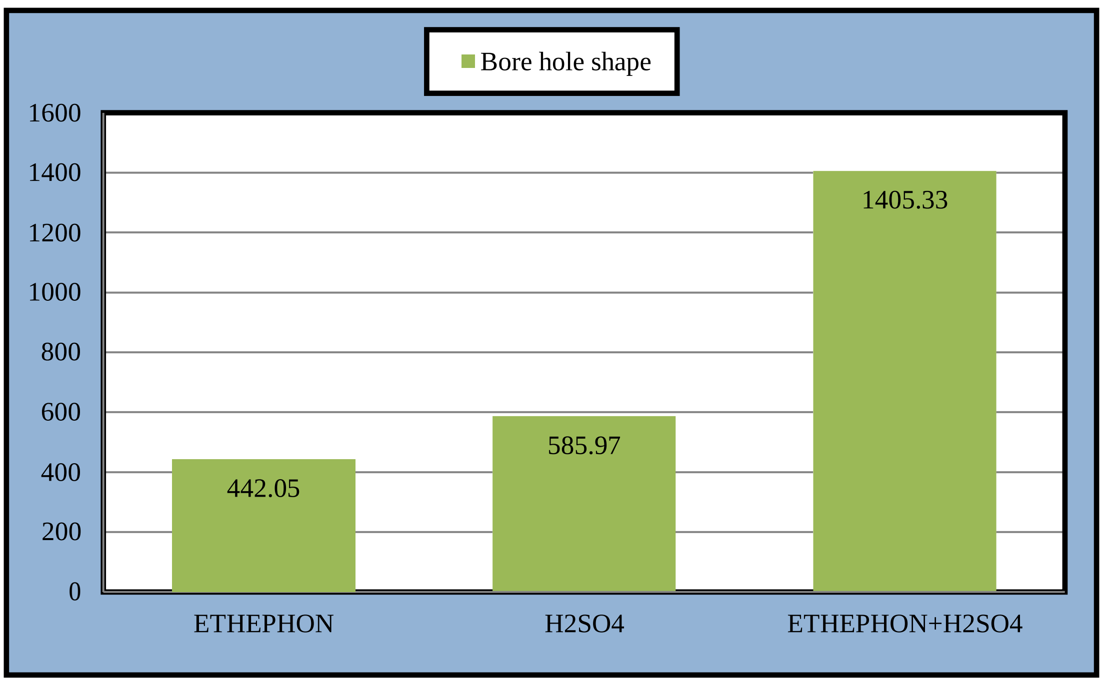


Figure 4.25. Total yield of resin (g) by using various chemicals in Borehole method

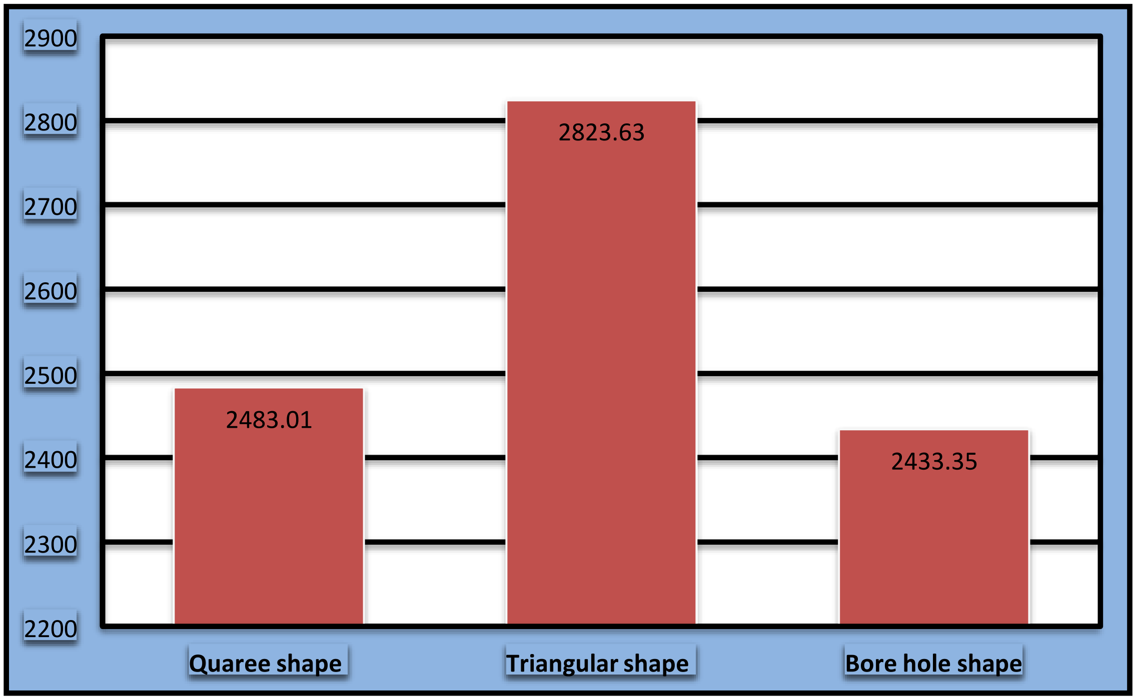


Figure 4.26 Total yield of resin(g) by different methods of tapping during both the year

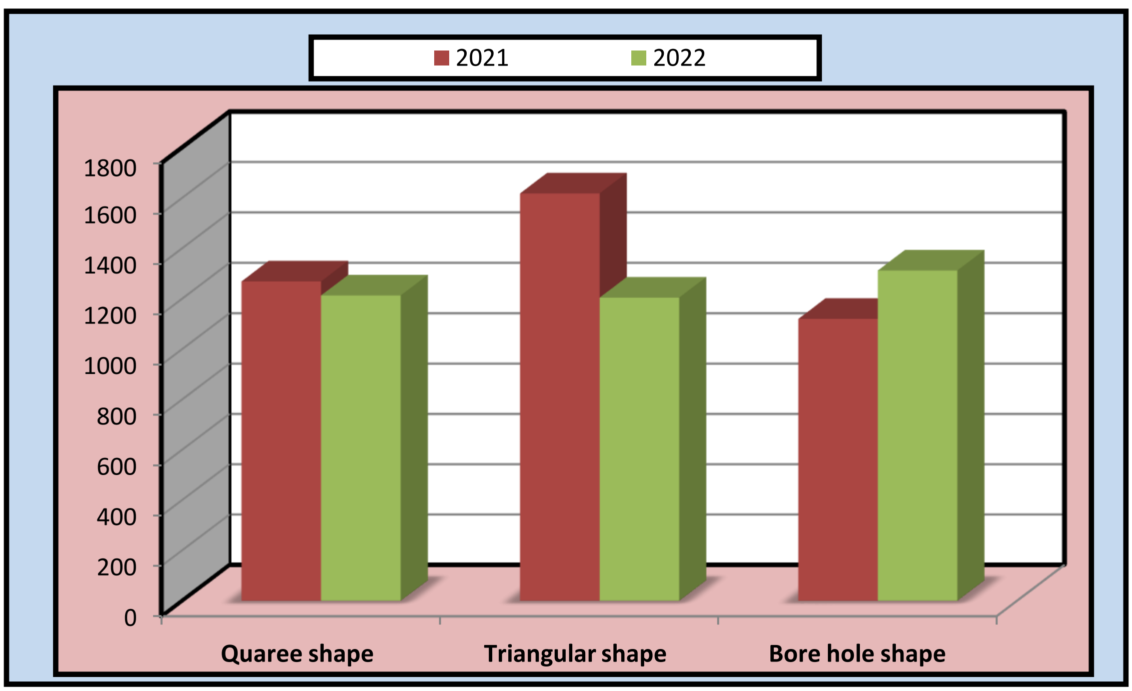


Figure 4.27. Comparison of resin yield by using different methods of tapping during 2021-2022

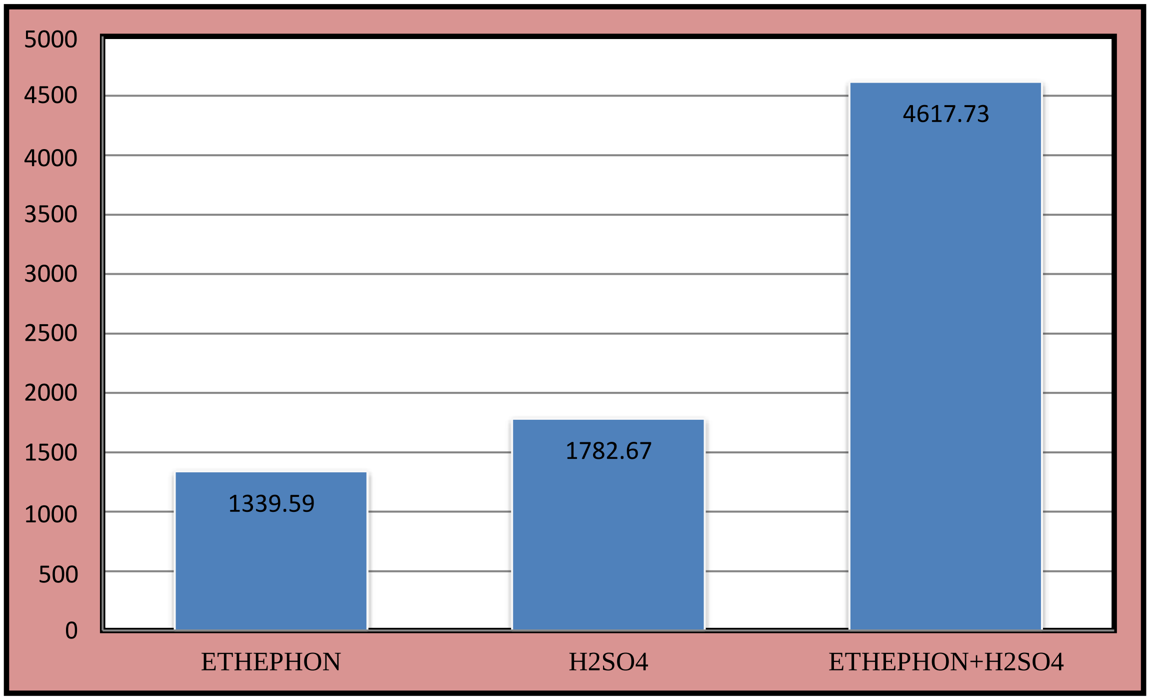


Figure 4.28 Resin yield from trees by using various chemical in 2021-2022

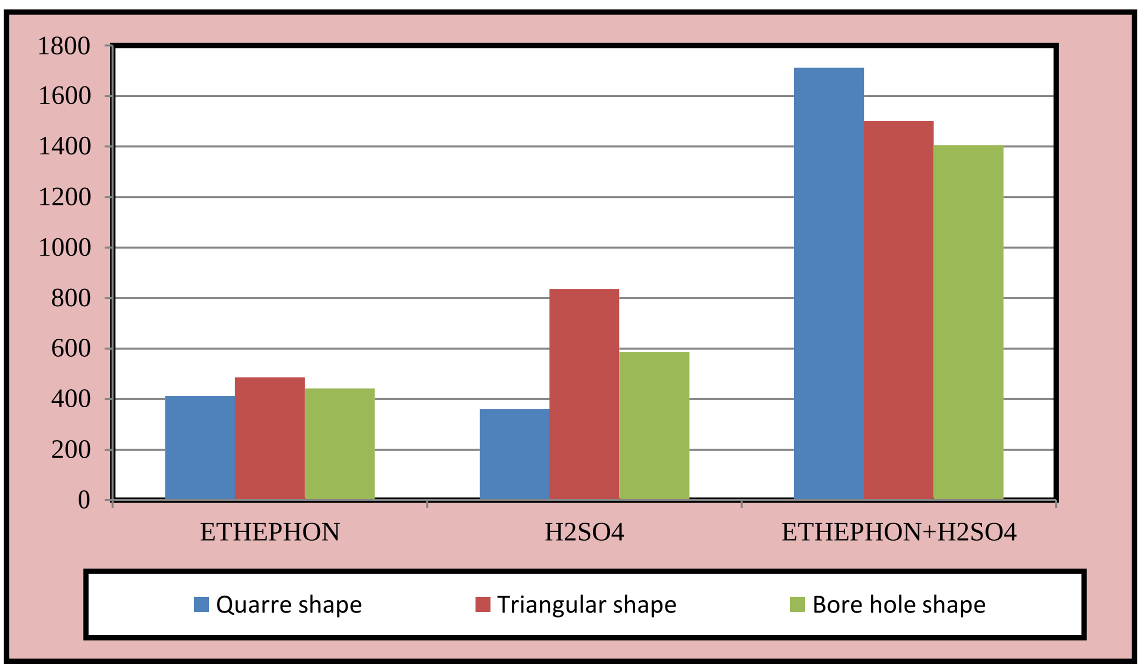


Figure 4.29. Comparison of resin yield by using different chemicals in different shape in both theyears

Table 4.32. Total resin yield obtained in different months

	Year of tapping	March	April	May	Total yield
Temperature	2021				
Maximum		35	38	35	
Minumum		22	25	25	
Rh(%)	2021				
Maximum		22	17	44	
Minumum		10	7	21	
Temperature	2022				
Maximum		39	45	41	
Minumum		19	25	26	
Rh(%)	2022				
Maximum		18	15	12	
Minumum		12	9	10	
Quarre shape	2021	210.14	739.03	320.17	1269.34
	2022	190.66	636.47	386.54	827.13
Triangular shape	2021	304.89	771.04	542.59	1618.52
	2022	285.45	507.11	412.55	1205.11
Borehole shape	2021	195.27	566.77	358.65	1120.69
	2022	245.26	698.63	368.77	1312.66

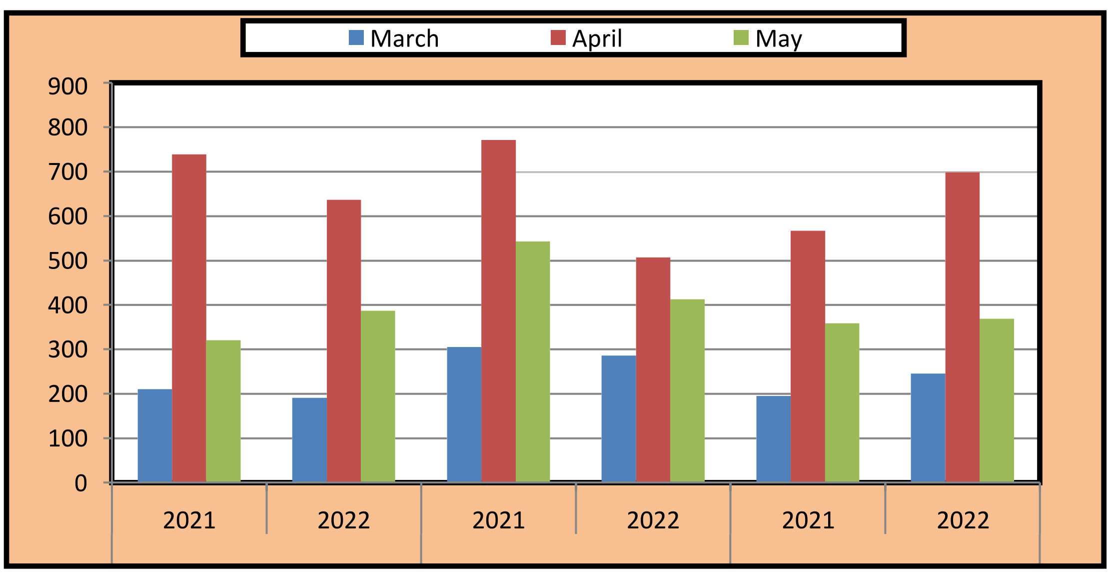


Figure 4.30 Month wise resin yield in *Pinus patula*

4.18 Statistical analysis

In Quarree method of tapping highest resin yield/tree (41.15 g/tree/90 days) was obtained in T14 PQ treatment (E 30%+H 15%) which was statistically at par with T13 PQ (E 30%+ H10%) with a yield of 37.97 g/tree followed by T9PQ @ 37.61 g/tree. Whereas, in triangular method of tapping highest yield was obtained in T5PT treatment with a yield of 101.43 g/tree followed by T14PT treatment (E 30%+H 15%) @ 40.04 g/tree. Similarly, in Borehole method of tapping highest resin yield /tree was obtained in T15 PH (E 30%+H 20%) treatment which was highly significant with a yield of 42.68 g/tree which was statistically at par with T14 PH (E 30%+H 15%) @39.62 g/tree. The highest resin yield/tree was obtained in T15PH treatment (42.68g/tree which was statistically at par with T14 PH treatment (39.62g/tree) and T6PH treatment (38.47 g/tree). Whereas, the lowest resin yield of 19.75 g/tree was recorded in T8PH treatmentwhich was at par with T9PH treatment (24.82g/tree).

Table 4.33 Statistical analysis of resin yield in *Pinus patula*

Treatments	Mean yield(g)	Treatments	Mean yield(g)	Treatments	Mean yield(g)
T1PQ	16.32	T1PT	14.64	T1PH	21.01
T2PQ	23.51	T2PT	31.73	T2PH	29.87
T3PQ	28.77	T3PT	34.62	T3PH	22.80
T4PQ	21.20	T4PT	18.27	T4PH	28.83
T5PQ	18.26	T5PT	**101.43**	T5PH	30.37
T6PQ	20.52	T6PT	19.77	T6PH	38.47
T7PQ	21.63	T7PT	25.09	T7PH	21.61
T8PQ	35.54	T8CPT	24.85	T8PH	19.75
T9PQ	37.61	T9PT	19.01	T9PH	24.82
T10 PQ	23.64	T10 PT	25.61	T10 PH	20.25
T11PQ	32.37	T11PT	25.25	T11PH	20.18
T12 PQ	24.45	T12 PT	31.85	T12 PH	23.68
T13PQ	37.97	T13PT	24.19	T13PH	23.15
T14PQ	**41.15**	T14PT	40.04	T14PH	39.62
T15 PQ	30.89	T15 PT	34.26	T15 PH	**42.68**
SE(m) ±	2.32	SE(m) ±	2.07	SE(m) ±	2.51
SE(d)	3.29	SE(d)	2.92	SE(d)	3.55
CD(p=0.05)	6.71	CD(p=0.05)	5.97	CD(p=0.05)	7.26

4.19. Quality parameters Analysis

The physical parameters were analyzed in the laboratory and explained as follows

4.19.1. Colour and aroma

The *Pinus roxburghii* resin samples obtained from high elevation area like Bhundakona having light yellow in colour and those samples collected from lower elevation having dark yellow in colour, but both the samples contain strong characteristic odour (table 4.34). Lekha (2002) noticed that the resin tapped from *Pinus roxburghii* trees in Himachal Pradesh by using borehole method and rill method of tapping and it was found that resin obtained from rill method are white in colour and resin obtained in rill method of tapping was yellow to dark yellow in colour.

The resin samples of *Pinus kesiya* and *Pinus patula* were having strong camphorlike aroma with creamy white and yellowish white color respectively.

Tabale 4.34. Comparison of Colour and odours of resin samples

	Pinus roxburghii	***Pinus kesiya***	***Pinus patula***
Colour	Light and dark yellow	Cream white	Yellowish white
Aroma	Strong odour	Strong camphor	Strong camphor

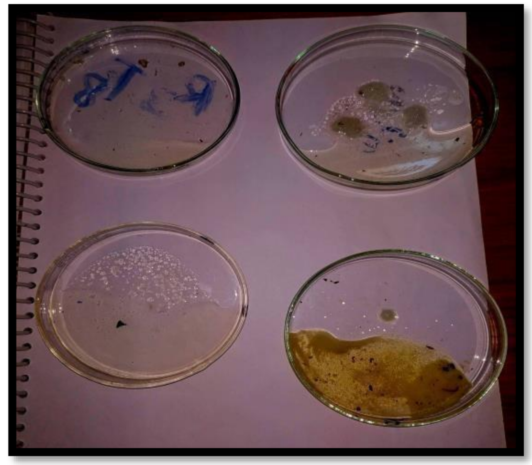
4.19.2 Turpentine and Rosin content.

Singhal (1996) conducted resin tapping experiment in Solan and collected various resin samples across different places of Himachal Pradesh. She found that Turpentine oil content in Chir-pine varies from 17.33 % to 27.05 %, whereas rosin content varies from 71.72 % to 78.72 %. Singh and Ashokan (1986) reported the turpentine oil content in Chir-pine was 18%. In the present experiment the rosin content was comparatively higher (84%) and the turpentine oil content was comparatively lower than of above mentioned earlier study findings. The decrease in turpentine oil concentration in comparison to temperate areas could be due to the fact that the temperature of tropical environment was substantially higher and the collection containers remained open instead of closed and subjected to loss of essential oil content. Sharma (1987), reported that the increase in rosin content with increase in storage period is due to evaporation and oxidation of oleoresin. Bardyshev *et al* (1973) also observed that resin collected at the end of tapping year contained 86.55 % rosin and that collected at every 10-25 days' interval contained 76.35 % rosin. The perusal of present study data depicted the similar observations as the resin collected from the field was processed after (a few weeks stored in the laboratory) therefore, the rosin content was found to be higher.

The oleoresin tapping experiment conducted by Dayal (1986) on *Pinus insularis* (Curently known as *Pinus kesiya*) in Arunachal Pradesh and found that the content of turpentine oil and rosin was 21 % and79%, respectively. Swain and Patnaik (1998) while conducting their experiment at Koraput, Odisha reported that rosin content and turpentine oil content in Khasi pine was 65% and 22.57 %, respectively. The present study observations revealed that the rosin content is found to be higher (82%) than of turpentine oil (18%). However *Pinus patula* resin samples (25g) on distillation gave 8.52% of turpentine oil and 91.48 % of rosins shown in table 4.35 and figure 4.31 . Teshome (2011), observed that diameter class of 25-30 cm produced highest turpentine oil contain.

Table 4.35. Content of Rosin and Turpentine

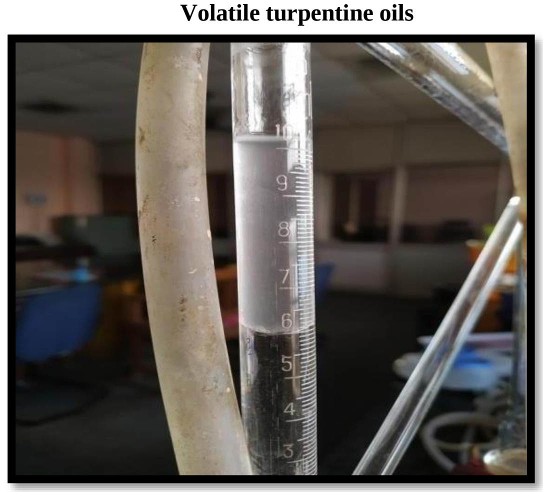
	Pinus roxburghii	*Pinus kesiya*	*Pinus patula*
Turpentine Oil (%)	16	18	8.52
Rosin(%)	84	82	91.48



Weighing of resin samples for estimation of moisture content and Melting of resin resin samples after heating

Rosin content of resin samples

Volatile turpentine oils



Clevengers appartus were used to separate rosin and turpetine oil.

Plate 4.3. Separation of Rosin and turpentine oil in the laboratory

4.19.3 Solubility test

The solubility of resins of different species was determined by using various solvent such, hot water, cold water, acetone, benzene and chloroform. The results obtained are summarized in (Table 4.36). In case of water as solvent, it was found that the all the resin samples were found insoluble. The solubility of Chirpine resin was found higher in both Benzene and Chloroform and lowest in Acetone. In *Pinus kesiya* the resin samples were found to be highly soluble in Chloroform and equally soluble Acetone and Benzene. Whereas, in *Pinus patula* the samples were highly soluble in Chloroform, followed by Acetone and Benzene (figure 4.32)

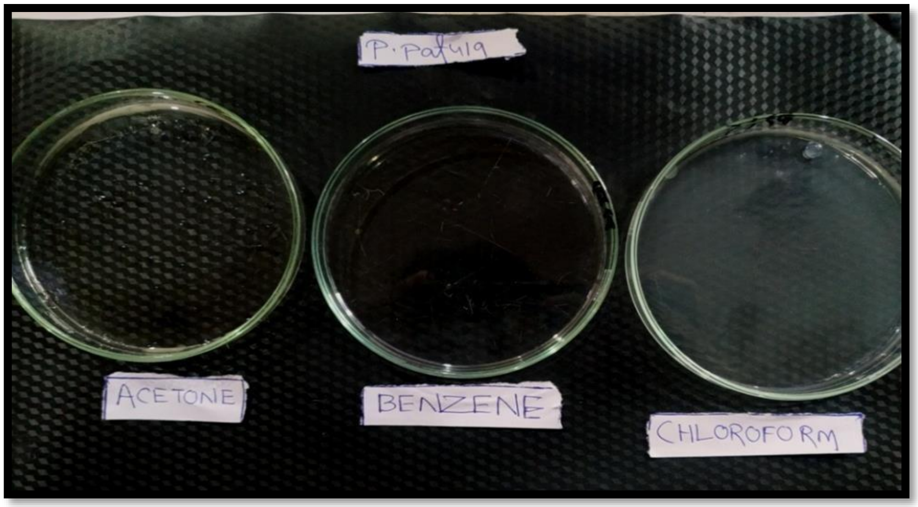
Table 4.36. Solubility of samples in different solutions

Solubility	*Pinus roxburghii*	*Pinus kesiya*	*Pinus patula*
Acetone	1.14%	1.31%	1.07%
Benzene	1.27%	1.31%	0.92%
Chloroform	1.27%	2.17%	1.28%

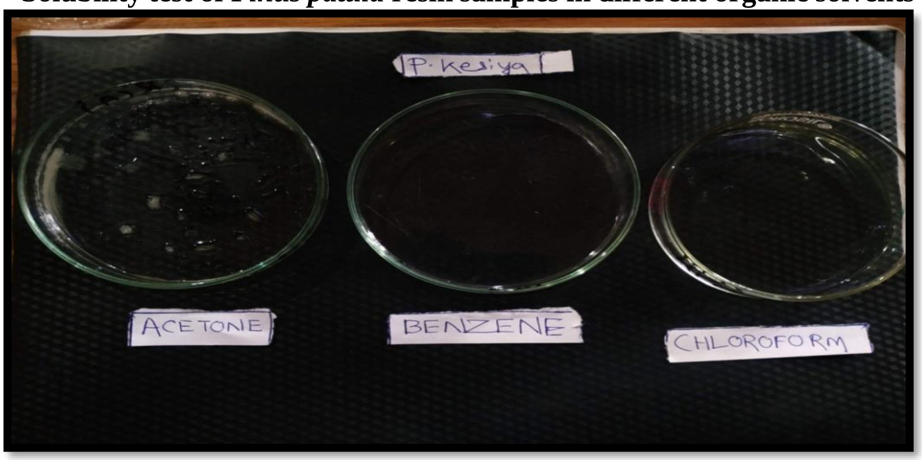
4.19.4 Moisture and Ash content

The moisture content of resin samples was determined using hot air oven. The highest moisture content of 0.75 % was observed in the resin samples of *Pinus patula*, followed by 0.75 % in *Pinus kesiya* and minimum moisture content was observed in *Pinus roxburghii* (0.04%). Ahmad *et al.* (2017) collected resin samples of *Pinus roxburghii* from Kashmir valley and carried out studies on its quality parameter studies and found that moisture content in the resin sample was 3%, which is higher than the present observation.

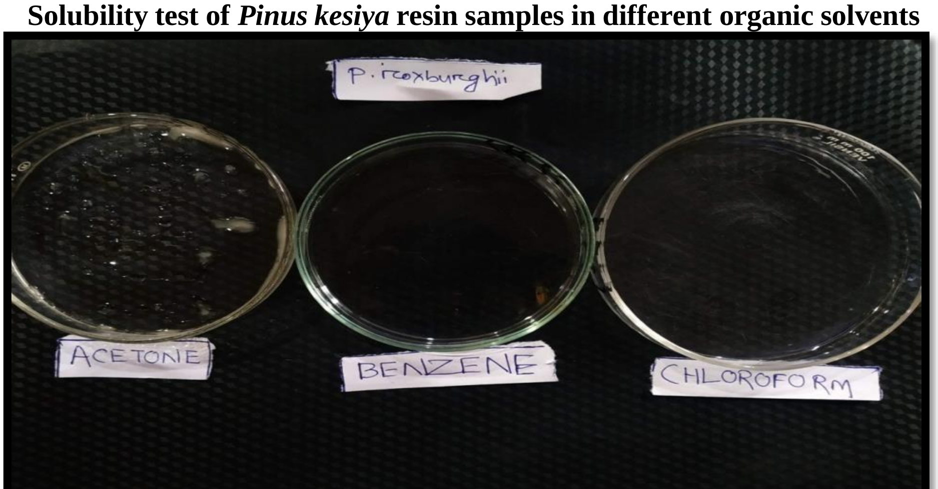
The ash content in the resin was determined by muffle furnace and the value observed was of *Pinus roxburghii, Pinus kesiya* and *Pinus patula* are 2 %,1% and 1 % , respectively. Ahmad *et al.* (2017) reported that ash content of resin samples of Chirpine was 12±1.73 (Table 4.37). The ash content indicates the presence of inorganic elements existing in salt form. Low values of ash content indicate more



Solubility test of *Pinus patula* resin samples in different organic solvents



Solubility test of *Pinus kesiya* resin samples in different organic solvents

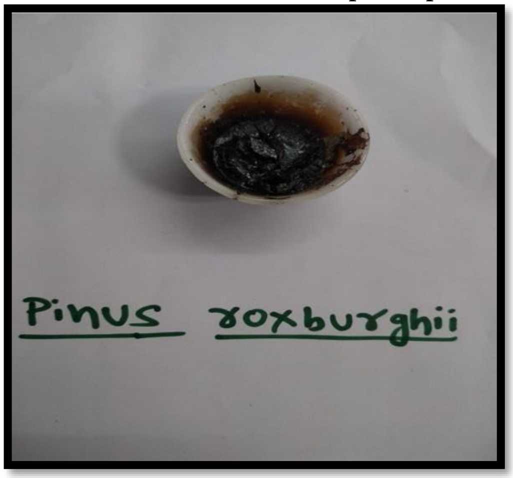


Solubility test of *Pinus roxburghii* resin samples in different organic solvents

Plate 4.4. Solubility percentage of resin samples in Acetone, Benzene and Chloroform

Estimation of Ash content of resin samples in Muffle furnace

Rosin samples kept in crucible for analysis purposes



Ash content of Resin samples after inginiton

Plate 4.5.Estimation of Ash Content

compatible with stomach environment and low levels of contamination during gathering and handling of crude babul gum. Total ash content is used to determine the critical levels of foreign matter, acid insoluble matter, salts of calcium, potassium and magnesium (Mocak *et al*., 1998). Lekha (2002), revealed that ash content in *Pinus roxburghii* rosin tapped from borehole method was 0.55 % and resin tapped in Rill method was 0.65%, respectively. Whereas, in other two species ash content has not been done yet at global level. Whereas, in the present findings, the rosin samples were having high ash content (21%). As no other worker did the study on ash content of rosin so this result will be reference for other worker.

Table 4.37. Moisture and Ash content in the samples

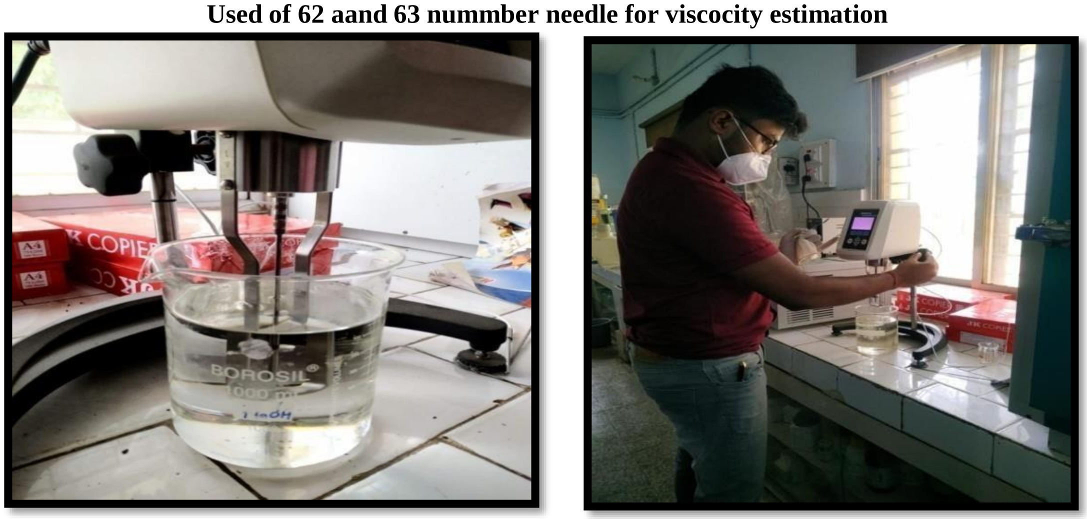
	Pinus roxburghii	***Pinus kesiya***	***Pinus patula***
Moisture conten (%)	0.04	0.75	1.1
Ash content in resin (%)	2	1	1
Ash content in rosin (%)	21	21	21

4.19.5. Viscosity

The viscosity of different resin samples was calculated by using Brookfield viscometer at a rotation of 100 rpm with the use of spindle (No. 62 and 63) and at room temperature (approximately 32°C). Resin sample of 36 g of each Pine species (4%) was dissolved in 900 ml of benzene solution. It was found that while using 62 number spindle resin sample of *Pinus roxburghii* having high viscosity of 2.10 cp, followed by *Pinus kesiya* (1.50 cp) and minimum value of viscosity recorded in resin sample of *Pinus patula* (0.90 cp). However, by using 63 number needle the viscosity of all the samples are found to be equal *i.e* 1.20 cp. The viscosity test of the resin of these species not worked out by any other worker so the result obtained of this study can be used as reference for other worker.

Prepartion for solubility test

Used of 62 aand 63 nummber needle for viscocity estimation



Estimation of Viscocity of resin smaples by using Brookfied DV-E Viscometer

Plate 4.6. Determination of solubility and Viscosity

Table 4.38 Viscosity analysis of resin samples

Viscosity	***Pinus roxburghii***	***Pinus kesiya***	***Pinus patula***
62 number needle	2.10 cp	1.50 cp	0.90 cp
63 number needle	1.20 cp	1.20 cp	1.20 cp

4.20. Healing of incisions after tapping

Healing of the wounded part began after 8 to 9 months with the formation of callus of bark tissues from the side edges of the injured part in all three methods of tapping that are used in these species. The longitudinal and radial axis of the wood have been observed to grow calluses. In Quarree and Triangular method of tapping callus was suberized in the longitudinal section. Whereas, in borehole incisions callus was suberized on the radial (outer) surface extending towards the depth of a hole. The formation of callus and its extension is presented in plate 4.7. On the edges of holes, callus a mass of undifferentiated cells was formed. Callus developed a protective layer below which cambium produced new vascular tissue. The rate of healing was found to be highest in *Pinus roxburghii* followed by *Pinus kesiya* and *Pinus patula*. Lekha and Sharma (2010) also reported that healing percentage achieved decreasing trend with increase in the diameter of boreholes in *Pinus roxburghii* trees. As sustainability point of view both Borehole and Quarre methods of tapping should be used for extraction of resin as the rate of healing seems to be more faster and due to this fire damage to the tree can be also minimized since the surface area is less exposed.

Sealing of Inscisions after resin tapping by localy availabale soils/muds

Rate of healing and callus formatio in *Pinus patula* and *Pinus roxburghii* (Triangular and Quarre method)

Rate of healing in *Pinus kesiya* and *Pinus roxburghii* (Triangular and Borehole method)

Plate 4.7. Rate of healing in different Pine trees

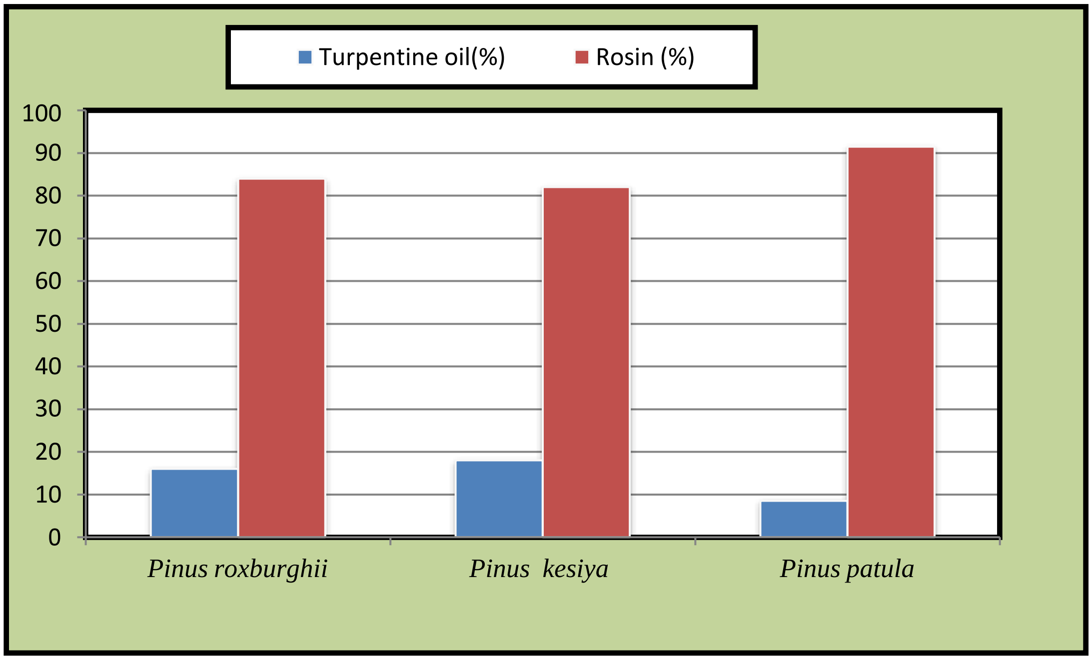


Figure 4.31 Turpentine and rosin content of different resin samples

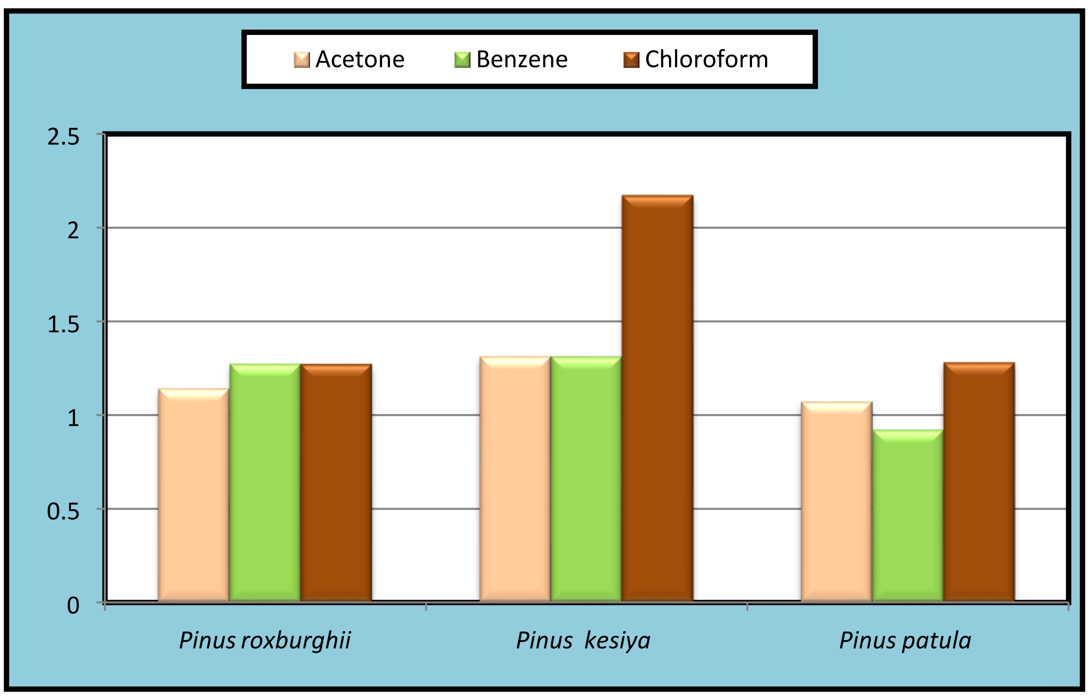


Figure 4.32 Solubility of resin samples in different organic solvents

4.20. Economic Potential of resin tapping in the study area

In today's marketplace, resin-based items such as disinfectants, perfumes, synthetic pine oil, denaturants, cosmetics, and paints are in high demand. According to an IINRG report of 2016, India imports more resin than it exports, despite the fact that India has potential pine tree resources (especially *Pinus roxburghii* as it comes under number 3rd position in growing stock volume as per FSI, 2019 Report). The reason for poor production could be due to erroneously destructive tapping methods resulting in tree damage. The results of present experiment can be disseminated to local communities for commercial resin tapping in *Pinus roxburghii* and *Pinus kesiya*. The borehole method of tapping was shown to be more cost-effective in *Pinus roxburghii*, followed by the Quarre method in *Pinus kesiya*. In *Pinus patula* the triangular method of tapping yielded maximum resin output but the yield was lower than the other two species, which might be due to the species' hereditary capacity, the thermic conditions, or other environmental factors. Although the vegetative growth can be noticed in this species, the resin yield potential was lesser. This species is native to Mexico and was widely planted in various places of India because of its rapid growing ability. Hence for the commercial harvesting of resin we should go for *Pinus roxburghii* and *Pinus kesiya* with above discussed and proposed methods.

Collection and Selling of pine cones in Amarkantak

Collection of pine needle for thatching purposes by local people

Nutricious seeds of *Pinus roxburghii* act as sources of foods for primates

Plate 4.8. Pine based sustenance and habitat

CHAPTER -V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

In previous chapter the data and inferences were presented in detail. In this chapter summary of all the findings and study conclusions are presented.

Among the different methods of tapping applied on *Pinus roxburghii* trees during the year of 2021, highest resin yield/tree was obtained from borehole method of tapping in the T13CH treatment (Ethephon 30%+ H_2SO_4 10%) with a yield of 323.41 gram per tree in diameter class of 45-50 cm. Whereas, in Quarre method of tapping maximum resin yield (294.41 g/tree) was recorded in T15CQ (Ethephon 30%+ H_2SO_4 10%) treatment in diameter class of VI (50-55 cm). Similarly in triangular method of tapping, trees yielded maximum resin of 151.89 g/tree) which was recorded in T10CT (Ethephon 20%+ H_2SO_4 10%) treatment in the diameter class of 40-45 cm.

In the first year of tapping during 2021 (First of March to last week of May) by using various methods highest total resin yield (7532.6 g from 45 trees) which was obtained from Borehole method, followed by Quarre method (3864.8 g from 45 trees) and lowest yield was obtained in triangular method (2723.4 g from 45 trees).

The resin yield varied significantly among different chemical stimulant concentrations injected/ sprayed into different incisions. In Quarre method of tapping by Ethephon chemical, the highest yield of resin 439.22g was obtained in 30% concentration and lowest yield (82.68 g) obtained in 10 % ethephon concentration. While, using H_2SO_4 chemical, highest yield of 192.23 g was obtained in 20% chemical concentration and lowest yield (102.12 g) was obtained in 10 % concentrations. However, in combine dose of treatment, highest resin yield of 883.22 g was recorded from Ethephon 30% + $H_2SO_4$20% and lowest yield obtained in Ethephon 10% + H_2SO_4 15%.

As per the results, temperature plays a crucial role in resin yield. In the year 2021, highest resin yield in each method of tapping was observed in the month of April *i.e.,* in Borehole method (4431.45 g), in Quarre method (1964.09 g) and in Triangular method (1339.13 g), followed by May and lowest yield was collected in the month of March.

During the second year of resin tapping in 2022, the highest resin yield (414.03 g/tree) was obtained from borehole method by using T14CH (Ethephon 20%+$H_2SO_4$15%) treatment in the diameter class of 45-50 cm with boreholes of 3 cm depth and 2 cm diameter. Whereas, by using quarre method of tapping highest resin yield (275.63 g/tree) was obtained in T14 CQ (Ethephon 20%+$H_2SO_4$15%) treatment in diameter class of 45-50 cm. While by using triangular method of tapping, highest resin yield (162.11 g/tree) was collected by using T11 CT (Ethephon 20%+H_2SO_4 15%) treatment in the diameter class of 40-45 cm.

Among all the methods applied in present study, total resin yield by using borehole method was found to be highest (8561 g from 45 trees) followed by quarre method (4236.1g from 45 trees) and the lowest (3410.5 g from 45 trees) was obtained in triangular method of resin tapping in Quarre method.

Temperature plays a crucial role in resin yield. During the year 2022, highest resin yield in all the method of tapping obtained in the month of May (1828.22 g), followed by April (1507.37 g) and lowest yield (900.42 g) was collected in the month of March.

The resin yield varied significantly among different chemical stimulant concentrations injected/sprayed into different incisions. In Quarre method of tapping by Ethephon chemical the highest yield (165.96 g) was obtained in 30% concentration and lowest yield (107.53 g) obtained in 10 % ethephon concentration. While using H_2SO_4 chemical highest yield (445.71 g) was obtained in 15% chemical concentration and lowest yield (118.54 g) obtained in 10 % concentration. However, in the combine dose of treatment, highest resin yield (826.89 g) was collected from Ethephon 30% + H_2SO_4 15 % and lowest yield (171.53 g) obtained in Ethephon 10% + $H_2SO_4$20%

The total yield obtained by different method of tapping in all the treatment during both the year was found to be highest in Borehole method(16094 g in 180 days of tapping from 270 trees),out of this treatment number T13 CH (Ethephon 30%+ $H_2SO_4$10%) yielded highest resin yield (1045.7 /year means 348.56 g/tree).Similarly the total yield obtained by using Quarre shape cut was of 8100.9 g in 180 days of tapping from 270 tree; out of this treatment number T15 CQ(Ethephon 30%+ $H_2SO_4$20%) yielded highest resin yield of 831.70 g/year (mean277.23 g/tree).It was noticed that the minimum value (6133.8 in 180 days of tapping from 270 tree) of resin yield was obtained in Triangular method of tapping, out of this treatment number T11 CT (Ethephon 20%+ H_2SO_4 15%) yielded highest resin yield of 336.35 g/year means 112.12 g/tree.

The color of resin samples obtained from *Pinus roxburghii* was found to be of two types colours such as light yellow colour (resin samples of Bhundakona) and dark yellow colour (resin samples of Kabirchabutra). However, both the samples have strong resinous odour. In the present study the turpentine and rosin content was found to be 16 % and 84 %, respectively.

In solubility test it was found that resin samples are highly (1.27% each) soluble in Benzene and Chloroform and least soluble (1.14%) in Acetone. The ash content in the resin samples and rosin samples was 2 % and 21%, respectively. In terms of its moisture content (percent) it was observed that resin samples having less moisture percent i.e.,0.04%.

The viscosity value was determined by using Brookfield viscometer with spindle number of 62 and 63 at a rotation of 100 rpm. The viscosity value was found to be 1.20cp (62 number needle) and 1.20 cp (63 number needle).

In case of *Pinus kesiya*

Among the different methods of tapping followed in *Pinus kesiya* trees during the year of 2021 highest resin yield/tree was obtained in Quarre method of tapping in the T14 KQ (Ethephon 30%+ $H_2SO_4$15%) treatment with a yield of 129.24 gram per tree in the diameter class of 40-45 cm. Whereas, in triangular method of tapping maximum resin yield (92.02 g/tree) was recorded in T11KT (Ethephon 20%+ H_2SO_4 15%) treatment in the diameter class of V (45-50 cm). Similarly in borehole method of tapping yielded maximum resin yield (52.64 g/tree) and was recorded in T10KH (Ethephon 20%+ $H_2SO_4$10%) treatment in the diameter class of 40-45 cm.

In the first year of tapping during 2021 (First of March to last week of May) by using various methods highest resin yield (2038.37 g) was obtained in Quarre method, followed by Triangular method (1413.8 g) and lowest yield was obtained in borehole method (1280.59 g).

The resin yield varied significantly among different chemical stimulant concentrations Injected/sprayed into different incisions. In Quarre method of tapping by using Ethephon chemical the highest yield (82.29g) was obtained in 30% concentration and lowest yield (55.9 g) obtained in 10 % ethephon concentration. While using H_2SO_4chemical highest yield (97.55 g) was obtained in 20% chemical concentration and lowest yield (87.24 g) obtained in 10 % concentration. However, in the combine dose of treatment highest resin yield (387.73 g) was obtained from Ethephon 30% + $H_2SO_4$15% and lowest yield (67.39 g) obtained in Ethephon 10% + H_2SO_4 15 %.

Temperature plays a crucial role in resin yield out of total 2038.37 g of resin obtained from Quarre method of tapping highest quantity (1083.1 g) was obtained during the month of April, followed by May (606.78 g) and lowest yield (348.49 g) was collected in the month of March. In triangular method of taping out of 1413.8 g of resin highest quantity (708.74 g) was collected during month of April followed by May (434.58 g) and minimum yield obtained in March (270.48 g). Similarly in the borehole method of tapping out of 1280.59 g resin collected, highest quantity (528.02 g) was obtained during month of April, followed by (471.8 g) in the month of May and minimum yield (280.77 g) was obtained in the month of March.

Among the different methods of tapping followed in *Pinus kesiya* tree during the year of 2022, highest resin yield/tree was obtained in Quarre method of tapping in the T15 KQ (Ethephon 30%+ H_2SO_4 20%) treatment with a yield of 84.18 gram per tree in diameter class of 40-45 cm. Whereas, in triangular method of tapping maximum resin yield (80.68 g/tree) was recorded in T11KT (Ethephon 20%+ H_2SO_4 15%) treatment in the diameter class of IV (45-50 cm). Similarly in borehole method of tapping yielded maximum resin (61.39 g/tree) and was recorded in T15KH (Ethephon 30%+ $H_2SO_4$20%) treatment in the diameter class of 40-45 cm.

The total yield obtained in second year of tapping during 2022 by using various methods and highest resin yield (1862.84 g) was obtained in Quarre method, followed by Triangular method (1601.54 g) and lowest yield was obtained in borehole method (1589.02 g).

The resin yield varied significantly among different chemical stimulant concentrations sprayed into different incisions during the year 2022. In Quarre method of tapping by using Ethephon chemical the highest yield (81.87 g) was obtained in 30% concentration and lowest yield (55.51 g) obtained in 10 % ethephon concentration. While using H_2SO_4 chemical highest yield (161.61 g) was obtained in 20% chemical concentration and lowest yield (80.74 g) obtained in 10 % concentration. However, in the combined dose of treatment, highest resin yield (252.53 g) was collected from Ethephon 30% + H_2SO_4 20% (T15 KQ) and lowest yield (91.03g) obtained in Ethephon 20% + $H_2SO_4$10% (T10KQ)

Temperature plays a crucial role in resin yield. In all the three methods of tapping highest yield was obtained in the month of April. Out of total 1862.84 g of resin obtained from Quarre method of tapping highest quantity (1030.46 g) was obtained during the month of April, followed by May (547.28g) and lowest yield (285.1 g) was collected in the month of March. In triangular method of taping out of 1589.02 g of resin highest quantity (809 g) was collected during month of April followed by May (471.24 g) and minimum yield obtained in March (308.78 g). Similarly in the borehole method of tapping out of 1601.54 g highest quantity (927.2 g) which was obtained during the month of April, followed by (472.59 g) in the month of May and minimumyield (201.75 g) was obtained in the month of March.

In the year 2021, Quaree method of tapping was conducted in Bhundkona area, located at higher elevation of 1100 m amsl and faces North-Eastern aspects. Whereas, in 2022 Quarre method tapping was conducted in Kabirchabutra (1025 amsl) which was located comparatively at lower elevation than Bhundakona area facing South-west aspects as a result of sunlight penetration that was also lower, therefore in the second year of taping total resin yield was found to be lower in comparison to previous year of 2021.

The total yield obtained by different method of tapping in all the treatment during both the year was found to be highest in Quarre method (3901.21 g in 180 days of tapping from 270 trees),out of this treatment number T14 KQ (Ethephon 30%+ H_2SO_4 15 %) treatment yielded highest resin yield (271.32 g /year means 90.44 g/tree).Similarly the total yield obtained by using triangular shape method was of 3002.82 g in 180 days of tapping from 270 tree; out of this treatment number T11KT (Ethephon 20%+ $H_2SO_4$15%) treatment yielded highest resin yield of 259.05 g/year with average of 86.35 g/tree. It was observed that the minimum value (2882.13 in 180 days of tapping from 270 tree) of resin yield was obtained in borehole method of tapping, out of this treatment number T10 KH (Ethephon 20%+ H_2SO_4 10%) yielded highest resin yield of (149.01 g/year means 49.67 g/tree).

The color of resin samples obtained from *Pinus kesiya* was found to be creamy white and it contains strong camphor like aroma. The turpentine and rosin content were foundto be 18 % and 82 %, respectively.

In solubility test it was found that resin samples were highly soluble (2.17 %) in Chloroform and least soluble (1.31%) in Acetone and Benzene. The ash content in the resin samples and rosin samples was 1 % and 21%, respectively. In terms of its moisture per cent it was found that resin samples having less moisture percent *i.e.*,0.75 %. The viscosity value was found to be 1.50 cp(62 number needle) and 1.20 cp (63 number needle).

Case of Pinus patula

Among the different methods of tapping followed in *Pinus patula* tree during the year of 2021, highest resin yield/tree was obtained in Triangular method of tapping in the T5 PT treatment (H_2SO_4 15%) with a yield of 162. 56 g per tree in the diameter class of 40-45 cm. Whereas, in Quarre method of tapping maximum resin yield (48.29 g/tree) was recorded in T8PQ treatment (Ethephon 10%+ H_2SO_4 15%) in the diameter class of III (35-40 cm). Similarly, the borehole method of tapping yielded maximum resin yield (44.64 g/tree) was recorded in T14 PH treatment (Ethephon 30%+ H_2SO_4 15%) in the diameter class of 35-40 cm.

In the first year of tapping during 2021 (First of March to last week of May), by using various methods highest resin yield (1618.52 g) was obtained in triangular method, followed by Quarre method (1269.34 g) and lowest yield was obtained in borehole method (1120.69 g).

The resin yield varied significantly among different chemical stimulant concentrations injected/sprayed into different incisions. In triangular method of tapping by using Ethephon chemical the highest yield (109.98 g) was obtained in 30% concentration and lowest yield (51.02 g) obtained in 10 % ethephon concentration. While using H_2SO_4 chemical highest yield (487.68) was obtained in 15% chemical concentration and lowest yield (52.43 g) obtained in 10 % concentration. However, in the combined dose of treatment highest resin yield (126.66 g) was collected from

Ethephon 30% + H_2SO_4 15% (T14 PT) and lowest yield (50.43 g) obtained in T9PT treatment Ethephon 10% + H_2SO_4 20 %.

Temperature plays a crucial role in resin yield. Out of total 1269.34 g of resin obtained from Quarre method of tapping highest quantity (669.12 g) was obtained during the month of April (739.03 g), followed by May (320.17 g) and lowest yield (210.14 g) was collected in the month of March. In triangular method of taping out of 1618.52 g of resin highest quantity (771.04 g) was collected during month of April followed by May (542.59 g) and minimum yield obtained in March (304.89 g). Similarly in the borehole method of tapping out of 1120.69 g highest quantity (566.77 g) was obtained during the month of May, followed by (358.65g) in the month of April and minimum yield (195.27 g) was obtained in the month of March.

Among the different methods of tapping applied on *Pinus patula* tree during the year of 2022, highest resin yield/tree was obtained in Quarre method of tapping in the T9 PQ treatment (Ethephon 10%+ H_2SO_4 20%) with a yield of 47.52 gram per tree in the diameter class of 35-40 cm. Whereas in triangular method of tapping maximum resin yield (42.95 g/tree) was recorded in T15 PT treatment (Ethephon 30%+ H_2SO_4 20 %) in the diameter class of III (35-40 cm). Similarly in borehole method of tapping yielded maximum resin yield of 42.38 g/tree in T15KH treatment (Ethephon 30%+ H_2SO_4 20%) in the diameter class of 40-45 cm.

The total yield obtained in the second year of tapping during 2022 by using various methods was found to be highest in (1312.66 g) borehole method followed by quarre method (1213.67 g) and lowest in triangular method (1205.11 g).

The resin yield varied significantly among different chemical stimulant concentrations sprayed into different incisions during the year 2022. It was found that during the year 2022 highest resin yield was obtained in Borehole method. In borehole method of tapping by using Ethephon chemical the highest yield (104.37 g) was obtained in 20% concentration and lowest yield (64.34 g) was obtained in 10 %

ethephon concentration. While using H_2SO_4 chemical highest yield (116.29 g) was obtained in 20% chemical concentration and lowest yield (97.6 g) obtained in 15 % concentration. However, in the combined dose of treatment highest resin yield (118.15 g) was collected from Ethephon 30% + H_2SO_4 20% (T15 PH) and lowest yield (64.95 g) obtained in Ethephon 20% + H_2SO_4 15% (T11 PH treatment).

As mentioned in the earlier case, here also the temperature plays a crucial role in resin yield. Out of the total 1213.67 g of resin obtained from Quarre method of tapping highest quantity (636.47 g) was obtained during the month of April, followed by May (386.54 g) and lowest yield (190.66 g) was collected in the month of March. In triangular method of taping out of 1205.11 g of resin highest quantity (507.11 g) was collected during month of April followed by May (412.55 g) and minimum yield obtained in March (285.45 g). Similarly in the borehole method of tapping out of 1312.66 g, highest quantity (698.63 g) was obtained during month of April, followed by (368.77g) in the month of May and minimum yield (245.26 g) was obtained in the month of march.

The total yield obtained by different method of tapping in all the treatment during both the year was found to be highest in Triangular method collected 2823.63 g in 180 days of tapping from 270 trees),out of this treatment number T5PT (H_2SO_4 15 %) yielded highest resin yield (304.28 g /year or 101.43 g/tree).Similarly the total yield obtained by using Quarre shape cut was of 2483.01 g in 180 days of tapping from 270 tree;out of this treatment number T14PQ (Ethephon 30%+ H_2SO_4 15%) yielded highest resin yield of 123.46 g/year or 41.15 g/tree . It was noticed that the minimum yield obtained in borehole method value of 2433.35 in 180 days of tapping from 270 tree, out of this treatment number T15 PH (Ethephon 30%+ $H_2SO_4$20%) yielded highest resin yield *i.e*123.53 g/year or 41.18 g/tree.

The color of resin samples obtained from *Pinus patula* was found to be pure yellowish white and it contains strong aroma like camphor. The turpentine and rosin content wasfound to be 8.52 % and 91.48 %, respectively.

In solubility test it was found that resin samples were highly soluble (1.28 %) in Chloroform, followed by Acetone (1.07%) and least soluble (0.92 %) in Benzene. The ash content in the resin samples and rosin samples was 1 % and 21% respectively. In terms of its moisture per cent it was found that resin samples having high moisture percent *i.e.*1.10 %. as compared to resin samples of other species.

The viscosity value was determined by using Brookfield viscometer with spindle number of 62 and 63 at a rotation of 100 rpm. The viscosity value was found to be 0.90 cp (62 number needle) and 1.20 cp (63 number needle).

CONCLUSIONS

- In *Pinus roxburghii* resin yield showed increasing trend with increase in diameter and chemical concentration, the middle aged trees having 45-50 cm diameter class yielded maximum resin yield per tree in each method of tapping . Among all the three methods used for resin tapping in *Pinus roxburghii* highest resin yield (261.95g/tree) was observed in borehole method, followed by Quarre method (153.43 g/tree) and minimum yield (108.56 g/tree) was observed in Triangular method of tapping.
- It was observed that among all the concentrations of chemicals tried for resin tapping, combined dose of Ethephon 30% + H_2SO_4 10% yielded maximum resin yield of 348.56 g/tree in borehole method of tapping, followed by Quarre method 277.23 g/tree in Ethephon 30% + H_2SO_4 20%, and minimum yield 112.12 g/tree observed in Ethephon 20% + H_2SO_4 15%.
- The location, elevation, aspects and climate had a significant influence in resin yield. *Pinus roxburghii* trees located at Bhundakona area yielded higher resin yield as compared to Kabirchabutra (As Bhundakona located at an elevation of 1100 mamsl and - faces North-Eastern aspect and Kabirchabuta located at 1020 mamsl, faces south-west aspects.
- During the month of April each year highest resin yield was oozed out in all the methods followed by May and March.

- Resin samples of *Pinus roxburghii* content highly aromatic odour with light to dark yellow in color and the turpentine and rosin content in the sample was 84 % and 16 %, respectively (as compared to temperate area the turpentine oil percentage was relatively lower due to the tropical climatic conditions).
- The moisture content and ash content in resin sample was 0.04% & 2 %, respectively. While conducting the solubility test resin samples were highly soluble in both Benzene and Chloroform and least soluble in Acetone.

Case of Pinus kesiya

In *Pinus kesiya* resin yield showed increasing trend with increase in diameter and chemical concentration, the middle aged trees having diameter class of 40-45 cm yielded maximum resin yield per tree in each method of tapping. Among all the three methods used for resin tapping in this species highest resin yield (62.01 g/tree) was observed in quarre method, followed by triangular method (47.82 g/tree) and minimum yield (45.13 g/tree) was observed in borehole method of tapping.

- It was observed that among all the different concentration of chemicals tried for resin tapping combine dose of Ethephon 30% + H_2SO_4 15 % yielded maximum resin yield of 90.44 g/tree in Quarre method of tapping, followed by Triangular method 86.35 g/tree in Ethephon 20% + H_2SO_4 15%, and minimum yield 49.67 g/tree observed in Ethephon 20% + H_2SO_4 10 %.
- During the month of April highest resin yield was oozed out in all the methods followed by May and March.
- Resin samples of *Pinus kesiya* content camphor like aromatic odour with creamy white in color and the turpentine and rosin content it was 82 % and 18 %, respectively.
- The moisture content and ash content in resin sample was 0.75 % & 1 %, respectively. In the solubility test, it was found that resin samples were highly soluble in Acetone and least soluble in Chloroform and Benzene.

Case of Pinus patula

In *Pinus patula* resin yield showed increasing trend with increase in diameter and chemical concentration, the middle aged trees having diameter class of 35-40 cm yielded maximum resin yield per tree in each method of tapping. Among all the three methods used for resin tapping in this species highest resin yield (47.06 g/tree) was observed in Triangular method, followed by Quarre method (43.27 g/tree) and minimum yield (38.58 g/tree) was observed in borehole method of tapping.

- It was observed that among all the different concentration of chemicals tried for resin tapping the refreshing agent Sulphuric acid with 15 % concentrations yielded maximum resin of 101.43 g/tree in triangular method of tapping, followed by borehole method 41.18 g/tree in Ethephon 30% + H_2SO_4 20%, and minimum yield 41.15 g/tree observed in Ethephon 30% + H_2SO_4 15% concentration.
- During the month of April each year highest resin yield was oozed out in all the methods followed by May and March.
- Resin samples of *Pinus patula* smells camphor like aromatic odour with creamy white in color and the turpentine and rosin content in was 91.48 % and 8.52 %, respectively.
- The moisture content and ash content in resin sample was 1.10 % & 1 % respectively. In the solubility test, it was found that resin samples are highly soluble in Chloroform followed by Acetone and least soluble in and Benzene.
- It was also observed that trees those are tapped at higher elevation (*i.e* Bhundakona R-237 compartment) yielded maximum resin in quantity in comparison to the lower elevation (i.e. Kabirchabutra P-232 and Chakratirath P-231 compartments).

- Resin samples of *Pinus roxburghii* obtained from higher elevation area observed to be light yellow in colour, whereas resin collected from lower elevation was dark yellow in colour.
- The present experiment revealed that both *Pinus roxburghii* and *Pinus kesiya* are more viable for resin tapping, so adequate training and capacity building programmes should be implemented by the State Forest Department. This could be beneficial to local communities in order to improve their livelihoods as well as for the sustainability of pine forest in the area.
- The aforementioned Pinus species has a fast growth rate, long fibre length, and deep roots, which facilitate the recovery of abandoned and degraded sites of the study area. Because of the environmental services and returns and ecosystem rehabilitation purposes, plantations of both of these native species should be promoted in the study area. This will improve the tree cover as well aslivelihood security.

Suggestions for Future Research work

- Other species of Pines were found in the study area of the Amarkantak and East Karanjiya ranges, and they had a similar growth pattern in terms of diameter and height, therefore, these potential tree species might be chosen for further tapping purposes.
- The pine species tapped in the current experiment had a distinctive aromatic odour, which could be related to the presence of terpenes (the volatile component). As a result, suitable chemical compositional investigations, such as TLC, HPLC, and GCMS, are required.
- Pine-based sustainable tourism models can also be built in these locations, as other states, like as Odisha, where these tropical pines were introduced in the same year, developed pine resorts for ecotourism.
- The dry pine needles available in the fine forest can be used for production of bio-briquets. Bio-briquets fund to be useful in meeting the local wood fuel

requirement as well as its use in electricity generation from gasifier. As in Uttarakhand this process of generating electricity from pine needles by using biomass gasification technology is underway. This will also help in preventing the forest fire problem during the hot summer year as the pine needles contain essential oils which are highly inflammable. This also aids in income generation of local inhabitants

- The study area has potential of natural regeneration of pine species provided the area is protected from collection of cones from the forest area.
- The proposed method of resin taping in the present study will help to reduce the wastages, provide better healing conditions. These aspects are important for the health of the trees.
- Local community may find the resin tapping as an alternate livelihood and for that the community needs to be trained and JFMCs be empowered.
- The pine cones can be transformed into a variety of decorative items and sold in the market which helps the local community for income generations. Therefore proper training on this domain may be provided.

CHAPTER -VI

REFERENCES

Abib C.F., Ntoupka M., Peltier R., Harmand J.M. and Thaler P. 2013. Ethephon: a tool to boost gum Arabic production from *Acacia senegal* and to enhance gummosis processes. *Agroforestry Systems*, 87(2): 427-438

Abraf. Associação Brasileira De Produtores de Florestas Plantadas (Brasil).2012. Anuário estatístico da ABRAF 2013, base year 2012 [online]. http://www. ipef.br/estatisticas/relatorios/anuario-ABRAF13-BR.pdf [quoted, 08.17.2013].

Afej, S.M., Huseini, F.H., Tajalizadekkhoob, Y., Mirarefin, M., Sharifi, F.,Taheri, E., Saeednia, S., Larijani., B. and Fakhrzadeh. 2014.Determination of Phenolic Compounds in *Pinus eladeica* by HPLC. *Journal of Medicinal Plants*,13(49):pp 22-33.

Ahmad Mir, I. Jahan, N.2017. Standardization and Characterization of Oleo Resin of Pine obtained from Pinus roxburghii Sarg. *American Journal of Pharmatech Research*,7(6) :211-227.

Alexandrian. *J. Agri. Res.* **11**(1): 167-181

Anonymous, 1965. Resin tapping study in *Pinus radiata* plantation. *Inf. Tech. Inst. For.,* Satiago, 19: 61 pp.

Anonymous, 1972. Resin tapping and the manufacture of turpentine and rosin. Indian Forest Utilization, F.R.I. Dehra Dun 11:826-848.

Anonymous, 2010. Achanakmar-Amarkantak Biosphere reserve. Biosphere Reserve Information Series, 2(1–2), 158.

Anonymous, 1969. Wealth of India. Raw material Volume VIII.CSIR, New Delhi, 69-78 pp.

Anonymous. 2009. Rosin collection work: An overview. (http://www.forestrynepal.org/images/resin%20work%20in%20nepal.pdf. Assessed on 1/4/2009.).

Anthkowaik, L. 1992. Effect of floridmex TH (dicholoroethanophosphonic acid) onresin yield. *Sylvan* .136(6):45-49.

Armitage and Burley, J. 1980. *Pinus kesiya* Royle ex Gordon. Tropical Forestry Paper, Oxford Forestry Institute, University of Oxford, No.9, 189 pp.

Arya, R. 2019. Sustainable Oloegum resin harvesting from *Commiphora wightii* through non destructive tapping technique. *Indian Forester*,145(4):368-374.

Badran, O. A. 1963. A study on the production of resin from *P. brutia* in Syria.

Baradat, P. and Yazdani, R. 1988. Genetic expression for monoterpenes in clones of *Pinus sylvestris* grown on different sites. *Scandinavian Journal of Forest Research.* 3 (1): 25-36.

Bardyshev, I.I., Udarov, B.E., Bulgakov, A.N. and Kuladin, V.P. 1973. Chemical composition of turpentine from oleoresin of individual pines collected in the normal way or once per season. *Lesnoi Zhurnal* 16(5): 118-120.

Barrett, J.P. 1963. Relation of relative oleoresin yielding potential to geographic seed source of slash pine. Abstr. of thesis, in *Desert Abstr.* 24(5): 1774-1775.

Benayoun, J. and Fahn, A. 1979. Intracellular transport and elimination of resin fromepithelial duct cells of *Pinus halepensis*. *Ann. Bot*. 43: 179-181.

Bhatt, J.R. and Ram Mohan Y.H. 1990. Ethephon-induced gum production in *Acacia senegal* and its potential value in the semiarid regions of India. *Current Science*, 59(23): 12.

Bhatt J.R., Nair M.N.B. and Mohan Ram H.Y. (1989). Enhancement of oleo-gum resin production in *Commiphora wightii* by improved tapping technique. *Current Science*, 58(7): 349-357.

Bhatt, J.R. 1987. Gum tapping in *Anogeissus latifolia* (Combretaceae) using Ethephon.

Bhatt, J.R. and Ram Mohan Y.H. 1990. Ethephon-induced gum production in *Acacia senegal* and its potential value in the semiarid regions of India. *Current Science*, 59(23): 12.

Bhatt, J.R., Nair, M.N.B. and Mohan Ram H.Y. 1989. Enhancement of oleo-gum resin production in *Commiphora wightii* by improved tapping technique. *Current Science*, 58(7): 349-357.

Bishop, G.N. and Marckworth, G,D. 1933. Resin tapping experiment on *Pinus elliottii* and *Pinus taeda*. *J. For*. 31: 953-60.

Brahmi, M.K. 1994. Resin tapping in Chirpine of lower diameter class. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, H.P. India.

Brahmi, M.K., Kaushal, A.N. and Sharma, K.R. 2000. Resin tapping from lower diameter classes of Chirpine by rill method using group of different blaze width in Himachal Pradesh. *Indian Forester* pp 83-88.

Buchert, G.P., O.P. Rajora, J.V. Hood and B.P. Dancik, 1997. Effects of harvesting on genetic diversity in old-growth Eastern White Pine in Ontario, Canada. *Conserv. Biol*., 11: 747-758

Byng, J.W. 2015. The Gymnosperm Handbook. Plant Gateway press. Hertford, United Kingdom, 1–3. ISBN9780992999322.

Chadha, Y. R. 1982. Indian pine resin- its chemical composition and utilization. In: Cultivation and utilization of medicinal and aromatic plants (ed. C K Atal and B M Kapoor). 331-338.

Chalk, L. 1983. Secretory structures in wood. pp. 68-69. In: Anatomy of the dicotyledons (eds. C.R. Metcalfe and L. Chalk). 2nd Edn. Vol II. Clarendon Press, Oxford.

Chaturvedi, J.K., 1982. Tropical pines in Madhya Pradesh. *Indian Forester*,108(2),163–170.

Chaudhari, D.C. Uniyal, D.N. and Shiva, M.P. 1988. Comparative studies on the healing rate of Blazes tapped by Cup & Lip method (Channels) and Rill Method (Rills) in *Pinus roxburghii*. *Indian Forester*, 446-452.

Chaudhari, D.C., C.L. Goel, B.D. Joshi, D.N. Uniyal, A. Prasad and R.S. Bisht, 1992. Correlation between diameter and resin yield by rill method of tapping. *Indian Forester*, 118: 456-459.

Chaudhari, D.C., Goel, C.L. and Uniyal, D.N. 1992 b. Rill method- The only resort to resin tapping from pines. MFP News: 2(1&2), Comforts, India, Dehradun.

Chaudhari, D.C., Uniyal, D.N. and Shiva, M.P. 1988.Comparative studies on the healing rate of Blazes tapped by Cup & Lip method (Channels) and Rill Method (Rills) in *Pinus roxburghii*. *Indian Forester*, 446-452.

Chaudhari, D.C.; Goel, C.L., and Uniyal, D.N. 1992 b. Rill method- The only resort to resin tapping from pines. MFP News: 2(1&2), Comforts, India, Dehradun.

Chaudhari, D.C., Goel, C.L., Chaubey, A.K., Uniyal, D.M. 1991.Boosting Resin Production with 20 percent (Volumetric) and mixture stimulant from chirpine (*Pinus roxburghii* Sargent). *Indian Forester*.117(1): 37-43.

Chowdhary, Y.P. 1967. Resin tapping of kail *(Pinus wallichiana)* in the undivided Punjab. *Proc. 11th Silv. Conf.* Dehradun 3: 346-351.

Clements, RW. 1961.Air temperature and gum yield. *Res. Note Stheast For. Exp. Sta.* No.168: 2pp

Composition and method for stimulating flow of pine gum. 1967 (U.S. Patent NO. 3359681)

Coppen, J.J., Robinson, J.M., Kaushal, A.N. 1988. Composition of xylem resin from *Pinus wallichiana* and *Pinus roxburghii*. *Phytochemistry*. 27(9): 2873-2875.

Coppen, J.J.W. and G.A. Hone, 1995. Gum Naval Stores: Turpentine and Rosin from Pine Resin. 2nd Edn., Natural Resources Institute, Food and Agriculture Organization, Rome, Italy, ISBN-13: 9789251036846, Pages: 62

Coppen, J.J.W.; Hone, G.A. Gum naval stores, turpentine and rosin from pine resin. In: Non-Wood Forest Products 2. FAO, Rome, Italy (1995) 62 pp. ISBN 92-5-103584-5.

Correa, K.C.S.R., Lima, J.C. and Neto, A.G.F. 2012. Pine oleoresin: Tapping green chemicals, biofuels, food production, and carbon sequestration from multipurpose trees –A review. *Food and Energy Security*,1(2):81-93.

Correa, K.C.S.R., Lima, J.C. and Neto, A.G.F.2012.Pine oleoresin: Tapping green chemicals, biofuels, food production, and carbon sequestration from multipurpose trees –A review. *Food and Energy Security*.1(2):81-93.

Cunnigham, A. 2012. Pine resin: biology, chemistry and applications. In: Fett Neto AG, Rodrigues-Correa KCS (eds) Pine tapping recent advances. Boston: PCA, pp 1-8, ISBN 978-81-308-0493-4**.**

Dayal, R.1986. Studies on oleoresins of *Pinus merkusii* and *Pinus insularis* from Arunachal Pradesh. *Indian Forester*,112(8):734-736**.**

Deb, C.R. and Tandon, P. 2000.Induction of somatic embryogenesis in *Pinus kesiya* Royle ex Gord. Ph.D.(Botany) Thesis. North-Eastern Hill University.

Deshmuhk, D.K. and Payal, P.S. 1964. Factor affecting resin yield in Chir. Indian Forest Records, XVII (V).

Deshmukh D K and Dutt U. 1967. Some aspect of resin tapping in chir pine. Proc XI Silvi Conf. Dehradun. Ill: 340-345.

Deshmukh D.K. 1966. Characterization of Chir pine (*Pinus roxburghii* Sargent) for resin yielding capacities. *Indian Forester*, 92 (7): 368-390.

Deshmukh, D. K. and Dutt, U. 1967. Some aspect of resin tapping in Chir pine. Proc XI Silvi Conf. Dehradun. Ill: 340-345.

Deshmukh, D.K. 1966. Characterization of Chir pine (*Pinus roxburghii* Sargent) for resin yielding capacities. *Indian Forester*, 92 (7): 368-390.

Dione, M. and Vassal. J. 1998. Gummosis and gum production cycles in *Acacia senegal* L.In: *Acacia senegal*, edited by Campa, C., Grignon, C., Guenye. M. and Hamons, S. 123-134.

Drocnev, J.G. and Toburdanoiskij. 1957. Comparative efficiency of descending and ascending methods of tapping.

Dvorak, W.B., Jordan, A.P., Romero, J.L., Hodge, G.R. and Furman, B.J. 2012. Quantifying the geographic range of *Pinus patula* var longipedunculata in Southern Mexico using morphologic and RAPD marker data quantifying the geographic range of *Pinus patula* var longipedunculata in Southern Mexico using morphologic and RAPD marker dat. T*he Southern African Forestry Journal* 192:37-41. https://doi.org/10.1080/20702620.2001.10434130.

Essl, F., Mang, T., Dullinger, S., Moser, D. and Hulme, P.E. 2011. Macroecological drivers of alien conifer naturalizations worldwide Ecography 34(6):1076-1084. https://doi.org/10.1111/j.1600- 0587.2011.06943.x.

Fahn, A., Werker, E. and Ben Tzur, P. 1979. Seasonal effects of wounding and growth substances on development of traumatic resin ducts in *Cedrus libani*. New Phytol.82.: 537-544.

FAO,1995. Naval stores: turpentine and rosin from pine resin naval stores: and rosin from pine resin. FAO, Rome. 53 Pages.

FAO, 2007a. Non-Wood Forest Products 18. World Bamboo Resources. A thematic study prepared in the framework of the Global Forest Resources Assessment 2005. 2:11

FAO, 2007b. Global Forest Resources Assessment-2005: Progress towards Sustainable Forest Management. FAO Forestry Paper 147, Rome

Farjon, A., 2017. A Handbook of the Worlds Conifers. Koninklijke Brill NV Publishers, Leiden, The Netherlands, 981069. ISBN 9789004324497

Flotynski, J. 1964. Investigation on the effect of the main meteorological factors on resin yield in tapping. *Foliafor*. Polon (Lens.) No. 10, 177-244.

Franceschi, V.R., Krokene, P., Christiansen, E. and Krekling, T. 2005. Anatomical and chemical defenses of conifer bark against bark beetles and other pests. *New Phytol*., 167: 353-376.

FSI. 2019. Forest Survey of India. India State of Forest Report. Ministry of Environment Forest and Climate Change, Government of India. Dehradun.

FSI. 2021. Forest Survey of India. India State of Forest Report. Ministry of Environment Forest and Climate Change, Government of India. Dehradun.

Ghosh, R.C., Singh, B. Sharma, R.K. and Dhaundiyal, U.D. 1982. Performance of different provenances of chirpine in comparison to *Pinus caribaea, Pinus patula* and *Pinus kesiya* in the sub-Himalayan zone. *Indian Forester*. 108(1): 29-38.

Gomez, K.A. and Gomez, A.A. 1984.Statistical Procedure for Agricultural Research(2nd edn), John Willey and Sons.;New York,USA,60p.

Greenwod, G. and Morey, P. 1979. Gummosis in honey mesquite. *Bot. Gaz.* 140: 32-38.

Grochowski, W. 1951. Characteristic of the flow of pine resin. Prace. Inst.Bad.Lesh 72:1524.

Guha, S.R.D. 1958. Chemical pulps and writing and printing papers from Chir (*Pinus longifolia* Roxb.) *Indian Forester,* 84:235-240.

Gulati, N.K., Fernandez, R.R. and Payal, S.S. 1983.Supplemeting resin production by tapping Blue pine (*Pinus wallichiana*). *Indian Forester*.109(6): 379-383.

Gundidza, M., Mmbengwa, V., Sibambo, R.S., Magwa, L.M., Mushisha, O., Benhura, A.M., Gundidza, E. and Samie, A. 2011. Rheological, moisture and ash content analyses of a gum resin from *Commiphora africana.African J. Food Science*, Vol. 5(4), pp. 188 – 193.

Gurgel Filho, O.A. and Gurgel Garrido, L.M.A. 1977. The effect of diameter and crown on resin production. *BrazilFlorestal,*8(32): 27-32.

Hadiyane, A., Sulistyawati, E., Asharina, W.P. and Dungani, R. 2015. A Study on Production of Resin from *Pinus merkusii* Jungh. Et De Vriese in the Bosscha Observatory Area, West Java-Indonesia. *Asian Journal of Plant Sciences* 14 (2): 89-93.

Hall M.A. and Smith A.R. 1995. Ethylene and the responses of plants to stress. Bulgarian J. *Plant Physiology*, 21(2-3): 71-79.

Harrington. 1969. Production of Oleoresin From Southern Pine Trees. *Forest Products Journal*, 19(6):31-35.

Harsh, L.N., Tewari, J.C., Khan, H.A. and Ram M. 2013. Ethephon-induced gum Arabic exudation technique and its sustainability in arid and semi-arid regions of India. *Forests, Trees and Livelihoods,* **22**(3): 204-211.

Hassan, A. and Amjid, Imran. Journal of Medicinal Plants Research ,3(9): 670-673.

Hassan, A .and Amjid, I.2009.Gas chromatography-mass spectrometric studies of essential oil of *Pinus roxburghii* stems and their antibacterial and antifungal activities. *Journal of Medicinal Plants Research*, 3(9): 670-673.

Hazarika, A.K. and Bhagat, S.D. 1984. Study on *Pinus wallichiana* resin from Arunachal Pradesh. *Indian Perfumer*, 28(2):98-104.

Hillman, W.S. 1962. The physiology of flowering. Holt. Rinehart, and Winston Inc New York.

Hodge, A.W. and Johnson, J.D. 1997. Borehole oleoresin production from slash pine. *Southern Journal of Applied Forestry*,21(3):108-115.

Hodges, A.W. 1995. Management strategies for a borehole resin production system in Slash pine. Dissertation submitted to University of Florida.

Hodges, J.D., Elam, W.W., Watson, W.F. 1977. Physical properties of the oleoresin system of the four major Southern pines. *Can. J. For.Res,*7(3):520-525.

IINRG, 2020. Standardization of resin tapping technique in *Pinus kesiya* for sustainability and conservation of natural resources, Project on *Pinus kesiya* resin at ICAR Research Complex for NEH Region, Umiam,68-70.

Joshi, H.B. 1972. Lowering of minimum diameter for resin tapping in chir *(Pinus roxburghii* Sargent t) ·*Indian Forester* 98(7): 441-447.

Kalela, E.K. 1946. Resin tapping experiment in Northern pine woods. *Acta For. Fenn,*52(2): 1-39

Kashio, M. and D. V. Johnson. 2001. Monograph on benzoin (Balsamic resin from Styrax species). Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Bangkok, Thailand, 210.

Kashyap, S.D. 1978. Chemical evaluation of high resin yielders in Chir (*Pinus roxburghii* Sargent) marked in Hamirpur Forest Division, Himachal Pradesh. 53p.

Kaushal, A.N. and Khosla, P.K. 1984. Potential of economic utility of Pines: Proceedings of IUFRO group P.S.01 held at Manuas (Brazil): 18-20 p

Kaushal, A.N. and Sharma, K.R. 1988. Tapping of resin in Chir and Bluepine. Bulletin No. RT 1.

Kaushal, A.N. and Kashyap, S.D. 1980. High resin yielders in Chirpine and their economic importance. Proceedings of National symposium on Improvement of Forest Biomass. HPKVV, Solan, H.P., India.

Kedarnath S. 1971. Evolving high oleoresin yielding strains of Chir pine (*Pinus roxburghii*) through breeding. Sympine Technical papers Vigyan Bhavan, New Delhi. D1-D5.

Kedarnath, S. 1971. Evolving high oleoresin yielding strains of chir pine (*Pinus roxburghii*) through breeding. In seminar on the role of pine resin in the Economic and Industrial Development of India, 13-14th April, Vigyan Bhawan, New Delhi. Q1-Q35.

Khan, I., Singh, V. and Chaudhary, A.K. 2012. Hepatoprotective activity of *Pinus roxburghii* Sarg. wood oil against carbon tetrachloride and ethanol induced hepatotoxicity.

Khan, N.A. 1983. Study of phenotypic variation in *Pinus wallichiana* A.B. Jackson (Blue pine) in selected areas of Jammu & Kashmir and Himachal Pradesh. M.Sc. Forestry. Thesis submitted to HPKVV, College of Agriculture, Solan (HP). 67 p.

Koev, D., Lazarova, M., Ognyanov, I., Kyleva, L. and Todorova, M. 1989. The amount and qualitative composition of turpentine in oleoresin-indices of resin productivity in Scots pine. *Nauka-za-Gorata*, 2:35-41.

Konovalov, N.A. and Mochalov, SA 1978. Resin productivity of various morphological forms of *Picea obovata* in the Central cerals. *LesnoiZhumal,*4: 25-28.

Kossuth, S.V. 1984. Multipurpose slash Pine; Genetics and Physiology of gum naval stores production USDA, *For.Ser.Gen.Tech.* Report, NE-90,70-83.

Kozlowski, T.T. 1971. Growth and development of Trees.vol II New York: AcademicPress.54-55pp.

Krishnamurthy, T., Juyal, S.P. and Upadhaya, L.P. 1971. A review of some investigations on pines for their oleoresin. In seminar on the role of pine resin in the Economic and Industrial Development of India, 13-14th April, Vigyan Bhawan, New Delhi. Q1-Q35.

Kuruwanshi, V.B. and Katiyar, P. 2017. Establishment of sustainable gum tapping techniques in dhawda (*Anogeiussus latifolia*) using ethephon. *Trends in Biosciences*, 10(6): 11376- 11380.

Kuruwanshi, V.B., Katiyar, P. and Khan, S. 2017. Scientific Approaches of Gum Tapping in Gum Karaya (*Sterculia urens* Roxb.) for High Gum Production. *Int. J. Curr. Microbiol*. App. Sci. 6(8): 3366-3374.

Langenheim, J.H. 2003. Plant Resins: Chemistry, Evolution, *Ecology and Ethnobotany*. Timber Press, Portland.

Lekha, C. 2002. Standarization of borehole method of oleoresin tapping in chirpine (*Pinus roxburghii* Sargent). M.Sc. Thesis, University of Horticulture and Forestry, India.

Lekha, C. and Sharma, K.R. 2010. Healing of Boreholes in *Pinus roxburghii* Sarg. *Indian Forester*,140(9):369-373.

Li, Z., 1991. Effect of resin tapping on timber growth. Yunnan For. Sci. Technol., 3: 78-82.

Li, Z., Zhu, W., Fan, Y.C., Ye, J.L. and Li, G.H. 2014. Effects of pre and post-treatment with ethephon on gum formation of peach gummosis caused by *Lasiodiplodia theobromae*. *Plant Pathology*, 63(6): 1306-1315.

Lohani, D. N. 1968. Factors affecting yield of resin of chirpine. UP For, Leaflet For. Dep., Nainital 17: 19.

Lohani, D. N. 1973. Resin tapping research. A review of Pastwork and the current approach. *Proc. First Conf.* Dec. 6-10, Dehradun.

Lohani, D.N. 1968.Factors affecting yield of resin of Chirpine, UP Forest, Leaflet Forest Department, Nainital 17-19.

Lohani, D.N. 1985. Resin tapping in Chir pine (*Pinus roxburghii*). U.P. Forest Bulletin. Lucknow No 51-53.

Lohani, D.N. 1984. Resin Tapping research a review of past work and the current approach. Proc 1stconference. Dehradun.649-656 pp.

Magini E. 1958. Resin tapping - its advantage and disadvantages technical and economical aspects. Italy: research on the tapping of the Mediterranean Pines. 6th Sess. FAO & Jt. Subcomm. Medit. For. Prebl. Madrid No.FAO/SCM/67-B,

Maheshwari, P. and Konar, R.N.1971. Pinus. New Delhi: Council of Scientific and Industrial Research 130 p (Botanical Monograph no 7) Illustrations, map Geog 1-4, 6. Systematics: Gymnospermae (Pinus).

Mathauda, G.S. 1956. Factors governing the resin production of chir pine. Proc. 9th Silv. Conf. Dehradun. 129-136 pp.

Mathauda, G.S. 1961. Influence of climate conditions on resin yield from chir pine. *Indian Forester*, 87(1): 20-25

Mc Reynolds, R.D. 1971.Heritability and Seasonal changes in Viscosity of slash pineoleoresin. U.S. Dept. *Agric. For. Serv. Res*. Notes SE-147.

McReynolds, R.D. and Kossuth, S.V. 1984. CEPA in Sulphuric acid paste increases oleoresin yields. *Southern Journal of Applied Forestry*. 8(3): 168-172

McReynolds, R.D. and Kossuth, S.V. 1985. CEPA in Sulphuric acid paste increases oleoresin yields. *Southern Journal of Applied Forestry*.9(3): 170-173.

McReynolds, R.D. and Kossuth, S.V. 1984. CEPA in Sulphuric acid paste increases oleoresin yields. *Southern Journal of Applied Forestry*. 8(3): 168-172

Messari, A. and Saya. I. 1960. The anatomical and Physiological mechanism of resin tapping III. Mechanism of the immobilization and drainage of the resin after wounding**.**

Mirov, N.T.1945. Effect of the crown on the composition of oleoresin in Pines. *Tour For*. 43: 35-38.

Mishukov, N.P. and Kulakov, V.E. 1970. Individual variation in *Pinus sibirica* as regards resinyield. *Izv. Sib. Otd.* AN SSSR (10) (Ser. Biol. Nauk No. 2), (62-6)

Miyamoto K., Kotake T., Sasamoto M., Saniewski M. and Ueda J. (2010). Gummosis in grape hyacinth (*Muscari armeniacum*) bulbs: hormonal regulation and chemical composition of gums. *J.Plant Research,* 123(3): 363-370.

Mocak, J., Jurasek, P., Phillips, G.O., Varga, S., Casadei, E. and Chikemai, B.N.1998. The classification of natural gums. X. Chemometric characterization of exudate gums that conform to the revised specification of the gum Arabic for food use, and the identification of adulterants. *Food Hydrocoll* 12:141–150.

Mohsenin, N.N. 1986. Physical properties of plant and animal material. 2nd revised and updated addition. Gordon and breach science publication, New York, P. 711.

Moulalis, D.1981. Variation in resin production of Aleppo pine in Kassandra-Chalkidiki. *Ann. Regional Sci*., 19: 467-488.

Murtem, G., 1998. Studies on the effect of morphological parameters on oleoresin yield in Chirpine *(Pinus roxburghii* Sargent). M.Sc. Thesis, University of Horticulture and Forestry, India.

Mutton, R.W. 1922.Relationship between diameter of tree and gum yield. U.S. Dep. Agril.Bull.1061.

Nair, M.N.B., Bhatt, J.R. and Shah, J.J. 1985. Induction of traumatic gum cavities in sapwood of the Neem (*Azadirachta indica* A. Juss.) by ethephon and paraquat. *Indian Journal of Experimental Biology*, 23: 60-64.

Nayak, A.P. and Prajapati, R.K. 2020.Standardization of sustainable oleogum resin tapping technique in Salai (*Boswellia serrata* Roxb.) from tropical dry deciduous forest of Chhattisgarh, *Int. J. Curr. Microbiol* and *App. Sci*, 9(10):1- 16.

Nebeker, T.E., Schmitz, R. F. and Tisdale, R. A. 1995. Comparison of oleoresin flow in relation to wound size, growth rates and disease status of lodgepole pine. *Can. J Bot.* 73(3): 370-375.

Nimkar, A.U. and Sharma, K.R. 2007. Analysis of turpentine and rosin of high resin yielders and check trees in Chir pine (*Pinus roxburghii*), *Indian Forester*, 134(1): 41-50.

Olien, W.C. and Bukovas, M.J. 1982. Ethephon induced gummosis in sour cherry (*Prunus cerasus* L.) 1. Effect of xylem function and shoot water status. Plant physiol. 70: 547-555.

Papajiannopoulos, A. 1997. The future of resin tapping in Greece. *Ann. Regional Sci*., 37: 233-239.

Pejoski B. 1956. Comparative studies on resin tapping of *Pinus nigra* and *Pinus sylvestris* at Mariova. *God. Zhorn. Zemj. Sum. Fak. Univ. Skopje. (Sum.)* 10:17-125.

Perry, J.P. 1992. The Pines of Mexico and Central America. Timber Press. 41(1):170-171. http://www.jstor.org/stable/1222523.

Persad, V. 1983. Rill method of resin tapping and storage obtained from Chirpine (*Pinus roxburghii* Sargent). M.Sc. Thesis, HPKVV, Palampur.68p.

Peters, W. J. 1971. Variation in oleoresin yielding potential of selected Slash Pines. *Forest Science*,17(3):306-307.

Philippou, I. 1986. Chemistry and Chemical Technology of Wood. Giachoudi Giapouli Publ., Greek, pp: 231-239.

Prasad, J. and Joshi, H. B. 1974. Effect of Chemical stimulants on Chir resin yield, *Hul for* 100(4):246-249.

Pratt, H.K. and Goeschl, J.D. 1969. Physiological roles of ethylene in plants. Ann. Rev. *Plant physiol*. 20: 541-584.

Prokazin, E.P. 1958. From *Pinus sylvestris* with a high resin yield. *Lesn.Hoz*.11(4): 19-21.

Rajkhowa, S. and Khan, W. 1962. The effect of periodicity, length and breadth and depth of freshening on the resin yield from young *Pinus roxburghii* Sarg. and seasonal response, *Indian Forester*, 88(2):125-129.

Rawat, G. S. 2001. A manual of borehole resin tapping technique in Chir pine (*Pinus roxburghii*), Forest Research Institute, Dehradun, India.

Roberts, D.R.1973.Inducing light wood in pine trees by paraquat treatment, U.S. Forest Service Research Note, SE-191.

Romanovskij, G.G. and Bestemjannikov, Ju. V. 1968. Effect of stem diameter on resin yield when tapping with H_2SO_4 Gidro. *Lesohim. Prom*, 28(8):12-13.

Roychoudhury, N., Gupta, D., 2016.Achanakmar-Amarkantak biosphere reserve, India: A diverse tropical forest ecosystem. *Van Sangyan*,3(6): 1–9.

Roychoudhury, N., Sharma, R., Yadav, D. K. and Kushwaha, D. K. 2012. Achanakmar-Amarkantak Biosphere Reserve: a paradise of Biodiversity. *Vaniki Sandesh* 2 (4): 27-37.

Roychoudhury, N., Sharma, R. and Gupta, D.K. 2016. Achanakmar-Amarkantak Biosphere Reserve, India: A diverse Tropical Forest Ecosystem. *Van Sangyan* 3(6):1-9.

Samanta, J.N., R. Saravanan, Gajbhiye, N.A. and Mandal, K. 2012. Growth, photosynthetic competence and oleo-gum resin production of guggal (*Commiphora wightii*) across soil moisture and nitrogen gradient. *J. Trop. For. Sci.*, 24: 538-545.

Santos, Wd., Lemos Souza, D.C., Moraes, M.Td. and Ananda Virginia de Aguiar, A.V.de. 2016. Genetic variation of wood and resin production in *Pinus caribaea* var. hondurensis Barret & Golfari Silvae Genetica,65-13:1-37.

Schopmeyer, C. S. and Larson, P.R. 1954. Predicting yields of gum from measurements of trees. *Naval Store Review*,64 (7): 10-17.

Schopmeyer, C. S., Mergen, F., and Evans, T. C.1954. Applicability of Poiseuille's law to exudation of oleoresin from wounds on slash pine. *Plant Physiol*. 29: 82-87.

Schopmeyer, C.S. 1953. The characteristics of high yield trees. *Naval stores Review*, 63(12).

Sehgal, R.N. and Chauhan, S.K. 1993. Genetic analysis of stand and nursery characters of selected seed stands of Chirpine. *Indian J. Trop*. Bioi. 1: 221-225.

Seth, S.K. and Lohani, D.N. 1971. The history production and potential of resin in India. Proc. Seminar on the Role of Pine resin in the economic and industrial development of India.

Shah, J.J. 1983. Gum, resin and gum-resin secretion in plant. *Acta Bot. Ind*, 11: 91-96.

Shah, J.J. and Setia, R.C. 1976. Histological and histochemical changes during the development of gum canals in *Sterculia urens*. *Phytomorphology,* 26: 151-158.

Sharma, K.R. and C. Lekha, 2013. Tapping of *Pinus roxburghii* (Chir Pine) for Oleoresin in Himachal Pradesh, India. *Adv. For. Lett*., 2: 51-55.

Sharma, K.R., D.S. Meena and C. Lekha, 2014. Effect of tree diameter and number of boreholes on oleoresin yield in *Pinus roxburghii* Sargent. *Indian Forester*, 140: 875-881.

Sharma, O. P. 2002. Efficient resin tapping and its processing in Himachal Pradesh: an overview. *Indian Forester*, 128 (4): 371-378.

Sharma, D.P. 1982. Resin tapping technology (*Pinus roxburghii*). M.Sc. Thesis submitted to HPKVV, Palmpur, 43p.

Sharma, K.R. 1987. Tapping technique for oleoresin in Blue Pine. Ph.D. Thesis, Dr.Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P), 90p.

Sharma, K.R. and Kaushal, A.N. 1991. Effect of freshening period and acid treatment on oleoresin yield from Blue pine (*Pinus wallichiana* A.B.Jackson). *Indian Journal of Forestry*,14(1):8-15.

Sharma, K.R. and Kaushal, A.N. 1992. Influence of some climatic factors on oleoresin yield from *Pinus wallichiana* AB Jackson. Research Development Report, 9(1-2):104.

Sheikh, M.I. 1978. More efficient resin production from *Pinus roxburghii*. *Pakistan Journal of Forestry*. 28(1);3-60.

Sheikh, M.I. 1979. Stimulation of flow of resin in *Pinus roxburghii* with chemicals. Project No. PK-FS-30. *Pakistan Forest Institute*, Pakistan.

Singh, L., Kasture, J., Singh, U.S. and Shaw, S.S. 2011.Ethnobotanical practices of tribal in Achanakmar-Amarkantak Biosphere Reserve. *Indian Forester*, 137(6):767- 776.

Singh, P., Fasih, M. and Prasad, G. 1982.Insect pests of exotic pines in India. Indian Forester, 108(1);93-107

Singhal, V. 1996. Screening of Chir pine half sib progenies for economically important traits. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (HP), India.

Sinha, G. 2017. Studies on Drying Characteristics of Babul Gum (*Acacia nilotica*). M.Sc (Agril. Engg.) Thesis. Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

Snow, A. G. 1944. The use of chemical stimulants to increase gum yields in slashand longleaf pines. U.S. Forest Serv. South. *Forest Exp. Sta. Occas*. Pap. 106, 36 pp.

Steele, R. J. 1869, Sap sprout, US Patent 87, 219.

Stephan, G. and Betancourt, Y. 1981. Resin yield of *P. caribaea*. and its possibilities. Stephan, G.O. 1967. The possibility of assessing the resin productivity in pines. *Arch. Forester*. 16(2): 119-127

Stephen, G. 1958. Resin tapping investigation on *Pinus sylvestris*.

Stephen, G. 1985. The effect of Camposan as a stimulant in resin tapping. *SozialisticheForstwirt-schaft*.35(9):280-281.

Strange, J.D. 1958. Report of Government of India on resin tapping. Rome.

Swain, D. and Patnaik, T. 1998. Economy of Resin tapping from *Pinus kesiya* in Orissa, India. *Indian Forester*,124(7):511-515.

Swalesh, M. and Indra, D. 1979. Indian wood turpentine oil scope, production and chemical composition. *Indian Perfumer*,23(2): 79-83.

Tadesse, W., Nanos, N., Aufion F.J., Alia, R. and Gil, L.2001. Evaluation of High Resin Yielders of *Pinus Pinaster* Ait. *Forest Genetics,* 8(4): 271-278.

Teresina, T. A. 1966. Relation of morphological characters of *Pinus sylvestris* to its resin yield. *Lesn. Z. Arhangel'sk* ,9(2): 13-14.

Teshome, T. 2011. Analysis of resin and turpentine oil constituents of *Pinus patula* grown in Ethiopia. Agriculture and Forestry Issue,3(1): 38-48.

Troup, R.S. 1921. The Silviculture of Indian Trees. ICFRE, Dehradun.

True, R. P. and Schopmeyer, C. S. 1958. Role of chemical treatment in stimulating resin flow. *Forest Sci.* 4(4): 296-305

True, R. P. and Schopmeyer. C. S. 1958. Role of chemical treatment in stimulating resin flow. *Forest Sci*. 4(4): 296-305

U.S. Patent NO. 3359681. 1967. Composition and method for stimulating flow of pine gum.

Upadhyay, M. A. 1957. Progress of *Pinus longifolia* resin industry in Uttar Pradesh. *Indian Forester*, 83(1): 26-33

Valentini, G. 1957. Anatomical observations on resin tapped pines. *Ann. Acad. Ital. Sci. For*. 6: 283-291.

Venkaiah, K. and Shah, J.J. 1984. Distribution, development and structure of gumducts in *Lannea coromandelica* (Houtt.) Merril. Ann. Bot. 54: 175-186.

Venkaiah, K. 1991. Ethephon in liquid Sulphuric acid increases Oleoresin Yield in Chirpine. *Indian Forester*.117(2):120-123.

Verma, V.P.S. 1971. Use of H_2SO_4, paste in resin tapping of Chir pine. *Indian Forester*. 98(8): 458-461.

Verma, V.P.S. 1978. Use of H_2SO_4, paste in resin tapping of Chir pine. *Ind. For,* 98(8): 458-461.

Verma, V.P.S. and Suri, R.K. 1978. Geographic variation in the chemical composition of turpentine oil of Chir pine (*Pinus roxburghii* Sargent). *Indian Perfume*, 22(3): 179-81.

Verma, V.P.S. and Payal, P.S. 1976. Resin yield potential of Chir Pine (*Pinus roxburghii* Sargent). *Indian Forester*. 102(10):712-720.

William, C.M. 2002. Products of resin Processing. *Forests and Forest plants,* 2(1-10).

Wolter, K.W. and Zinkel, D.F. 1984.Observations on Physiological mechanisms and chemical constituents of Induced oleoresin synthesis in *Pinus resinosa*. *Can J.For*. Res.1(3).452-458.

Wolter, K.E. 1977. Ethelyne potential alternative to *Bipyridilium herbisides* for inducing light wood in red Pine. *Proc Annu. Lightwood Res*. Conf.90-99 pp.

Wright, J.W. 1981. Genetic variation of height diameter ratio in scots pine. For. Dept. Mechegan State Univ., USA. pp113-121

Yadav, B.B., Billore K.V., Joseph T.G. and Chaturvedi D.D. 1999. Cultivation of Guggulu. CCRAS, New Delhi.

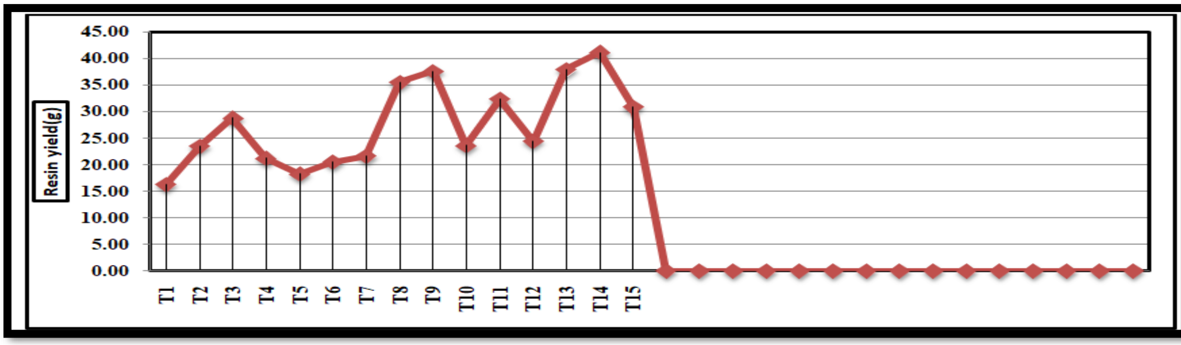
Yadav, R.K. 2008.Working Plan for the Anuppur Forest Division 2008 to 2018. Madhya Pradesh Forest Department.

Zafar, I., Fatima, A., Khan, S. J., Rehman, Z. and Mehmud, S. 2010. GC-MS studies of needles essential oil of *Pinus roxburghii* and their antimicrobial activity from Pakistan. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 9(3): 468-473.

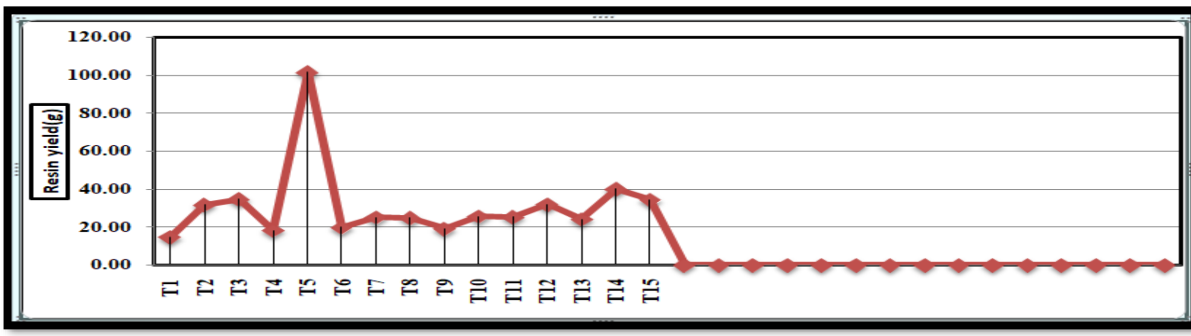
Zajlder, J.1995. Improving the Quality of crude Resin of *Pinus syslvestris*. *Sylwan*, 98(4): 279-293.

Zamski, E. 1970. The effect of micro climatic conditions on resin duct formation and resin A secretion in *Pinus halepensis* Mill. La- Yaaran. 20 (1/2): 7-18

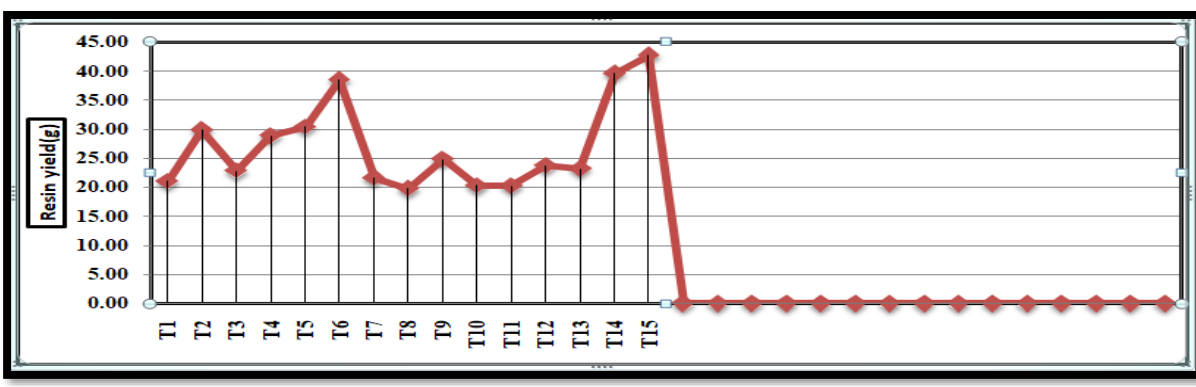
APPENDIX



Mean resin yield per tree by using quarre method of tapping in *Pinus patula*

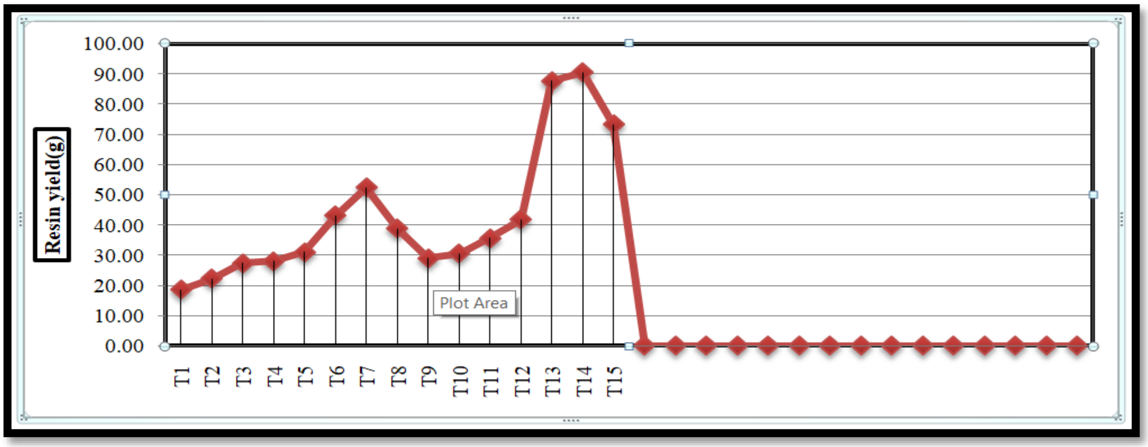


Mean resin yield per tree by using triangular method of tapping in *Pinus patula*

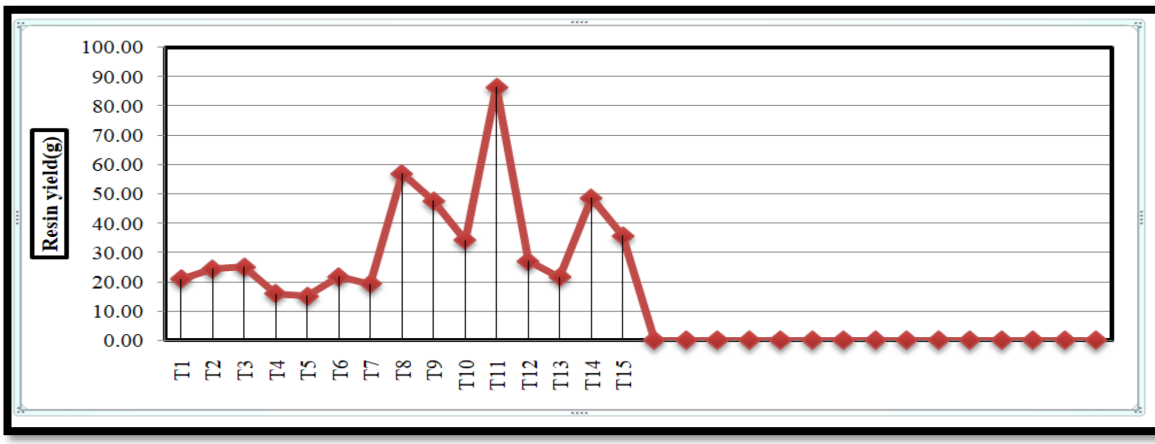


Mean resin yield per tree by using Borehole method of tapping in *Pinus patula*

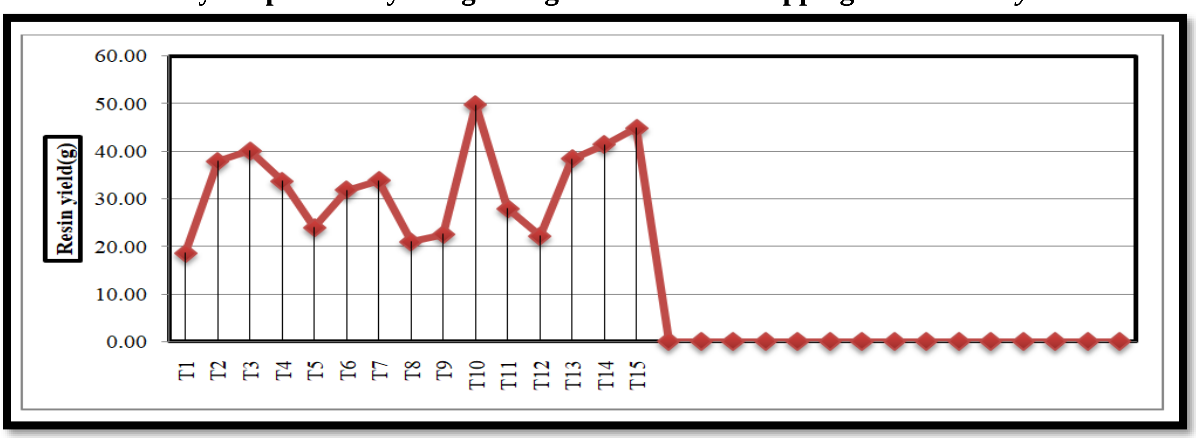
APPENDIX –I Per tree resin yield from *Pinus patula* by using various methods of tapping



Mean resin yield per tree by using quarre method of tapping in *Pinus kesiya*

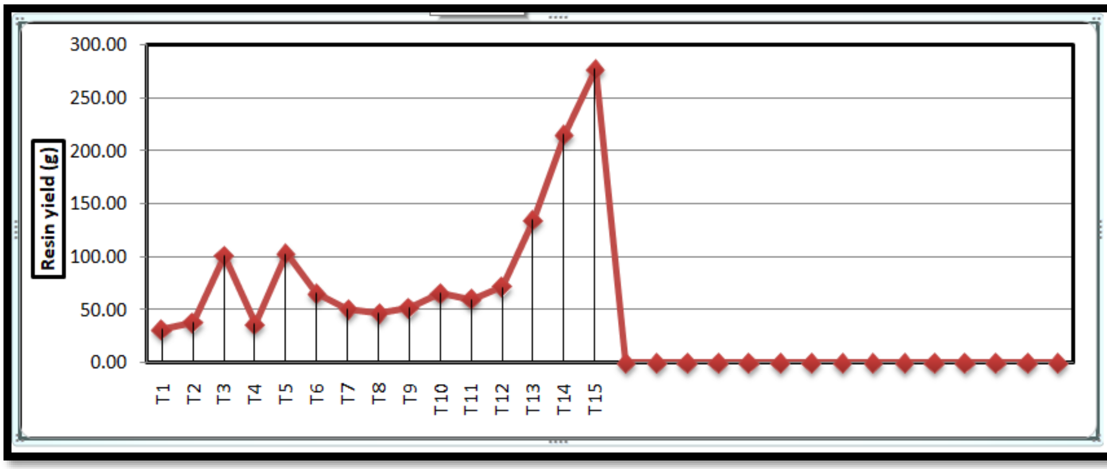


Mean resin yield per tree by using triangular method of tapping in *Pinus kesiya*

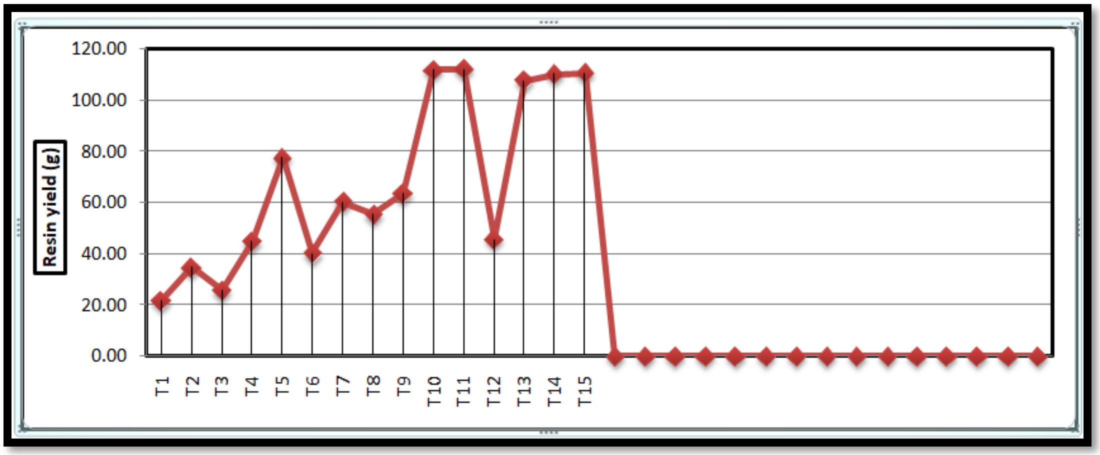


Mean resin yield per tree by using Borehole method of tapping in *Pinus kesiya*

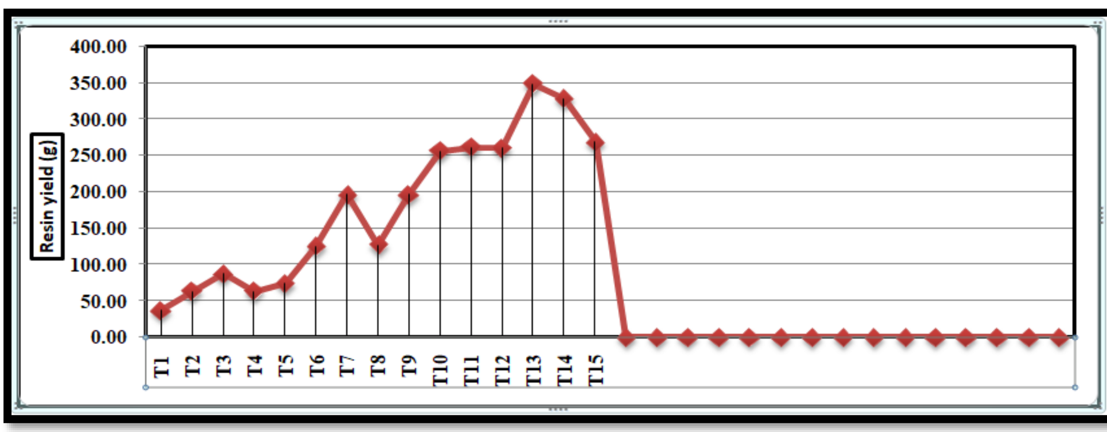
APPENDIX –II Per tree resin yield from *Pinus kesiya* by using various methods of tapping



Mean resin yield per tree by using Quarre method of tapping in *Pinus roxburghii*



Mean resin yield per tree by using triangular method of tapping in *Pinus roxburghii*



Mean resin yield per tree by using Borehole method of tapping in *Pinus roxburghii*

APPENDIX –III Per tree resin yield from *Pinus roxburghii* by using various methods of tapping

Pinus patula	Ethephon	H_2SO_4	Ethephon+H_2SO_4	Total
Quarre shape	411.59	359.9	1711.52	2483.01
Triangular shape	485.95	836.8	1500.88	2823.63
Bore hole shape	442.05	585.97	1405.33	2433.35
Total	1339.59	1782.67	4617.73	7739.99

Appendix-IV: Total yield of resin in both the year of tapping from *Pinus patula* trees

Pinus kesiya	Ethephon	H_2SO_4	Ethephon+H_2SO_4	Total
Quaree shape	409.16	613.57	2878.48	3901.21
Triangula shape	422.64	317.04	2272.14	3002.82
Bore hole shape	534.03	536.61	1811.49	2882.13
Total	1365.83	1467.22	6953.11	9786.16

Appendix-V: Total yield of resin in both the year of tapping from *Pinus kesiya* trees

Pinus roxburghii	Ethephon	H_2SO_4	Ethephon+H_2SO_4	Total
Quaree shape cut	1023.63	1234.43	5842.79	8100.85
Triangular shape	492.86	975.84	4665.12	6133.82
Bore hole shape	1125.36	1514.66	13453.58	16093.6
Total	2641.85	3724.93	23961.49	30328.27

Appendix-VI: Total yield of resin in both the year of tapping from *Pinus roxburghii* trees

RESUME

Name	:	Amit Prakash Nayak
Father's Name	:	Pradeep Kumar Nayak
Mother's Name	:	Anita Nayak
Date of Birth	:	30thMarch 1996
Present Address	:	At/Po-Biripata,Via-Priripur,Dist-Jajpur,Odisha,Pin-755013
Mobile No.	:	7978918695
Email ID	:	amit30396@gmail.com
Permanent Address	:	At/Po-Biripata,Via-Pritipur,Dist-Jajpur,Odisha,Pin-755013

Academic Qualification

Degree	Year	Score (%)	University/ Board
M.Sc. (Forestry)	2019	83	IGKV, Raipur, Chhattisgarh
B.Sc. (Forestry)	2017	81.8	O.U.A.T. Odisha
Higher Secondary	2013	69.50	C.H.S.E. Odisha
Matriculation	2011	73.83	B.S.E. Odisha

Professional Experience (if any):	Forest Work Experience, Wildlife Census Experience, Certificate course on Geo-Informatics for Biodiversity Conservation Planning
Publications:	Research papers (08),Review paper(01)Book chapters (02),
NET Qualification:	ASRB NET(Agroforestry) 2020(55.56%)

Signature