DEVELOPMENT OF TAPPING TECHNIQUES FOR SUSTAINABLE EXTRACTION OF BIOPOLYMERS FROM MAJOR GUM PRODUCING TREES OF MUNGELI REGION OF CHHATTISGARH

M.Sc. (Ag) Thesis

by

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Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Manendra Kumar Ghritlahare

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CERTIFICATE-I

This is to certify that the thesis entitled **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is are cord of the bonafide research work carried out by **Manendra Kumar Ghritlahare** under my/our 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 has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

P. Katiyar
Chairman

Date: 17/07/2017

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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CERTIFICATE – II

This is to certify that the thesis entitled **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** submitted by **Manendra Kumar Ghritlahare** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants has been approved by the external examiner and Student's Advisory Committee after oral examination.

2.9.17
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Director of Instructions ________

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(Manendra Kumar Ghritlahare)

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LIST OF SYMBOLS

Symbols	Description
%	Per cent
@	At the rate
0C	Degree Celsius
cm	Centimetre
cp	Centipoise
et al.	Et alibi
etc.	Etcetera
Fig.	Figure
g	gram
h	Hour
ha	Hectare
i.e.	That is
kg	Kilogram
m	Metre
mg	Milligram
min.	Minute
ml	Millilitre
mm	Millimetre
m2	Square metre
NS	Non significant
Qtls	Quintals
t.	Tonnes
t/ha	Tonnes per hectare
ppm	Parts per million
rpm	Revolutions per minute
viz.,	Namely
vol.	Volume
wt.	Weight

LIST OF ABBREVIATIONS

Abbreviation	Description
Agri.	Agriculture
AOAC	Association of Official Analytical Chemists
BIS	Bureau of Indian Standard
C.G.	Chhattisgarh
Conc.	Concentrated
$CuSO_4$	Copper sulphate
D.F.	Degree of Freedom
FAO	Food and Agriculture Organization
FAA	Formalin Acetic Acid Alcohol
Fig.	Figure
HCl	Hydrochloric acid
H_2SO_4	Sulphuric acid
ICAR	Indian Council of Agricultural Research
IGKV	Indira Gandhi Krishi Vishwavidyalaya
K_2SO_4	Potassium sulphate
MSS	Mean Sum of Square
NTFP	Non Timber Forest Produce
pH	Physical hydrolysis
RH	Relative Humidity
SS	Sum of Square
SV	Source of Variance
T	Treatment
Temp.	Temperature

THESIS ABSTRACT

a)	Title of the Thesis	:	Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh
b)	Full Name of the Student	:	Manendra Kumar Ghritlahare
c)	Major Subject	:	Plant Physiology
d)	Name and Address of the Major Advisor	:	Dr. (Smt.) Pratibha Katiyar College of Agriculture, IGKV, Raipur, (C.G.)
e)	Degree to be awarded	:	Master of Science in Agriculture (Plant Physiology)

Signature of Student

P. Katiyar

Signature of Major Advisor

Date : 17/07/2017

Signature of Head of Department

ABSTRACT

Collection of gum/resin exudates from trees is important livelihood sources for local dwellers. Traditional gum tapping is crude and unscientific and deep incision cruse severe injury to trees and leads to death of the tree therefore the population of trees decreasing day by day. Dhawara (*Anogeissus latifolia*), Rohina (*Soymida febrifuga* Roxb.), Saja

(*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) are important gum producing trees of Chhattisgarh and its gum having considerable pharmaceutical, commercial and industrial importance. Therefore, the study was under taken to develop scientific and safe sustainable tapping techniques for extraction of biopolymer for major gum producing trees of Mungeli region of Chhattisgarh. The study was under taken four experimental trees Dhawara, Rohina, Saja and Chirounji in two season winter and summer. The three mechanical T_1 (traditional, single cut with axe), T_2 (double cut with axe), and $T_{3,}$ semi circle/arc (12 cm Length x 6 cm width x 4 cm deep) where applied at 1m DBH to gum tapping. For chemical methods of tapping various five gum inducing or enhancer *i.e.* T_1 (distilled water), T_2 (ethephon @ 3.9%), T_3 (H_2SO_4 @ 1%), T_4 (ethephon @ 3.9% + H_2SO_4 @ 1%), T_5, HCl @ 1% 4 ml was injected by drill method (at 4 cm deep and 4 cm diameter slant hole) and gum inducer was injected by injector and covered the hole with clay. The observation was recorded *i.e.* diameter of trunk at 1m DBH (tree girth), elevation of tree, season of application of treatments, direction of application, temperature, RH%, time required for starting exudation of biopolymers, flow rate of gum production/tree. The physical properties and physicochemical properties *i*.e. solubility, viscosity, pH, ash content and protein percent was analyzed in gum samples obtained from mechanical, traditional and chemical methods of tapping and compared for their flow rate, production of gum/tree and physical and physicochemical properties, it was observed that the all the four experimental trees can be tapped in winter as well as summer using ethephon @ 3.9% or ethephon @ 3.9% + H_2SO_4 @ 1% for maximum production of biopolymers in Dhawara, Rohina, Saja and Chirounji but Saja can be tapped mechanically by semi arc method of tapping for high production of gum. However, the viscosity, solubility was not changed significantly in chemical tapped gum samples.

शोध सारांश

शोध ग्रंथ का शीर्षक	:	"छत्तीसगढ़ के मुंगेली क्षेत्र के प्रमुख गोंद उत्पादन वाले पेड़ों से जैवबहुलक के टिकाऊ निकासी के लिए दोहन तकनीकों का विकास"
छात्र का पूरा नाम	:	मनेन्द्र कुमार धृतलहरे
मुख्य विषय	:	पादप कार्यिकी
प्रमुख सलाहकार का नाम और पता	:	डॉ. प्रतिभा कटियार, प्राध्यापक, पादप कार्यिकी विभाग, कृषि महाविद्यालय, ई.गां.कृ.वि. रायपुर, (छ.ग.)
प्रदान की जाने वाली उपाधि	:	कृषि विज्ञान में स्नातकोत्तर (पादप कार्यिकी)

छात्र का हस्ताक्षर

P. Katiyar

प्रमुख सलाहकार का हस्ताक्षर

दिनांक : 17/07/2017

विभागाध्यक्ष के हस्ताक्षर

सारांश

गोंद उत्पादन करने वाले वृक्षों से गोंद का निष्कर्षण संग्रहण वहां के स्थानीय निवासियों के लिए महत्वपूर्ण आजीविका का स्रोत है प्राकृतिक गोंदो का दवा उद्योग एवं अन्य औद्योगिक उपयोग हाल के वर्षों में काफी बढ रहा है गोंद निःस्त्राव की पारंपरिक विधि कच्ची एवं अवैज्ञानिक है गहरा चीरा असमयोजित निष्कर्षण इनके जीवन को तथा प्राकृतिक आवास को भी प्रभावित करता है। अतः छत्तीसगढ के मुंगेली क्षेत्र में पाए जाने वाले प्रमुख गोंद उत्पादक वृक्षों जैसे धवरा

(एनोजिसस लेटिफोलिया राक्स) रोहिना (सोयमिडा फेब्रीफ्यूजा राक्स) शाजा (टर्मनेलिया टोमेन्टोसा राक्स) तथा चिरौंजी (बुचनेनिया लेनजान स्प्रेन्ज) का अध्ययन गोंद के निष्कर्षण की पारंपरिक एवं नई मशीन एवं रसायनिक तकनीकों के मानकीकरण के लिए तुलनात्मक अध्ययन किया गया। इन प्रजातियों में अधिकतम गोंद प्राप्त करने के लिए मशीन तकनीक टी1, कुल्हाड़ी द्वारा एक काट, टी2, कुल्हाड़ी द्वारा दो काट तथा टी3, अर्धचंद्राकार काट एवं पॉच रासायनिक विधियां टी1 (आसवन जल 4 मिलीलीटर), टी2 (ईथेफोन 3.9 प्रतिशत), टी3 (सल्फ्यूरिक अम्ल 1 प्रतिशत), टी4 (ईथेफोन 3.9 प्रतिशत + सल्फ्यूरिक अम्ल 1 प्रतिशत), टी5, (हाइड्रोक्लोरिक अम्ल 1 प्रतिशत) वृक्षों के तनों पर 1 मीटर की ऊंचाई पर गिरमिट द्वारा छिद्र बनाकर उसमें रसायनों को 4 मिलीलीटर डालकर फिर उस छिद्र को गीली मिट्टी द्वारा बंद करके किया गया, साथ ही वृक्षों के तनों की 1 मीटर जमीन की सतह के ऊपर की गोलाई तथा वृक्षों की लगे रहने की जगह की समुद्र सतह से ऊंचाई, तापमान, आर्द्रता एवं गोंद निकलने का समय, मात्रा, स्त्रावण की दर, गोंद की मात्रा प्रति वृक्ष तथा प्राप्त गोंद का भौतिक एवं रासायनिक परीक्षण किया गया तथा उनमें रासायनिक विधि द्वारा प्राप्त गोंद के भौतिक एवं रासायनिक गोंद में क्या परिवर्तन आया उसमें भी अध्ययन किया गया जिसके लिए उस में घुलनशीलता, लसीलापन, प्रोटीन तथा राख की मात्रा का भी विश्लेषण किया गया तथा यह पाया गया कि केवल मात्रा को छोड़कर अन्य तीनों ही वृक्षों में गोंद का निष्कर्षण रासायनिक विधि द्वारा टी4, ईथेफोन तथा सल्फ्यूरिक अम्ल के साथ–साथ उपयोग करने से अधिक मात्रा में अच्छी वर्ग का उत्तम गुणवत्ता वाला गोंद प्राप्त किया जा सकता है, जबकि मात्रा में यदि अर्धचंद्राकार काट बनाकर (12 सेंटीमीटर लंबाई x 6 सेंटीमीटर चौड़ा x 4 सेंटीमीटर गहरा) काट करने पर रासायनिक विधि की तुलना में अधिक गोंद प्राप्त होता है। साथ ही प्राप्त गोंदो का रासायनिक परीक्षणों से ज्ञात हुआ की गोंद की गुणवत्ता पर भी गोंद के निष्कर्षण हेतु प्रयोग किए गए रसायनों का विशेष प्रभाव नहीं पड़ता है।

CHAPTER - I

INTRODUCTION

Gum and resins are low volume, high value produce and important non-timber forest produce (NTFP) and viable income sources for thousands of forest dwellers, especially tribals in India (Pal *et.al* 2012). Gum are the natural biopolymers (plant exudates) having number of applications in food and pharmaceutical industry. Most of them are regarded as safe by The FDA (Food and Drug Administration, USA) and biodegradable. Because of their biocompatibility, nontoxic, low cost, environment friendly processing and local availability, these are preferred over synthetic polymers in food, pharmaceutical and cosmetic industries. Gum trees are economically important and found in tropical moist and dry deciduous forests, produce a significant quantity of gum, which are widely used as industrial, food and medicinal purposes in India (Bhattacharya *et. al.* 2012). Gum production increases at high temperature and limited moisture (Sao, 2012). Gum production is a pillar of family economy and considered as an income-generating source that requires only a low input of work after the rainy season (Gaafar, 2005).

India is a rich centre of plant bio-diversity having more than 45,000 plant species including about 120 gum and resin yielding plants. Indonesia, India and China are among the world's major producer of gums and resins. India produces annually about 2,81,000 tons of gums and resin about 1500 tons of gum-resins. Annual average export during 2001-02 to 2005-06 was Rs 7,848 million. This included Rs. 1,371 million of resins and Rs. 6,363 million of gums. India is traditional largest producer of lac, guar gum and karaya gum. In recent years, due to the mature trend there has been a revival of interest in natural resin and gums extracted from forest by rural and tribal people who depend on these resources to sustain their livelihood. The gross value of goods and services provided by the forestry sector is estimated at an average of Rs. 26,330 crores *i.e.* about 2-37 % of GDP of this recorded forest revenue about 50 million population inhabiting forests and sub-forest areas and 70% of employment in the sector is in minor forest produce (about 1.6 million man days). It is and admitted fact that neither the forest nor the tribals poor inhabiting these should be remove for environmental protection. The only approach appear to be developing minor forest products like natural resins and gums based economic activities in these areas to uplift the poor and maintain required forest cover or vegetation.

The major commercially important gums in good quantity are sourced from the central Indian forests, consisting of states like Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Orissa, Jharkhand and Bihar and to some extent Gujarat and Rajasthan. Chhattisgarh State is rich in forest and has vast variety of minor forest products to favorable agro climatic conditions resulting in good forest area *i.e.* 43.6 % of total (Bhattacharya *et. al.* 2012). Bastar region of Chhattisgarh is inhabited by more than 67 % of tribal population and they are dependent on forest. Annual rainfall varies from 1100-1700 mm. Chhattisgarh Plain Zone comprises Durg, Raipur, Rajnandgaon, Bilaspur, Raigarh, Kanaker, Sarangarh and Gharghoda tehsil of Raigarh. Chhattisgarh topography includes landforms of mountain ranges, plateau region and plain land areas.

Chhattisgarh is a pioneer state of India and has vast variety of minor forest produce to favourable agro climatic conditions resulting in good forest area *i.e.* 43.6 % of total. Gums are primarily categorized as Grade-I of Karaya (*Sterculia urens*) and Grade-II of Dhawda (*Anogeissus latifolia*), Babool (*Acacia indica*) and Khair (*Acacia catechu*) in Chhattisgarh state. The above four gums are nationalized gums in the state and annual average gum production was 202.50 Qtls during 2011-12 (Anonymous, 2013). The gum producing forest divisions in the Chhattisgarh state are Bilaspur (Mungeli, Dindori, Ratanpur, Takhatpur, Lormi), Raipur, East Surguja (Balarampur), Marvahi (Kota), South Surguja, Raigarh (Khamariya, Milupara), Dharamjaigarh, Manendragarh, Rajnandgaon, Mahasamund, Dhamtari, Korea, Sukma, Bijapur, Dantewada and West Bhanupratappur. The collection charges to the collectors at collection centres are paid by the purchaser at the rate fixed by Chhattisgarh State Minor Forest Produce (Trading and Development) Co-operative Federation Limited, Chhattisgarh government and the collection rate of *Sterculia urens* is Rs. 22000/- per Qtl for garde I, Rs. 15000/- per Qtl for grade-II and Rs. 10800/- per Qtl for grade III and

Rs. 2900/- per Qtl for Dhawda gum, Rs. 1740/- per Qtl for Babool and Khair gum for the year 2015-16.

In traditional method of gum tapping in different parts of the world, a number of tapping spots on tree trunks and branches depending on its size are made and in the process plants get injured at various points and produce only few amounts of gum (Tadesse *et al.*, 2007). Traditionally, trees are tapped by blazing, stripping of the bark or making deep cuts in the base of the tree with axe. Trees are tapped to increase gum yield by making incisions in the bark or treating with gum enhancer (ethylene) or ethylene-releasing compound such as ethephon (2-chloroethyl-phosphonic acid). The idea to use ethephon as gum inducer came from the thought that if ethylene is supplied artificially to the tree *via* the application of ethephon, the developmental response to stress could be accelerated and consequently, more gum exudates could be obtained. Ethephon can mimic the effect of water stress, as it releases the stress hormone ethylene in plant tissues. The gum yield increases with increase in concentration of ethephon.

An introduction of new tapping methods using ethephon (2 chloroethyl-phosphonic acid), a plant growth regulator, which is safe, inexpensive and nontoxic have increased exudation of gum/gum-resin in certain plants such as *Anogiessus latifolia* (Dhawara), *Acacia senegal* (Babool), *Sterculia urens* (Karaya) and *Mangifera indica* (Mango). These methods also ensure the sustainable yield, regeneration and survival of the tapped trees. *Anogeissus latifolia* besides providing fuel wood and timber, the tree yields a valuable gum called gum ghatti. Gum ghatti (Dhawara) has been used in India for calico printing, in confectionery, ceramics, food and pharmaceuticals. An improved tapping method based on application of ethephon yielded about 466 fold increase in gum (Bhatt, 1987). Gum tapping using scientific methods of gum exudation not only increase the life span of the tree but also yields good quality gum of high International value (Gupta *et al.*, 2012).

Dhawara (*Anogeissus latifolia*) belonging to combretaceae family available in Chhattisgarh (Sarguja, Bijapur, Raipur, Mungeli, Bilaspur District). This is a tree of tropical and subtropical climatic regions; it grows throughout the sub-Himalayan tract up to an altitude of 1200 m above mean sea level (AMSL) in central India and a large part of the Indian Peninsula hills at an elevation of about 1200 m. It is one of the most useful trees in India. Its leaves contain large amounts of tannin which is used in India. The leaves are fed by *Antheraea paphia* moth which produces the tassar silk used for commercial importance. Chemically leaves, bark and heartwood yield quinic and shikmik acids; leaves con-tain gallotannin (90% - 95% of the tannins). The young leaves and shoots contain 50% tannins (dry basis). The bark contains 12% - 18% tannins. Heartwood contains gallic acid, ellagic acid, its derivatives, quercetinand-myricetin. The gum is mainly the calcium salt of a com-plex, high molecular weight polysaccharic acid. The tree is the source of Indian gum. The *Anogeissus latifolia* (Dhawara) plant produces a good amount of gum popularly known as Ghatti gum. The gum is gray to reddish gray in colour. This gum mainly consists of calcium salts of high molecular weight polysaccharides which on hydrolysis yields arabinose, galactose, mannose, xylose and glucuronic acid. The physicochemical study of this gum showed high viscosity which solely depends upon pH of the medium.

Rohina (*Soymida febrifuga* Roxb.) (Meliaceae) tree distributed mainly in the tropical areas of Asia and one of the most popular traditional medicines in India. Commonly called as Indian red wood is a monotypic genus endemic to India A clear gum from the bark forms good adhesive mucilage and a strong red fibre from it is used for making ropes (Wealth of India, 1952). (Wealth of India, 1952). *Soymida febrifuga* (Roxb.) is represented by one species from India and East tropical Africa. A lofty deciduous tall trees, grows up to 22-25 m in height and 2.5-3.0 m in girth. Bark is very tough, exfoliating in large plates or scales. Leaves 22-45 cm, impairpinnate, long, crowded at the ends of branches, branchlets with persistent leaf bases. Flowers are bisexual, greenish white in large axillary or terminal panicles. Fruit is a black, obovoid, woody, septifragally 5-valved capsule. Seeds winged at both ends. Sapwood is whitish and heart wood dark blood red to reddish brown with silver streaks with an oily feel, without characteristic odour or taste (Kirtikar and Basu, 2003) It is distributed in the dry forests of peninsular India right up to Kerala and also occurs in North west Central India down through peninsular Srilanka, Gujarat, Uttar Pradesh, Bihar and Central India extending northwards to Merwara, the Mirzapur hills and Chota Nagpur, Ceylon and

Chengalpattu, Coimbatore, Dharmapuri, Nilgiri, Ramanathapuram, Salem, Tiruchchirapalli-South West India. Yoganarasimhan (1996), Kirtikar and Basu (2003). Flower is greenish white in colour, in large terminal or axillary divertically branched panicles often equating the leaves. Fruits are 2.5 to 6 cm long, black, woody in colour, obovoid in shape with 5 celled and 5 valved with winged seeds. Heartwood is dark blood red to reddish brown in colour. The bark has a bitter taste and has been utilized to treat fevers by tribal community and as a bitter tonic for general debility.

Chironji (*Buchanania lanzan* Spreng.) belonging to family Anacardiaceae. Some parts of the plant are also used to cure diseases, for instance roots in diarrhoea, leaves for skin diseases and healing wounds, gum/resins in diarrhoea, and fruits in asthma and cough. Locals also earn money by collecting gum/resins and lac by rearing kussumi strain of lac on the chirounji tree. Its gum is also having very high medicinal importance and used for antiseptic cream. During summer when green fodder becomes unavailable, local inhabitants use its leaf as green fodder for their animals, especially buffalo, goat and sheep. Some parts of the plant are also used to cure diseases, for instance roots in diarrhoea, leaves for skin diseases and healing wounds, gum/resins in diarrhoea, and fruits in asthma and cough. Locals also earn money by collecting gum/resins and lac by rearing kussumi strain of lac on the chirounji tree.

Saja (*Terminalia tomentosa* Roxb.) belonging to family Combretaceae. Saja is largely remained unexplored. *Terminalia tomentosa* Roxb. (Synonyms: *Terminalia alata* Heyne ex Roth, *Terminalia crenulata* Roth*, Terminalia elliptica* Willd.) is a member of the family of Combretaceae (Nadkarni *et al*, 1976). It is available specially in the humid regions of West Bengal and Orissa and also in the sub Himalayan regions including Sikkim (Jain *et al.* 2010.) Bark of *T.tomentosa* consists of tannins like arjunetin, arjunic acid, arjunolic acid, ellagic acid and gallic acid and triterpenoids including betulinic acid, oleanolic acid. Steroids like β-sitosterol have been reported to be present in the bark of *T.tomentosa* (Mallavarapu *et al.* 1986). The plant is known to many pharmacological properties like antifungal, antioxidant, anti-hyperglycaemic, anti-diarrhoea, anti leucorrheal. This may go a long way in raising the socio-economical status of tribal belt of Chhattisgarh state.

However, the destructive methods of tapping *i.e.,* blazing, cutting with axe are brutal and injurious for plant and causes species reduction in the state. Hence, the work on "**Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** will be conducted to establish the bio safe method of tapping of biopolymers for potential production with the following objectives:

1. To assess the efficacy of gum enhancers on initiation of gummosis.
2. Comparative study of biopolymers tapped through traditional (conventional), mechanical and chemical methods.
3. Study the impact of seasonal variation on qualitative traits and yield of biopolymers.

CHAPTER - II

REVIEW OF LITERATURE

A brief review of research work about the **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** under following headings:

2.1 Tapping techniques and gum yield

2.2 Gummosis process and time of exudation in gum tree

2.3 Quality parameter of gum

2.1 Tapping techniques and gum yield

Abib *et al.* (2012) stated ethephon is a tool to boost gum Arabic and *Acacia senegal* gum production and enhance process of gummosis.

Vashishth (2017) standardized the tapping techniques of gum extraction in *Lanneacoro mendelica* a valuable gum yielding tree. The studies indicated the tapping methods, tapping season, chemical concentrations on tree having dbh>40 cm from natural stand. He observed that in bore hole tapping method a hole 5cm is made on tree stem yield higher gum yield when injected with ethephon concentration of 300mg/ml and 400mg/ml in *Lannea coromendelica*. The maximum gum production was obtained in bore hole tapping method and minimum was procured from V-shaped tapping method. Ethephon has proved better extraction chemical over the sulphuric acid. Ethephon concentration of 300mg/ml showed the highest gum production of 144.2 grams/tree. However, lower concentration of sulphuric acid did not show significant results Ethephon induces gummosis without affecting the health of tree. Tapping seasons also significantly affect the gum production, the highest gum production of 66.94 gram /tree was obtained in April –June tapping season.

Arya *et al.* (2002) reported that at the same age (52 months) irrigated trees with greater girth at breast height (GBH) yielded nearly five times more gum (88 g) than control (18 g). Therefore, GBH along with age might be right criteria for selecting a tree for gum tapping.

Kanzaria *et al.* (2015) investigated the gum inducing chemical and ethephon 100 ppm /5ml in *Acacia Senegal* injected by drill method 5mm diameter and 4mm deep transverse hole. The maximum production was observed in ethephon treated trees.

Kramer and Kozlowski (1979) reported that the energy demanding process like bud growth/shoot development and flowering/fruiting occur during June-July and September January respectively, the only period during which the reserve metabolites are understand high in wood parenchyma is April-May. This seems to greater exudate yield are obtained in April-May than during any other time in a year. It is suggested that Gum ghatti *(Anogeissus latifolia)* should be tapped for commercial purpose in April-May and be given rest in the remaining part of the year.

Babu *et al.* (1989) observed the trees of the two species from the Sardar Patel University Botanical Garden, Gujarat, were treated by injecting with 2 ml of ethephon solution into the stem at 1.5 m above ground. Concentrations used per 2 ml water were 0, 240, 480 or 720 mg for *Bombax ceiba* (*Bombacopsis malabaricum*), and 0, 96, 192, 480, 768 or 960 mg for *Sterculia urens.* Injections were made into holes made with an increment borer reaching through to the xylem. Control treatments involved the injection of 2 ml distilled water into holes on the opposite side of treated trees, and into separate trees. The holes were sealed with wax after injection. The resulting gum exudation was measured. In *B. malabaricum* exudation started from treated holes after 10-12 days. The highest yields were from 240 mg (282 g gum) and 480 mg (378 g gum) treatments; there was no exudation from the 0 mg treatment. Exudation stopped after 7-10 days but further (lower) yields were obtained from holes or injuries made near the treated region for several days; yields were lower from fresh holes made below the original hole than from holes made above it. Exudation also occurred from holes made opposite the treatment hole at different heights. In *S. urens* exudation from treated holes also started after 10-12 days. The highest yield was from the 768 mg treatment (64.5 g gum), followed by the 960 mg treatment (38 g gum); there was a small exudation (0.5 g gum) from the 0 mg treatment. Exudation stopped after about 10 days, but a fresh hole made near the treatment site gave further exudation. Copious exudation was also obtained from holes made opposite and above and below the treatment site; exudation from holes vertically above the treatment site was immediate, in contrast to that from below, which was not.

Ballal *et al.* (2005a) found that gum yield was positively correlated with tapping intensity, rainfall, and minimum and maximum temperatures at tapping time, and negatively correlated with tapping time, and minimum and maximum temperatures at gum collection. Late tapping reduced the production of gum.

Ballal *et al*. (2005b) and Raddad and Luukkanen (2006) showed a positive relationship between gum yield and rainfall in the season preceding tapping and/or between gum yield and soil water content at the end of the rainy season.

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

Bhatt and Ram (1990) revealed that 0.8 to 0.9 kg of good quality gum can be obtained per tree by introducing 4 ml of ethephon containing 960 mg of the Bhatt and Ram (1990) revealed that 0.8 to 0.9 kg of good quality gum can be obtained per tree by introducing 4 ml of ethephon containing 960 mg of the active substance through a hole in the sapwood of Gum Arabic *(Acacia Senegal)* in April/May.

Bhatt and Ram (1990) studied the six Gum Arabic *(Acacia Senegal)* trees growing in the Chambal ravines, near Barhi, Madhya Pradesh. Five trees were treated with ethephon by introducing 4 ml solution (containing 480, 720 and 960 mg active ingredient) through a hole of 5 cm deep and 2.5 cm wide, slanting downwards and made using a hammer and chisel at 1.0-1.5 m above ground, in April/May. Little or no gum was produced by control trees (holes bored but no Ethephon added) and the most gum exudation (806-950 g/tree) obtained in the 960 mg treatment. Exudation started 4-8 days after treatment.

Das *et al.* (2014) studied gum tapping by chemical method in January to June 2014. The ethephon (2-chloroethylphosphonic acid) 39% was used in various dilution. In *Acacia nilotica* it was used in two trade names *i.e.,* E-Super and ethrel @ 39% diluted 100 times 0.39% @ 4ml and 2ml in to south direction, commencement of treatments in different trees were done since January to June and observed that 4ml E-Super (0.39% ethephon) was significantly effective to produce high quantity of gum in the month of May in *Acacia nilotica* (33.32 g/plant). The gum yield was positively correlated with tapping intensity, rainfall, and minimum and maximum temperatures at tapping time, and negatively correlated with tapping time, and minimum and maximum temperatures at gum collection.

Dione and Vessal (1998) observed the impact of rainfall and temperature variations and the time of tapping and their consequently on gum yield. The pre tapping rainfall affects the commencement of tapping. On the other hand, low temperature at tapping seems to seal off the gum exudation points. In general, peak gum production is apparently stimulated by the onset of drought conditions as the rainy season ended and air temperature rises.

Govindarajan *et al.* (2004) isolated (+) leucocyanidin. Later, ellagic acids and two new glycosides of ellagic and flavellagic acids were reported. Ethno botanically, the bark has been reported to be used in the treatment of various skin diseases such as sores, boil sand it ching, snake and scorpion bites, stomach diseases, colic, cough and diarrhoea though to date no biological/pharmacological report on the plant orits extract has been published. He reported the antioxidant potential of the 50% aqueous alcoholic extract of *A. latifolia* (ALE) for the first time.

Harmand *et al.* (2012) observed the best time to gum tapping the trees was at the beginning of the dry season, when the relative humidity dropped, depending on the location along the climatic gradient.

Li *et al.* (2014) reported the Peach gummosis, caused by *Botryosphaeria spp.* fungi, is the process of gum accumulation and exudation in plants. Ethephon (2- chloroethyl-phosphonic acid) has profound effects on plants, including enhanced production of secondary metabolites and regulation of plant diseases. This study investigates the effects of application of ethephon before and after inoculation with *Lasiodiplodia theobromae* on gum formation. Gum formation was promoted by ethephon treatment prior to pathogen inoculation, but inhibited by ethephon applied after the pathogen. The inhibitory effect was counteracted by 1-methylcyclopropane, which is an ethylene signal inhibitor. 1-methylcyclopropane also promoted gum formation.

Ngaryo *et al.* (2011) investigated the effect of tapping characteristics *i.e.,* length, width, depth, height and tree diameter on *Acacia Senegal* gum production. They observed that the ability of gum production is related to its size and diameter, especially the stem diameter was positively correlated with gum yield. The gum production was also significantly and positively correlated with crown diameter and tapping height and negatively associated with its depth.

Nair (2003) reported that artificial incisions are made in the tree trunk and the bark is slashed in Gum karaya *(Sterculia urens)*. The debarked area is freshened at the regular interval of 5-6 days. However, the quantity of gum increases when the holes made in the tree trunk is treated with ethephon. It can be ten times higher than the gum tapped by using traditional method.

Nair *et al.* (2004) stated the simple and safe technique of tapping with substantial increase in the yield is developed using ethephon to enhance gum yield and wound healing. After 45 days, a thick wound tissue has developed at the injured region and nearly replaced the damaged tissue. The wound is completely healed 60 days after tapping. The yield has increased approximately 20 to 30 times over the control and approximately 10 times more than the traditional tapping methods used by the local people. There was a marked difference in the yield among individual trees, presumably due to heterozygosity. The systematic and scientific tapping technique using ethephon as a stimulating agent for gummosis or gumresinosis could ensure substantial improvement and sustainable production of these materials. The concentration used for treatment is critical for each species. If it exceeds the optimum amount there will be possibility of die back and death of the plants.

Purkayastha *et al.* (1959) observed that the formation of ducts in the xylem or wood in response to injury which exude gum profusely and called these ducts as 'traumatic' ducts.

Rayudu (2003) studied on propagation and scientific collection of gum in Gum karaya (*Sterculia urens*) for sustainability. The quality of the tapped gum has deteriorated because of crude blazing techniques, poor handling and storage practices. It traces the attempts made by some botanists to improve the situation with scant results in quality improvement of gum through changes in handling processes. They have not been successful at all in introducing tapping methods that would help conservation of trees and improve the quantity of the tapped gum.

Saniewski *et al.* (1998) reported the effect of Ethephon (2-chloroethyl-phosphonic acid) at 1 or 2% (w/w) in lanolin induced gum and strongly enhanced the promoting effect of methyl jasmonate (JA-Me) on gum formation. Ethephon (100 mg/litre) substantially inhibited anthocyanin accumulation induced by JA-Me. These facts suggest that JA-Me plays an important role in gum formation as well as ethylene and in anthocyanin accumulation and that these processes are not necessarily accompanied by each other in peach shoots.

Stosser *et al.* (1979) reported that the gum duct formation is one of the processes involved in cell wall decomposition. This means that it is associated with living tissue. In cherry shoots, the beginning of gum duct formation can usually be seen in the nonlignified tissue formed by the cambium during lateral growth. The cells from which form the gum ducts are called the initial cells. They can be identified by their dense cytoplasm and by the more intense staining of their cell walls with the periodic acid-Schiff's (PAS) reaction for carbohydrates. The dissolution of cells starts in the centre of the initial cells. Gum ducts of different sizes finally form in the wood. After the gum ducts form, the cambium remains active, and the ducts finally become enclosed in the wood.

2.2 Gummosis process and time of exudation in gum tree

Abeles (1973) reported that Dhawada *(Anogeissus latifolia)* has no natural pre-formed gum producing tissue system in the wood but the gum cavities are induced schizo-lysigenously in the axial parenchyma of sapwood upon ethephon treatment. Ethylene may cause gum pocket or cavity or cyst formation in plants. The loss of middle-lamellar cohesiveness and the breakdown of the primary cell walls in the phloem tissue in and around gum pockets.

Bhatt (1987) reported the improved gum tapping method by ethephon treatment in trunk by injecting a syringe into holes made by increment borer. Gummosis is enhanced by ethephon application and 466 fold increased in gum yield was observed in plants treated with 1600 mg of active ethephon substance during April- May when plants becomes leafless. The ethephon application leads to 'schizo-lysigenous' formation of gum cavities in the axial parenchyma of sapwood and these results in the clogging of vessels of secondary xylem with gummy material.

Dadswell and Hillis (1962) reported that the gum canals or cavities as well as resin pockets developed in the hard woods are generally the result of damage to the cambium by the mechanical disturbances like abrasion, insect, fire etc.

Esau (1965) reported that the production of gums in plants is not well understood, these substances often accumulated in response to stress, injury, or bacterial, fungal or insect attack on the plant. Degeneration of cells resulting in the formation of complex, variable gums occurs in a broad range of species. This process, called gummosis, results in the depletion of starch in cells and in many cases appears to involve breakdown of cell walls. Gums are usually associated with xylem cells and special structures called gum ducts.

Fahn and Evert (1974) reported that the ducts initiate and develop schizogenously in the procambial region of the young stem below the shoot apex and lamina; inner ground tissue of rachis and petiole in *Ailanthus excelsa*, *Anacardiumoccidentale*, *Buchanania lanzan* and *Lanneacoro mandelica;* pith in the stem of *Anacardiumoccidentale*, *Ailanthus excelsa*, *Buchanania lanzan*and *Lanneacoro mandelica*, secondary xylem rays in stem of *Lanneacoromandelica* and procambium and inner ground tissue of mature embryo and in procambium of kernel of fruit in *Anacardiumoccidentale*. Schizogenous development of ducts is also reported in stem and leaves of *Rhusglabra*.

Ghosh and Purkayastha (1959) reported that the induced exudation is associated with the development of traumatic gum cavities in the secondary xylem. The traumatic development of gum ducts or cavities in the secondary xylem due to mechanical injury or ethephon treatment is also reported in Dhawada *(Anogeissus latifolia).*

Gupta *et al.* (2011) studied the effect of ethephon on Karaya (*Sterculia urens* Roxb) in production of gum enhancement and found significant impact of 4 ml ethephon injected twice , first in mid-March and second in first week of May per tree, further enhances the gum exudation without any apparent ill effect on health of the trees.

Joel and Fahn (1980a) reported that initiation and development of ducts are lysigenous in the secondary phloem of stem in *Anacardium occidentale*, *Buchanania lanzan* and *Lannea coromandelica*, cortex of stem, primary phloem of pseudocarp and endocarpic region of nut in *Anacardium occidentale*. Similarly ducts are found in shoot and fruit of *Mangifera indica*.

Parvathi *et al.* (2009) recently studied hypolipidemic activity of Dhawada *(Anogeissus latifolia)* gum.

Purkayastha (1959) observed that the formation of ducts in the xylem or wood in response to injury which exude gum profusely and called these ducts as 'traumatic' ducts.

Sao *et al.* (2012) reported that a gum in general, is any water-soluble or water-swellable polysaccharide. Exudate gums are produced by some trees, shrub and herbaceous perennials and are generally produced either naturally or in response to injury. They have been important items of international trade in the food, pharmaceutical, adhesive, paper, textile, and other industries for centuries. The gum exudes from trees and shrubs in tear-like, striated nodules or amorphous lumps. It dries in contact with air and sunlight and forms hard, glass like lumps. Gum production increases at high temperature and limited moisture.

Vander Molen *et al.* (1977) reported that the cell walls are transformed into gum may be cells of mature xylem or of cells in specialized parenchyma groups which differentiate in the cambium and later disintegrate and form the gum and duct lumen.

Wilde and Edgerton (1975) reported that the ethylene release may be a causative mechanism in gum pocket or cavity or cyst formation because the incidence of this type of gummosis trees treated with the ethylene releasing agents. The loss of middle lamellar cohesiveness and the breakdown of the primary cell walls in phloem tissue in and around gum pockets suggested an ethylene -induced tissue deterioration in phloem and other tissues.

2.3 Quality parameter of Gum

Al-Assaf *et al.* (2007) showed that molecular associations in Gum Arabic can lead to an increase in molecular weight in the solid state by maturation under controlled heat and humidity.

Anderson *et al.* (1968) investigated that the pH value of Gum Arabic *(Acacia Senegal)* to be 4.4 and it is slightly acidic because of the presence of few free carboxyl groups of its constituent acidic residue, *viz.* D-glucuronic acid and its 4-O-methyl derivative.

Ayoub *et al*. (1985) studied molluscicidal activity of the pods and stem bark of *Acacia* sub spp. *nilotica, tomentosa* and *astringents* against the snail species *Bulinus truncatus* and *Biomphalaria pfeifferi*. The spray-dried powders of the pods and stem bark of *Acacia nilotica* sub *spp*. *nilotica*, *tomentosa* and *astringents* prove to be promising vegetable molluscicidal.

Babu *et al.* (2011) reported that the fascinating structural features and significant biological activities of these limonoids class of compounds which have prompted us to investigate the plants of meliacae family. In our efforts to attain novel metabolites from *S. febrifuga,* two limonoids 1 and 2 were isolated from the methanolic extract.

BIS (1989) classified Gum ghatti *(Anogeissus latifolia)* into tree grades based on colour determined by visual examination. The gum colour of grade I off white to buff, grade II light amber to brown and grade III dark brown to near black.

BIS (2007) reported that the *Acacia* gum found a pale white to orange brown solid, which breaks with a glassy fracture. It is also available in the form of white to yellowish-white flakes, grannules, powder, roller dried or spray dried material.

Boothby *et al.* (1983) reported that gums are complexes of different substances, mostly polysaccharides of diverse structure. The composition of gum polysaccharides varies from species to species and from cultivar to cultivar.

Davidson (1980) reported that the natural gums (gums obtained from plants) are hydrophilic carbohydrate polymers of high molecular weights, generally composed of monosaccharide units joined by glucocidic bonds. They are generally insoluble in oils or organic solvents such as hydrocarbons, ether or alcohols. Gums are either water soluble or absorb water and swell up or disperse in cold water to give a viscous solution or jelly.

Dell and McComb (1978a) reported that the gum is soluble in cold or hot water (or at least it swells to form a gel), but insoluble in organic solvents. On the other hand, resin is insoluble in water but soluble in organic solvents.

Deshmukh *et al*. (2012) investigated that Gum ghatti *(Anogeissus latifolia)*is light yellow to brown colour powder available in a various grades depending upon its viscosity and solubility. The viscosity of 10 % dispersion of gum ghatti soluble grade I, II, III and IV were observed below 400 cps, 400-500 cps, 1000-2500 cps and above 2500 cps respectively at 250C on RVT Brookfield Viscometer at 24 hrs.

Dziezak (1991) reported that Gum arabic *(Acacia Senegal)* readily dissolves in cold and hot water in concentration up to 50 % because of the compact, branched structure and therefore, small hydrodynamic volume. Gum arabic solutions are characterized by a low viscosity, allowing the use of high gum concentration in various applications. Solution exhibit Newtanion behavior at concentration up to 40 % and become pseudoplastic at higher concentration.

El-Amin *et al*. (2013) investigated samples of Gum Arabic (*Acacia Senegal*) collected from the gum belt of North, South Kordofan and Blue Nile States (Sudan). Gum viscosity was measured using a Brookfield Viscometer (MYR Viscometer -version L spindle 3 speed 200 RPM). The viscosity of gum Arabicobtained from different areas in the gum belt, ranges from 50-130 cps averaging 67.7 cps for gum solution of 10 % concentration.

El-kheir *et al.* (2008) studied in physico-chemical properties of Gum Arabic (*Acacia senegal*) collected from Kordofan (Central Sudan) and Damazin (Blue Nile, Western Sudan). The results showed significant differences in moisture content, protein content and relative viscosity between Kordofan and Damazin gums. Damazin gum contained higher protein (3 %) and characterized by higher viscosity (24.81) compared to Kordofan gum.

Flindt *et al.* (2005) reported that the Gum Arabic (*Acacia senegal*) is a slightly acidic complex compound comprised of polysaccharides, glycoproteins and their calcium, magnesium and potassium salts. The chemical composition also determines the quality of the gum depending on its geographical origin, weather conditions at the time of harvest, soil, age and genotype of tree and the processing conditions.

Glicksman (1969) reported that the most widely used exudate gums in the food industry, gum arabic, gum tragacanth and gum karaya have the respective pH ranges 4.5-5.5, 5.6 and 4.4 4.7.

Ignace *et al.* (2015) reported that secondary metabolites such as flavonoids, alkaloids, tannins and phenolic compounds have been established as the bioactive compounds of plants. As part of our continuous endeavors of phytochemical pharmacological integrated studies on the Indian medicinal plants.

Islam *et al.* (1997) observed the chemical composition of Gum Arabic is complex and consists of a group of macromolecules characterized by a high proportion of carbohydrates, which are predominantly composed of D-galactose and L-arabinose units and a low proportion of proteins (<3%).

Janaki e*t al.* (1998) Thephysico-chemical characteristics of gum kondagogu (*Cochlospermum gossypium*) were examined for the first time. The gum was compared with conventionally used food grade gum karaya (*Sterculia* sp.). Chemical analyses revealed that gum kondagogu had higher soluble fibre, protein, tannin, calcium and potassium contents than karaya gum. Gum kondagogu also differs from gum karaya in terms of its intrinsic viscosity, water binding capacity and pH. The basic constituent sugars were similar to that of gum karaya but the proportions of the individual sugars varied. Gum kondagogu had a higher uronic acid (glucuronic and galacturonic acid, 63%) content than neutral sugars (arabinose, rhamnose and galactose, 37%), which could lead to significant differences in the utility and functionality of the gum.

Jefferies *et al*. (1977) reported that the viscosity of Gum ghatti (*Anogeissus latifolia*) and A. *albizia* gums increases with increasing proportion of dispersible gel respectively. This rheological behaviour is also exhibited by gum exudate studied. The high viscosity experience at higher concentrations may be due to increase in the strength of molecules-molecules interaction and the corresponding reduction in molecule-solvent interaction.

Joshi *et al.* (2013) Physicochemical and Phytochemical Investigated on Saja (*Terminalia tomentosa* Roxb.) the physicochemical study revealed the presence of moisture content as 12.5% w/w, total ash as 19.95% w/w, acid insoluble ash as 16.35% w/w, water soluble ash as 0.9% w/w, alcohol soluble extractive as 1% w/w, water soluble extractive as 0.8% w/w, ether soluble extractive as 0.2% w/w, foaming index as less than 100 & swelling index as 1.14 cm. The fluorescence analysis in short wavelength, long wavelength & day light is also reported, which is a tool to determine the chemical nature of crude drug.

Kaur *et al.* (2007) studied the rheological and structural characteristic of the gum and found that the molecular weight of is approximately 8.94X107 g/mol. The gummy solution at low concentration exhibits pseudoplastic, time dependant shear thickening behavior.

Le Cerf *et al.* (1990) distinguished three fractions in gum karaya *(Sterculia urens* Roxb.) based on their solubility in water. It is the least soluble of the exudates gum. When disperse in water, the gum particles do not dissolve but adsorb water and swell extensively to more than 60 times the original volume, producing a viscous colloidal sol. The swelling behavior of gum karaya is caused by the presence of acetyl groups in its structure.

Meer and Davidson (1980) classified Gum karaya (*Sterculia urens*) in two broad grades crude and processed but the Water Soluble Gum Association (WSGA) recognized four main grades based on the percentage of foreign and colour of gum. The gum must not contain > 3 % bark and foreign material to be acceptable for food and drug use. The grade I, II, III and IV contain bulk and organic matter 0-0.5 %, 0.5-1.5 %, 1.5-3 % and 3-6 %, respectively. The quality of gum on the basis of colour are white with slight grey cast grade I, very light tan grade II, tan colour grade III and brown colour grade IV.

Meer and Gerard (1980) reported that the viscosity of grade I gum ghatti (*Anogeissus latifolia*) was shown to vary from 30 to 400 cp for 5 % of solution. They also observed that the gum was almost completely soluble in water and heating at 90^0C improves the solubility.

Orwa *et al.* (2009) reported that Ghatti gum tapped from Dhawada (*Anogeissus latifolia*) is a good substitute for gum arabic and is used in calico printing, for sweetmeats, in dye processes, and as a binding agent in pharmaceuticals.

Peter *et.al.* (1993) Hakea gum a dried exudate from the plant *Hakea gibbosa* family Proteaceae. Gum exudates from species have been shown to consist of Larabinose and D-galactose linked as in gums that are acidic arabinogalactans (type A). Molar proportions (%) of sugar constituents Glucuronic acid, Galactose, Arabinose, Mannose, Xylose is 12:43:32:5:8. The 69 exuded gum is only partly soluble in water. Hakea gum a dried exudate from the plant *Hakea gibbosa* family Proteaceae. Gum exudates from species have been shown to consist of L-arabinose and D-galactose linked as in gums that are acidic arabinogalactans (type A). Molar proportions (%) of sugar constituents Glucuronic acid, Galactose, Arabinose, Mannose, Xylose is 12:43:32:5:8. The 69 exuded gum is only partly soluble in water.

Rabah (2011) has studied the rheological data of gum arabic and reported that density of *A. senegal* gum at room temperature is found to be higher than that of water only at higher concentration (>5 g/l). The density is also found to be strong function of temperature. At medium temperature >45 °C becomes lower than that of water even at low concentration (<2.5 g/l). The viscosity is found to be shear rate independent indicating Newtonian behavior. At low concentration *Acacia senegal* gum viscosity varies linearly with concentration and at high concentration (>10 g/l) varies exponentially.

Rahman *et al.* (2007) reported by *Anogeissus latifolia* contains a wide variety of chemical compounds, This plant contains different type of triterpenoids like 3-β-hydroxy- 28 acetyltaraxaren and β-sitosterol.

Saini (2008) have reported that babul plant is therapeutic used as anticancer, anti tumours, antiscorbutic, astringent, anti-oxidant, natriuretic, antispasmodial, diuretic, intestinal pains and diarrhoea, nerve stimulant, cold, congestion, coughs, dysentery, fever, hemorrhages, leucorrhoea, ophthalmia and sclerosis.

Seigler (2003) observed the physico-chemical properties of Babool *(Acacia nilotica)* have 13 % moisture content, 38 % solubility, 300-320 ^{0}C melting temperature, 3.54 ash content, 2.71 % protein and 78.15 % total soluble fibre.

Singh *et al*. (2010) Ghatti gum has been extensively evaluated as sustained release polymer due to its high gelling property.

Weiping (2000) reported that the viscosity of Gum karaya (*Sterculia urens* Roxb) dispersions depends on the grade but normally ranges from 120–400 cps for0.5% dispersions to 10000 cps for 3 % dispersions. This fluid has a non-newtonian pseudoplatic type behavior because its viscosity is inversely proportional to the shear rate. Viscosity stability depends on time of harvest, climate during harvest, storage conditions including temperature/humidity. Storage of dry gum results in a loss of viscosity, which is more pronounced for powdered than crude gum. Viscosities are higher when the gum is dispersed in cold water than in hot water. Boiling of the dispersion results in a permanently reduced viscosity, but heating increases the solubility and allows the preparation of dispersions up to 18%, compared to 4–5% in cold water. A decrease in viscosity is also observed following the addition of strong electrolytes and acid or alkali, but his decrease is smaller when the gum is hydrated prior to pH adjustment.

Whistler *et al.* (1993) reported that boiling of the gum results in a permanently reduced viscosity, but heating increases the solubility and allows the preparation of dispersion up to 18 % compared to 4-5 % in cold water. A decrease in viscosity is also observed following the addition of strong electrolytes and acid or alkali but this decrease is smaller when the gum is hydrated prior to pH adjustment.

CHAPTER - III
MATERIALS AND METHODS

The present investigation entitled **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** was carried out at village Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi, Dist. Mungeli (Chhattisgarh) whereas, laboratory work was done in Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, IGKV, Raipur (Chhattisgarh) during the year 2016-17. The details of study site, climate, soils and the methodologies during the course of investigation are briefly described

3.1 Study site

The study was conducted in naturally grown Dhawda *(Anogeissus latifolia), Rohina (Soymida febrifuga* Roxb.*), Saja (Terminalia tomentosa* Roxb. Ex DC.) and Chirounji *(Buchanania Lanzan* Spreng.) trees at Sanwatpur, , under the ATR Lormi, district Mungeli (Chhattisgarh) respectively during the year 2016-17.

3.1.1 Geographical location

Mungeli is located at 22.07°N 81.68°E. It has an average elevation of 288 metres (944 feet). Mungeli is located near the Bilaspur district around 35 kilometres from the Bilaspur and 100 kilometres away from the capital city of Chhattisgarh 'Raipur'. The study site Sanwatpur (under ATR) is situated at 22°17'42.0"N and longitude 81°48'18.1"E with an altitude of 333 meters above the mean sea level.

3.1.2 Climate

The climatic condition of experimental site is sub-humid dry tropical. The region receives an average annual rainfall of 1200-1400 mm, of which 80% occurs during rainy season from June to end of September and occasional rainfall during October to February. May is the hottest and December is the coolest month of the year. The mean monthly maximum temperature ranges between 27^0C in December and 42^{0}C in May and minimum temperature varies between 13.2^{0}C in December

3.1.3 Soils

The experimental site belongs to soil Bhata, Matasi, Kanhar for Dhawara, Rohina, Saja and Chiounji. The Entisol locally known as Bhata contain sand, clay and silt are gravelly sandy to sandy loam in texture. Red to reddish yellow colour is characteristics of Bhata soil. Murrum (psolites) are found on the surface. The inceptisols locally known as Matasi are light yellow or grey in colour. Texturally it is a clay loam contains sand, clay and silt. This soil shows slight acetic or neutral in reaction. The Vertisols which are locally known as Kanhar soils are characterized by fine texture, sticky nature, angular blocky structure, low to medium nitrogen, high potassium and low to medium phosphorus with low organic matter.

3.1.4 Physiography

In Chhattisgarh central plains agro climatic zone, there are 10 districts *viz.*; Bilaspur, Dhamtari, Durg, Janjgir-Champa, Korba, Kawardha, Mahasamund, Rajnandgaon, Raigarh and Raipur, which is also known as saucer-shaped upper Mahanadi basin. The longer part of this basin is undulating, flat terrain, and gentle slopes from west to east. The general geological features of the zone comprises of laterites, alluvium capping over horizontally bedded sequence of sedimentary rocks of limestone and dolomite on the top followed by limestone shade, quartzite sand stone, granite, gneisses and meta sediments of old age. These formations have very limited primary porosity and permeability to water.

3.1.4 Tree vegetation in Chhattisgarh

The total geographical area of Chhattisgarh is 137.90 lakh ha (4.15% of the geographical area of the country) which covers 63.55 lakh ha (46% of forest cover of its total geographical area) of forest area. Further, the state is well known in the country for its Sal forests, which occupy nearly 36% of total forest cover. Teak forests are also abundant here but mainly in western and southern parts of the state. Forests of Chhattisgarh are either tropical moist deciduous forests or tropical dry deciduous forests.

3.1.5 Weather condition during crop growth period

The meteorological observations rainfall, temperature, relative humidity and sunshine during the period of investigation have been presented in appendix A and shown in Fig 3.1.

3.2 Experimental Materials

The naturally growing Dhawda (*Anogeissus latifolia*), Rohina (*Soymida febrifuga* Roxb.), Chirounji (*Buchanania lanzan* Spreng.) and Saja (*Terminalia tomentosa* Roxb. Ex Dc.) trees were selected and investigated during the year 2015-16 and 2016-17 at Sanwatpur, under the ATR (Achanakmar Tiger Reserve Lormi, Dist. Mungeli (C.G.). The brief description of study trees are as follows:

3.2.1 Dhawda (*Anogeissus latifolia)*

Dhawara, also known as Gum ghatti is the dried exudates of *Anogeissus latifolia* a tree belonging to family *Combretaceae*. It is a large erect deciduous tree that may grow up to a height of 25 meters, with a smooth light coloured bark. Sometimes the bark has whitish grey depressions caused by exfoliation of bark. The maximum quality of gum is collected during summer month *i.e.* from March to mid of June. (Fig. 3.3)

3.2.2 Rohina (*Soymida febrifuga* Roxb.)

Rohina (*Soymida febrifuga* Roxb.) (Meliaceae) tree distributed mainly in the tropical areas of Asia and one of the most popular traditional medicines in India. Commonly called as Indian red wood is a monotypic genus endemic to India a clear gum from the bark forms good adhesive mucilage and a strong red fibre from it is used for making ropes. A lofty deciduous tall trees, grows up to 22-25 m in height and 2.5-3.0 m in girth. Bark is very tough, exfoliating in large plates or scales. Leaves 22-45 cm, imparipinnate, long, crowded at the ends of branches, branchlets with persistent leaf bases. Flowers are bisexual, greenish white in large axillary or terminal panicles. Sapwood is whitish and heart wood dark blood red to reddish brown with silver streaks with an oily feel, without characteristic odour or taste (Kirtikar and Basu, 2003). (Fig. 3.2 and Fig. 3.3).

3.2.3 Saja (*Terminalia tomentosa* Roxb. Ex DC.*)*

The plant is known to possess many pharmacological properties like antifungal, antioxidantanti-hyperglycaemic, antidiarrhoeal, anti leucorrheal. From the literature survey, it is learnt that no substantial work has been carried out on the

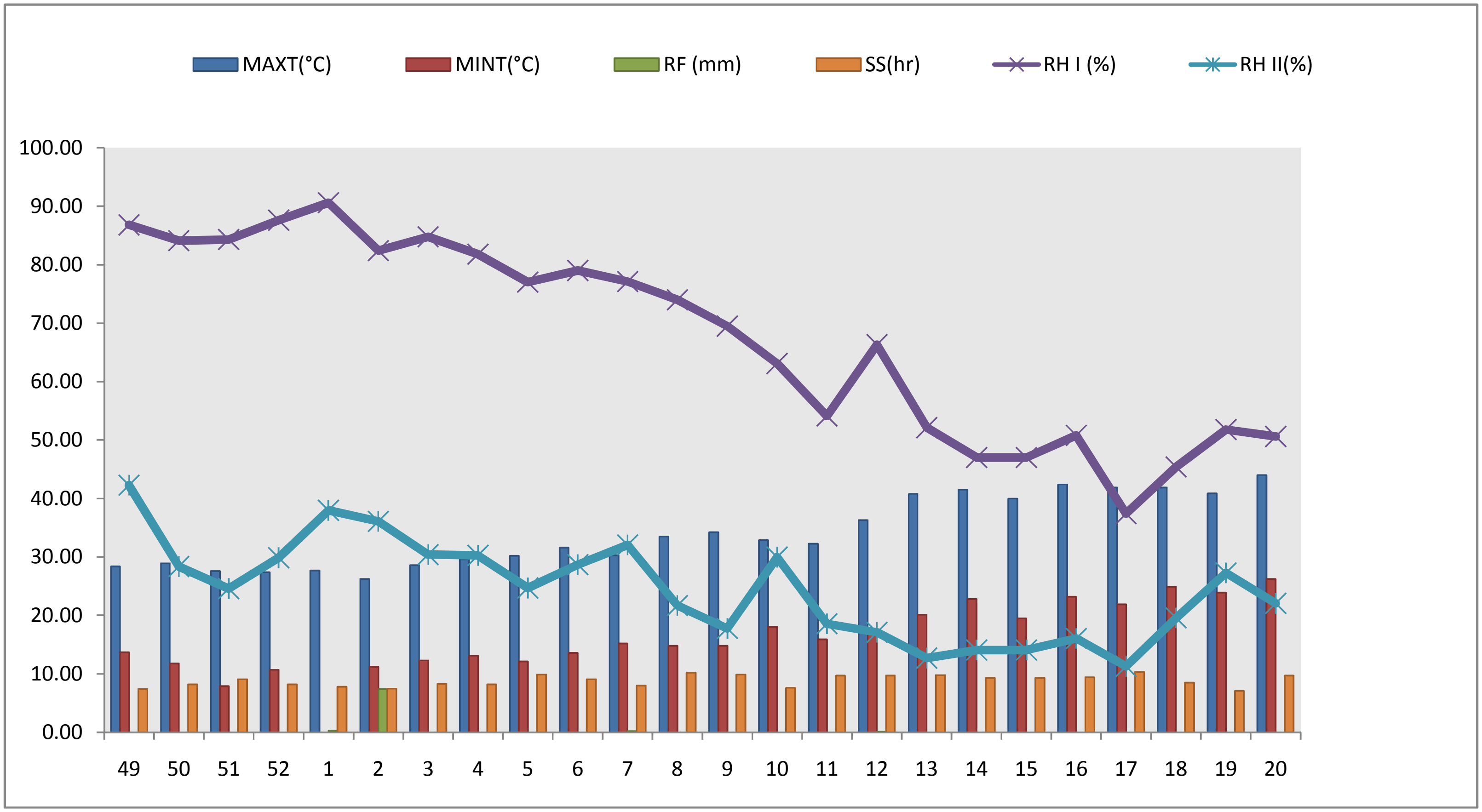


Fig. 3.1: Weekly meteorological data of experimental site during the period of December 2016 to May 2017.

leaves of *T.tomentosa* in terms of physicochemical and preliminary phytochemical screening of *T.tomentosa*. (Fig.3.4).

3.2.4 Chironji (*Buchanania lanzan* Roxb.)

Chirounji Tree is a medium-sized deciduous tree, growing to about 50ft tall. It bears fruits each containing a single seed, which is popular as an edible nut, Known as Chironji. It is common in our forest mostly in eroded ravine lands. It avoids waterlogged areas, but occurs locally in clay soils. It can identified by the dark grey crocodile bark with red blaze. It is fruits are considered as one of the delicious wild fruits. The seeds are also eaten. The seeds are regarded as substitute for almonds. Chironji tree produces gum benzoin similar but inferior to that from Styrax benezoin. Bark yields tannin (up to 13 percent) and used in tannin industries. A good species for afforesting bare hill slopes. It has tickly leathery leaves which are broadly oblong, with blunt tip and roundes base. Leaves have 10-20 pairs of straight, parallel veins. Pyeamidal panicles of greenish while flowers appear in early spring. Fruits ripen from April to May and remain on the tree for quite a long time. Flowering; January-March. (Fig. 3.4)

1.3 Experimental details

1.3.1 Mechanical tapping technique

Location of Experiment	:	Sanwatpur, under the ATR(Achanakmar Tiger Reserve Lormi, Dist. Mungeli (C.G.)
Species	:	Dhawada (*Anogeissus latifolia),* Rohina (*Soymida febrifuga* Roxb.), Chironji (*Buchanania lanzan* Sprenge.), Saja (*Terminalia tomentosa* Roxb. Ex DC.)
Design	:	Factorial Randomized Block Design
Number of Replications	:	3
Number of Treatments	:	3

3.3.2 Treatment details

T_1 : Single cut with axe

T_2 : Double cut with axe.

T_3 : Semi-circle cut (12 cm width x 6 cm length x 4 cm deep size)

3.3.3 Chemical tapping technique

Location of Experiment	:	Sanwatpur, under the ATR(Achanakmar Tiger Reserve Lormi, Dist. Mungeli (C.G.)
Species	:	Dhawada (*Anogeissus latifolia),* Rohina (*Soymida febrifuga* Roxb.), Chironji (*Buchanania lanzan* Sprenge.), Saja (*Terminalia tomentosa* Roxb. Ex DC.)
Design	:	Factorial Randomized Block Design
Number of Replications	:	3
Number of Treatments	:	5

3.3.4 Treatment details

T_1 : Treatment control (distilled water)

T_2 : Ethephon (3.9%)

T_3 : H_2SO_4 (1%)

T_4 : H_2SO_4 (1%) + Ethephon (3.9%)

T_5 : HCl (1%)

3.3.4 Traditional tapping Method

One cut (Control)

3.4 Gum tapping methods

The detailed methods of the experiments are described below:

3.4.1 Mechanical method of tapping

Three mechanical methods were used *i.e.* 1 Scar with axe, 2 Scar equally spaced with axe, use of semi arc method. These all were applied at 1 meter DBH (distance at breast height) and on more than one meter diameter trees. The

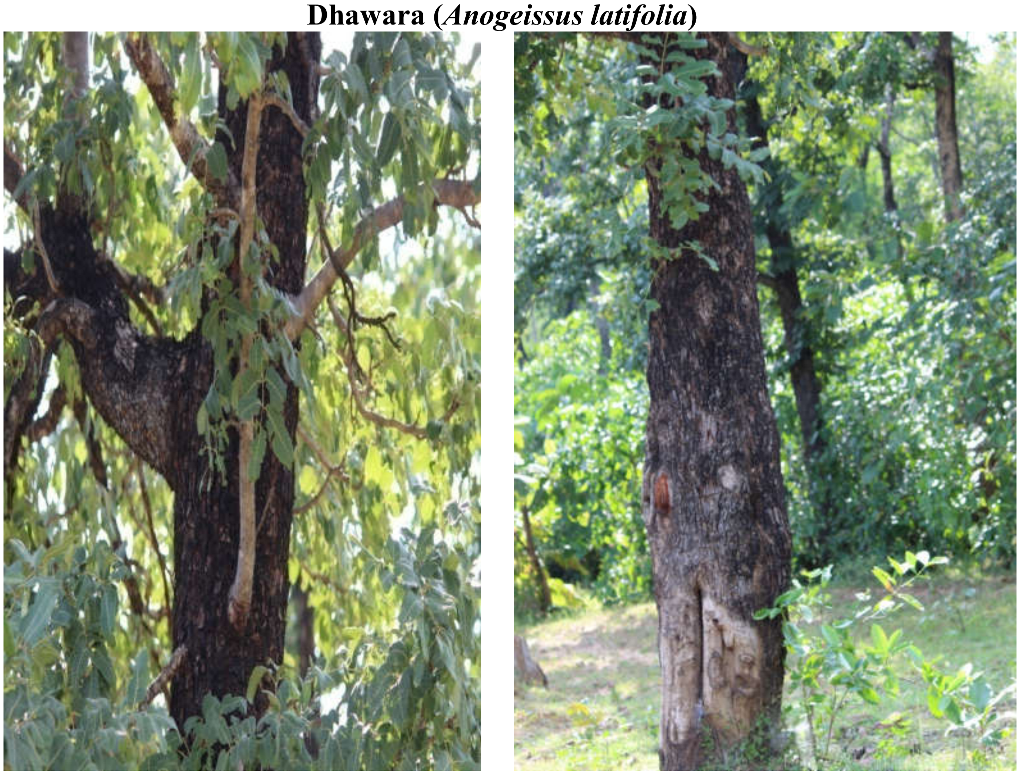
Tree with Fruit

Fruit

Leaves

Fig. 3.2 Different parts of experimental tree Rohina (*Soymida febrifuga* Roxb.).

Dhawara (*Anogeissus latifolia*)



Rohina (*Soymida febrifuga* Roxb.)

Fig. 3.3 Experimental tree species Dhawara (*Anogeissus latifolia)* and Rohina (*Soymida febrifuga* Roxb.)

Saja (*Terminalia tomentosa* Roxb. Ex DC.)

Chirounji (*Buchanania lanzan* Spreng.)

Fig. 3.4 Experimental tree species Saja (*Terminalia tomentosa* Roxb. Ex DC.) and Chirounji (*Buchanania lanzan* Spreng.).

treatments were applied since December 2016 to May 2017. The mechanical treatments were given as below:

1. Single scar was made with the help of axe around 5 cm long, 4 cm width and 4 cm deep on the tree trunk.
2. Two scars equally spaced were made with the help of axe around 4 cm deep each on the tree trunk till the second layer was exposed.
3. A semi arch scar (12cm length x6 cm width x4 cm deep) was made with the help of knife and bark remover till the second layer was exposed.

3.4.2 Chemical tapping technique

The chemical gum tapping of selected trees was initiated using different doses of gum enhancer ethephon (2-chloro-ethyl-phosphonic acid) (trade name E-Super) having 3.9%, Sulfuric acid 1%, and Hydrochloric acid in the tree trunk by Hand operated drill machine to induce gummosis. The whole treatments were made through a syringe of 10 ml volume. The 4ml gum enhancer was injected twice during the whole period of tapping. First treatment injected in March and second in the month of May. The drilling was done clock wise up to 2.5 cm deep and 4 mm diameter upward inclined hole (slant hole) and gum enhancer was injected in hole and covered with clay immediately.

3.5 Observations recorded

The observations included rate of gum exudation (g/tree/wk), time of treatment application, time of gum exudation, quantity of gum exudation (g/tree/season), tree girth diameter (m), duration of gum exudation, grading of gum, biochemical properties, quality of gum, quantity of gum exudation per plant, direction of cut and gum exudation were recorded in experimental season. The details of the observations are described below:

3.5.1 Rate of gum exudation (g)

The rate of gum exudation was measured by application of mechanical/chemical treatment and collecting the gum at different time intervals in a month. It was collected after one week of the commencement of treatment. It was calculated by weighing the exudates gum and divided it by time.

3.5.2 Time of treatment application

The chemical treatment was applied after 10 O'clock in between 10-12 am twice during the January and mechanical treatments were also given at the same time during the first week of December and January in the season.

3.5.3 Time of gum exudation

The gum exudation was observed after commencement of treatment in the morning, noon, afternoon and evening from the few hours after application of treatment.

3.5.4 Tree girth diameter (m)

The tree girth was measured with the help of measuring tape. All the mechanical and chemical gum tapping techniques were made in tree girth at least one meter above the soil surface. Generally 1m DBH (distance at breast height) prefer for the experimentation.

3.5.5 Duration of gum exudation

The application of treatment was done in winter as well as in summer in all the experimental trees to find out the impact of climate *i.e.* temperature, RH, and season on gum exudation as well as the impact of mechanical and chemical tapping was also compared.

3.5.6 Quantity of gum exudation (g)

The quantity of gum exudation was measured by collecting the gum at different time interval in a month and adds them. The yield data per year obtained was compared to check variation in gum exudates per month on the basis of weight.

3.5.7 Quality parameters

The study of quality analysis of gum samples was done in the laboratory of department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic plants, Indira Gandhi Krishi Vishwavidyalaya, Raipur (CG) laboratory. Analysis was repeated thrice and values of replications were average.

Fig. 3.5 Mechanical tapping method (semi arc) in Saja (*Terminalia tomentosa* Roxb.), Rohina (*Soymida febrifuga* Roxb.) and Chirounji (*Buchananialanzan* Spreng.).

T_4, Ethephon @ 3.9 + H_2SO_4 @ 1% T_2 , Ethephon @ 3.9% T_3 , H_2SO_4 @ 1%

Chemical method of tapping for Gum exudation in Rohina (Soymida febrifuga Roxb.)

T_4, Ethephon @ 3.9 + H_2SO_4 @ 1% T_2, Ethephon @ 3.9% T_3, H_2SO_4 @ 1%

Chemical method of tapping for Gum exudation in Chirounji (*Buchanania lanzan* Spreng.)

Fig. 3.6 Chemical method of tapping for Gum exudation in Rohina (Soymida febrifuga Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) by using different gum enhancer.

a) pH

The sample powder was thoroughly mixed in 1 g and was dissolved in 100 ml of hot distilled water. The mixture was allowed to stand for 5 min at room temperature before the pH and temperature was recorded using a pre-calibrated pH meter (Model ELICO L1614) (Ameh, 2012).

b) Colour

The grading of gum was done on the basis of colour and added impurities.

c) Viscosity (cp)

The viscosity of the gum was measured using a digital Brookfield DV-E viscometer (FAO, 1990a, b).The resistance to movement of a spindle is measured and expressed in terms of viscosity. The viscosity of the gum sample was determined in distilled water. The gum solutions were prepared by dispersing 50 mg of each gum sample separately in 100 ml of the distilled water in a 250 ml beaker at room temperature and mixed using a magnetic stirring overnight. If there were any lump in the solution, discard and prepare the fresh solution until a clear solution is obtained. Adjusted the temperature of the solution to 30^0C and measured its viscosity with digital Brookfield DV-E viscometer at 10, 20, and 30 rpm per minute using spindle no. 64, 63, 61 and 62 for Dhawara, Rohina, Saja and Chirounji respectively. The three readings were taken for each dilution and the average was obtained. The CGS physical unit for dynamic viscosity, the poise (P), is also named after Jean Poiseuille. It is more commonly expressed, particularly in ASTM standards, as centipoise (cP) since the latter is equal to the SI multiple millipascal seconds (mPa. s). For example, water at 20 °C has a viscosity of 1.002 mPa.

d) Solubility (%)

The solubility of the gum was determined in cold and hot distilled water, acetone, and ethanol. 1.0 g sample of the gum 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 and expressed as the percentage solubility of the gums in the solvents. (Eddy *et al.* 2012).

3.5.8 Biochemical Properties

The protein content of the gum was determined using the semi-micro Kjeldahl method (AOAC, 1990). Protein content was calculated using the nitrogen conversion factor of 6.25 as proposed by (Rodriguez *et al.,* 2004).

a) Digestion process

About 0.5 g of sample was transferred into the digestion tube and 5-7 gm of K_2SO_4 and $CuSO_4$ mixture added. 10 ml of concentrated H_2SO_4 was added and digestion tubes were placed on the digestion block with temperature set at 360^0C and then increased to 410^0C. After 2 to 3 hours when the samples turn colourless or of light green colour, the digestion tubes were taken out of digestion block. The tubes were then allowed to cool at room temperature.

b) Distillation process

Digested samples were subjected to Pelican make distillation unit and distillation of sample was carried out using 4% Boric acid and 40% Sodium hydroxide. 10 ml of Boric acid was then taken in conical flask, to which 2-4 drops of mixed indicator dye was added. The flask was placed beneath the condenser with the delivery tip immersed in the solution. The digested samples were transferred to distillation apparatus and 8-10 ml of 40% Sodium hydroxide was added to it. Around 20 ml of distillate was collected in a conical flask. A blank was always run containing the same quantity of the entire reagent but without the sample for every set of nitrogen determination.

c) Titration process

The distilled samples were titrated against the 0.05 N Sulfamic acid until the first appearance of violet colour as the end point. The titer value was used to calculate percent nitrogen.

$$\text{(Nitrogen \%)} = \frac{\text{(Vol. of Sulfamic acid – Vol. of blank) x Normality x 14 x 100)}}{\text{Sample weight (g) x 1000}}$$

Protein % = % Nitrogen x 6.25

3.5.8.2 Ash content

Ash content of the gum samples was determined by burning 5 g of gum sample in a muffle furnace at 600^{o}C for 4 hour. The ash content was expressed as a % ratio of the weight of ash to weight of the sample.

3.5.9 Effect of temperature and relative humidity on gum exudation

Beside girth class, number of injury and ethephon concentration, temperature and relative humidity are important factors which influenced the gum exudation.

3.5.10 Direction of cut and gum exudation

The Blazing/Drilling was done in the direction to east to south in all the direction to compare the production.

3.5.11 Quantity of gum exudation per plant

The quantity of gum exudation was measured by collecting the gum at different time intervals. On the basis of weighing the gum yield/plant was calculated for different methods of gum production.

3.5.12 Grading of gum

The collected gum was analyzed visually on the basis of colour and purity as classified by Meer and Davidson (1980) and BIS (1989).

3.6 Statistical analysis

3.6.1 Analysis of variance

Experimental data were analyzed statistically adopting the technique of analysis of variance (ANOVA) for factorial Randomized Block Design. The level of significance was observed at 5 percent probability (Gomez and Gomez, 1984).

3.6.2 Variability parameters

3.6.2.1 Range

The range of the distribution was expressed by the limit of the smallest and the largest value of each observation.

3.6.2.2 Mean

The mean was recorded by summing up all the observation and then dividing by the total number of observations.

$$\overline{X} = \frac{\Sigma X}{n}$$

Where,

Σx = Sum of all observations

n = Total number of observations

a. Critical difference

CD = S Ed x t value at 5 % at error degree of freedom

$$SEd = \frac{\sqrt{2EMS}}{r}$$

Where,

SEd = Standard error of difference between two treatment means

EMS = Error mean sum of square

r = Number of replications

b. Standard error of mean

$$SEm = \frac{\sqrt{EMS}}{r}$$

c. Coefficient of variation (CV) (%)

Coefficient of variation is standard deviation expressed as percentage of mean.

$$CV\ (\%) = \frac{SD}{X}\ X\ 100$$

Where,

SD = standard deviation

X = Mean of character

The Skelton of ANOVA table by used following

Source of variation	**D.F.**	**S.S.**	**M. S. S.**	**F cal**	**F tab**
Replication	(r-1)	RSS	RMSS	RMSS/EMSS	
Treatment	(t-1)	TSS	TMSS	TMSS/EMSS	
Species	(Sp-1)	SpSS	SpMSS	SpMSS/EMSS	
Int (Sp×T)	(v-1) (t-1)	ISS	IMSS	SpMSS×TMSS/EMSS	
Error	(r-1) (t-1)	ESS	EMSS		
Total	(r×t)-1				

In order to compare the mean value of treatments standard error and critical values were calculated as follows:

1) Standard error of mean SEm± = EMS/r

2) Critical difference (CD) = SE (d) x t value at 5% error (df)
3) Coefficient of variation (cv) = EMS/ GM x 100

Where,

DF = Degree of freedom	SS = Sum of square
MSS = Mean sum of square	EMS = Error variance
R = replication	GM = general mean
Fcal = Calculated F value	Ftab = Tabulated F value
SE = Standard error	(d) = Difference between two treatment means
Sp = Species	
T = Treatment	

CHAPTER-IV
RESULTS AND DISCUSSIONS

The present investigation entitled **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** was carried out at village Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi, Dist. Mungeli (Chhattisgarh) whereas, laboratory work was done in Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, IGKV, Raipur (Chhattisgarh) during the year 2016-17. The experimental findings of the present investigation have been described under the following heads:

4.1 Gum tapping through mechanical and chemical methods

4.2 Rate of gummosis process

4.3 Quality parameters and Biochemical study

4.1 Gum tapping through mechanical methods

The gum tapping was done through mechanical methods in 2016-17 in two season winter (December 2016 and summer 2017). Hence, the study was made *via* using various methods *viz.* control use of axe make single blaze (T_1) and mechanical making double cut on tree trunk at 1 m DBH (diameter at breast height (T_2) and Semi arc method (T_3), and compared them for production and yield purpose. The study was done in years 2016-17 started from December up to May. The cut on tree trunk healed after few weeks results are represented in Fig. 4.1.

4.1.1 The time requirement for gum exudation in mechanical tapping methods.

The time required for gum exudation in experimental trees was very important. It depend on season of exudation, temperature, Relative Humidity %, tree girth, elevation of tree, treatment applied on tree *i.e.* mechanical and chemical (various gum enhancers) etc. Result was represented in Fig. 4.2.

The mechanical as well as chemical treatments, were applied on all for experimental trees on winter as well as in summer and noticed the time required to start exudation of biopolymers and its duration of continuation of exudation.

It was observed that in Dhawara (*Anogeissus latifolia*), Rohina (*Soymida febrifuga* Roxb.), Saja (*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) the maximum tree girth at 1 DBH (Distance at breast height) was minimum in tree Chirounji. However, the minimum time required for exudation of biopolymers was observed in Rohina and Chirounji in all mechanical treatments. However, in Dhawara (*Anogeissus latifolia*) singel cut (traditional method) of gum tapping taken minimum time (1 wk) for starting of exudation however, once it start it continues upto March depicted in Table. 4.1.

In Rohina all types of mechanical treatments, single cut with axe, double cut and semi arc method the exudation was started within one week and continued up to February shown in Table.4.2. Whereas, in Saja (*Terminalia tomentosa* Roxb.) have taken less time of exudation in single cut (tradition method) for exudation of biopolymer as compared to double cut (2 wk) and semi arc method (2 wk.). However, once it started, continued to up to February. (Table 4.3)

In Chirounji (*Buchanania lanzan* Spreng.) single cut (traditional method) as well as semi arc method was toward to be effective up to March for exudation of biopolymers. However, double cut (T_2) was formed non effective for exudation of biopolymers is depicted in Table 4.4.

4.1.2 The time requirement for gum exudation in chemical tapping methods.

In chemical method of gum exudation various gum enhancer were used in various trees for tapping purposes. In their study the four experimental trees *i.e.* Dhawara, Rohina, Saja and Chirounji. The exudation of gum and tapping techniques has not yet standardized even these trees are tapped by traditional way for the exudation of biopolymer for medicinal and commercial purpose.

In the experimental trees treatments *i.e.* T_1 distilled water (control), T_2 (ethephon @ 3.9%), T_3 (H_2SO_4 @ 1%), T_4 (ethephon @ 3.9% + H_2SO_4 @ 1%), T_5 (HCl @ 1%) was used as gum enhancer to induce the artificial signals of stress to induce the biopolymer exudation. However, the mechanism of exudation in natural and the any hostile environment like, drought, flood, wound, insect attack high temperature, fire enhanced it.

In the experiment 4 ml of gum enhancer was used in two concomitant doses *i.e.* 1.12.16 and 29.1.17 in mentioned doses in same experimental trees in

Table 4.1 Time required for gum exudation in mechanical method in Dhawara (*Anogeissus latifolia*)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	Single cut	1.34	1-12-16	1	December, January,
T_2	Double cut with axe	1.28		3	February, March
T_3	Semi-circle	1.21		3	

Table 4.2 Time required for gum exudation in mechanical method in Rohina (*Soymida febrifuga* (Roxb.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	Single cut	0.97	1-12-16	1	December, January,
T_2	Double cut with axe	1.00		1	February
T_3	Semi-circle	0.97		1	

Table 4.3 Time required for gum exudation in mechanical method in Saja (*Terminalia tomentosa* (Roxb.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	Single cut	1.55	29-1-17	1	February
T_2	Double cut with axe	1.58		2	
T_3	Semi-circle	1.55		2	

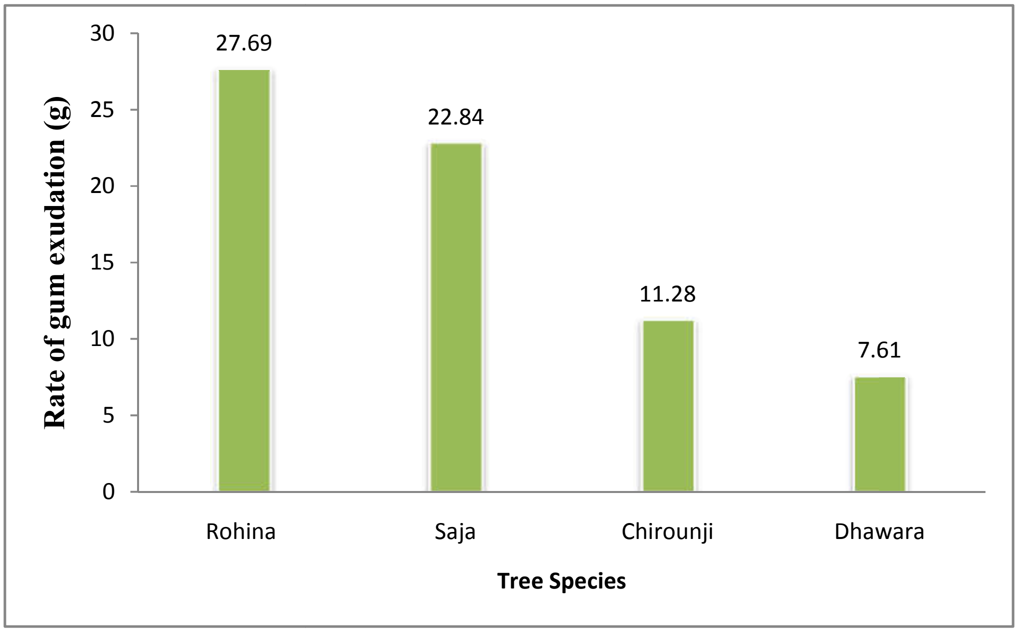


Fig. 4.1 Effect of mechanical methods and rate of gum exudation in experimental trees species.

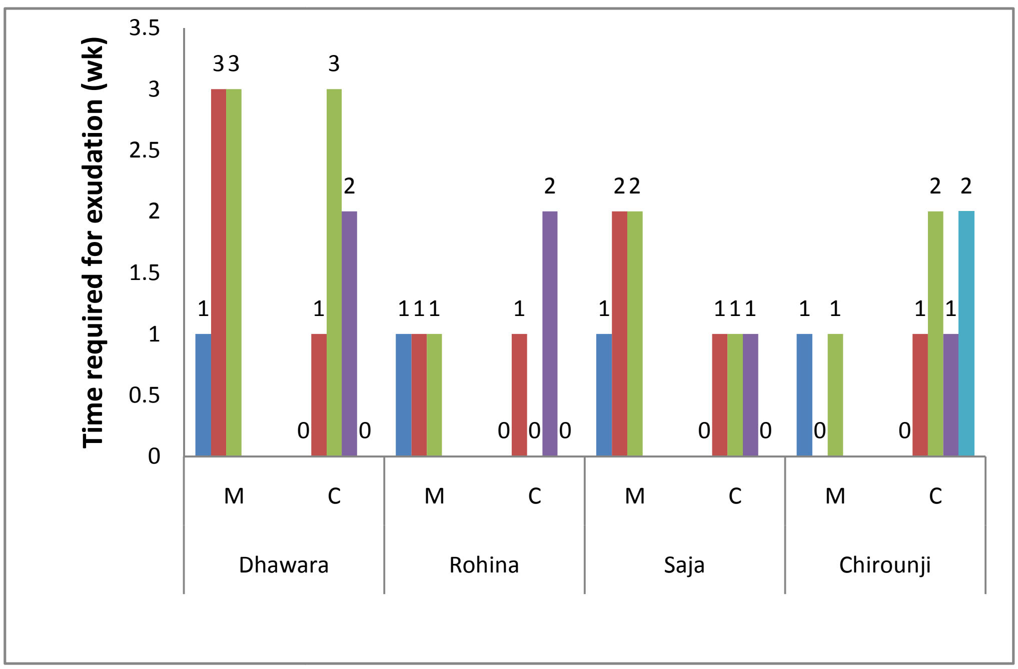


Fig. 4.2 Time required for gum exudation by mechanical and chemical methods in all experimental trees.

Table 4.4 Time required for gum exudation in mechanical method in Chirounji (*Buchanania lanzan* Spreng.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	Single cut	0.76	1-12-16	1	January, February, March
T_2	Double cut with axe	0.70		-	
T_3	Semi-circle	0.73		1	

Table 4.5 Time required for gum exudation in chemical method in Dhawara (*Anogeissus latifolia*)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	DW	1.50	1-12-16	-	-
T_2	Ethephon @3.9%	1.52	29-1-17	1	February, March, April, May
T_3	H_2SO_4 @ 1%	1.58		3	
T_4	Ethephon @3.9%+ H_2SO_4 @ 1%	1.58		2	
T_5	HCl @1%	1.55			

three replication and 4 ml distilled water was used as control. It was observed that the commencement of exudation were observed within week in treatment T_2 (ethephon @3.9% + H_2SO_4 @1%) 4 ml. However, when it was used in combination with H_2SO_4 T_4, ethephon @ 3.9% + H_2SO_4 @ 1% (4 ml) it take more time (2 wk) in starting of exudation and maximum time required for exudation was observed in T_3 H_2SO_4 @ 1%. However, the trees were selected for experimentation was of same range of tree girth 1.5-1.60m once the exudation started it continued up to May in Dhawara. (Table. 4.5 and fig. 4.2)

The trees was selected for experimentation of gummosis of Rohina, (*Soymida febrifuga* Roxb.) was having almost same tree girth like Dhawara ranged from 1.50 to 1.58 m and the exudation was observed only in T_2, ethephon @ 3.9%, 4ml and have taken minimum time one week, for exudation and in T_4, ethephon @ 3.9% + H_2SO_4 @1%, 4ml and in their treatment the exudation started within 2 wk. (Table. 4.6)

However, in Saja (*Terminalia tomentosa* Roxb.) the tree girth range was 1.60 – 1.70 m and T_2, ethephon @ 3.9%, 4ml, $T_{3,}$ H_2SO_4 @1%, 4ml, T_4 ethephon @ 3.9% + H_2SO_4 @1%, applied in two consecutive doses *i.e.* 1.12.2016 and 29.01.2017 were found equally same for time requirement for gum exudation 1 wk depicted in Table. 4.7. Whereas, in Chirounji (*Buchanania lanzan* Spreng.) tree was taken experimentation ranged in tree girth low 0.90 to 1.30 m and T_2, ethephon @ 3.9%, 4ml, $T_{3,}$ H_2SO_4 @1%, 4ml, T_4 ethephon @ 3.9% + H_2SO_4 @1%, 4ml were formed equally good and required 1 wk for exudation. Whereas, $T_{3,}$ H_2SO_4 @1%, and T_5, HCl @ 1% was found effective and have taken 2 wk for exudation. However, the exudation was continued up to March in all trees after induction of gummosis and it shown in Table. 4.8.

4.1.3 Rate of gum exudation

The rate of gum exudation shows the effect of temperature, relative humidity and other hostile environment on the release of biopolymers. Gum and resin are the biopolymer or end product of secondary metabolites which not re-enter in the metabolic pathways. Therefore, the study was commenced from winter (December) to summer (May) *viz.* using mechanical and chemical methods of gum production in Dhawara, Rohina, Saja and Chirounji and their was located at same elevation 333 m.

The monthly average production of biopolymers was measured in all four experimental trees in mechanical as well as in chemical methods of tapping. It was observed that in Dhawara (*Anogeissus latifolia*) in T_3, semi arc method the average maximum rate of exudation was observed in month Dec to Jan (0-2.4 g/tree) and total production of biopolymer per plant was also high 7.61 g/tree in Dhawara. However, the exudation was maximum in month of May 1.43 g in traditional method of tapping in Dhawara is shown in Table 4.9. However, in chemical method of tapping the maximum rate of gum exudation was obtained in between February to March (8.10 to 5.54 g) in T_4, ethephon @ 3.9% + H_2SO_4 @ 1%. (Table 4.10)

The temperature was 31.4^{0}c and RH % was 76.78 to 63.25% during that periods. However, treatment T_3, H_2SO_4 @ 1% was significantly superior when it applied the exudates was maximum during April at temperature 41.17^{0}c and RH% 49.22 and rate of exudation was maximum between March to April 1.06-17.7 g/tree is depicted in Table 4.10. The rate of gum exudation was nil in T_1, traditional method of tapping in Rohina (*Soymida febrifuga* Roxb..) and even in T_2, double cut with axe in mechanical method of tapping. It was significantly superior in T_3, semi arc method in between february to march 4.78-14.48 g/tree depicted in Table 4.11.

Their time february to march was also quite effective in exudation point of view in chemical method of tapping and treatment T_4, ethephon @ 3.9% + H_2SO_4 @ 1% (4 ml) was found to be significantly superior over other (15.58-30.01 g/ tree). However, T_2, ethephon @ 3.9% was found useful in inducing gummosis during winter in december 3.99 g/tree to february 5.79 g/tree results are depicted in Table 4.12.

The rate of gum exudation was measured upto May in all the experimental trees but in Saja (*Terminalia tomentosa* Roxb.) it was observed that in mechanical method of gum tapping in T_1, traditional method of tapping in Rohina (*Soymide febrifuga* Roxb.) and even in T_2, double cut with axe in mechanical method of tapping. It was significantly superior in T_3, semi arc method exudation was

Table 4.6 Time required for gum exudation in chemical method in Rohina (*Soymida febrifuga* Roxb.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	DW	1.50	1-12-16	-	-
T_2	Ethephon 3.9%	1.52	29-1-17	1	December, January, February, March, April
T_3	H_2SO_4 1%	1.58		-	
T_4	Ethephon+ H_2SO_4	1.58		2	
T_5	HCl	1.55		-	

Table 4.7 Time required for gum exudation in chemical method in Saja (*Terminalia taomentosa* Roxb.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	DW	1.60	1-12-16	-	-
T_2	Ethephon 3.9%	1.61	29-1-17	1	February
T_3	H_2SO_4 1%	1.67		1	
T_4	Ethephon+ H_2SO_4	1.58		1	
T_5	HCl	1.70			

Table 4.8 Time required for gum exudation in chemical method in Chirounji (*Buchanania lanzan* Spreng.)

	Treatments	DBH (in meter)	Date of treatment	Time Required (in wk)	Duration of gum exudation
T_1	DW	1.21	1-12-16	-	-
T_2	Ethephon 3.9%	0.97	29-1-17	1	January, February, March
T_3	H_2SO_4 1%	0.91		2	
T_4	Ethephon+ H_2SO_4	1.03		1	
T_5	HCl	1.28		2	

Table 4.9 Effect of mechanical methods on tapping and rate of gum exudation (g) in Dhawda *(Anogeissus latifolia)* during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi.

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	0.79	-	-	-	1.43	**2.22**
T_2		-	-	-	-	-	-	-
T_3		-	2.04	-	1.06	2.12	2.41	**7.61**
Total								**9.83**

T_1 (Control one cut with axe), T_2 (Double cut with axe), T_3 (Semi arc method)

Table 4.10 Effect of chemical methods on tapping and rate of gum exudation (g) in Dhawda *(Anogeissus latifolia)* during year 2016-2017 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi.

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2		-	5.245	1.78	1.29	-	2.16	**10.475**
T_3		-	-	-	1.06	17.7	-	**18.76**
T_4		-	-	8.105	5.54	-	3.43	**17.075**
T_5		-	-	-	-	-	-	-
Total								**46.31**

T_1 (Control, Distilled water), T_2 (Ethephon 3.9%), T_3 (H_2SO_4 1%), T_4 (Ethephon @ 3.9% + H_2SO_4 @ 1%), T_5 (HCl @ 1%)

Table 4.11 **Effect of mechanical methods on tapping and rate of gum exudation (g) in Rohina *(Soymida febrifuga* Roxb.) during year 2016 -17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi.**

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2		-	-	-	-	-	-	-
T_3		5.29	3.14	4.78	14.48	-	-	**27.69**
Total								**27.69**

T_1 (Control one cut with axe), T_2 (Double cut with axe), T_3 (Semi arc method)

Table 4.12 **Effect of chemical methods on tapping and rate of gum exudation (g) in Rohina *(Soymida febrifuga* Roxb.) during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi..**

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2		3.99	-	5.79	-	-	-	**9.78**
T_3		-	-	-	-	-	-	-
T_4		-	-	15.58	30.01	8.5133	2.87	**56.97**
T_5		-	-	-	-	6.37	-	**6.37**
Total								**73.12**

T_1 (Control, Distilled water), T_2 (Ethephon 3.9%), T_3 (H_2SO_4 1%), T_4 (Ethephon @ 3.9% + H_2SO_4 @ 1%), T_5 (HCl @ 1%)

Table 4.13 Effect of mechanical methods on tapping and rate of gum exudation (g) in Saja (*Terminalia tomentosa* Roxb.) during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi..

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	12.31	-	-	-	12.31
T_2		-	-	-	-	-	-	-
T_3		-	-	22.84	-	-	-	22.84
Total								35.15

T_1 (Control one cut with axe), T_2 (Double cut with axe), T_3 (Semi arc method)

Table 4.14 Effect of chemical methods on tapping and rate of gum exudation (g) in Saja (*Terminalia tomentosa* Roxb.) during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi..

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2			-	1.02	-	-	-	1.02
T_3		-	-	2.08	-	-	-	2.08
T_4		-	-	1.12	-	-	-	1.12
T_5		-	-	-	-		-	-
Total								4.22

T_1 (Control, Distilled water), T_2 (Ethephon 3.9%), T_3 (H_2SO_4 1%), T_4 (Ethephon @ 3.9% + H_2SO_4 @ 1%), T_5 (HCl @ 1%)

observed only up to February (12.31 g, 22.84 g) respectively. The T_3, semi arc method was found to be best for higher rate of gum exudation (22.84 g) is depicted in Table 4.13.

The time of exudation was up to Feb in chemical method also in Saja but treatment T_3, H_2SO_4 @ 1% was found superior over others. (Table 4.14)

In Chirounji (*Buchanania lanzan* Spreng.) the exudation was continued up to January only in T_3, semi arc method of tapping 11.28 g/tree. While, in other T_1, double cut method there was no exudation. (Table 4.15) Whereas, in chemical method of tapping it was started since Dec up to May in T_2, ethephon @ 3.9% and rate was highest since Dec to Feb. 2.42–6.88 g/tree. Followed by $T_{3,}$ H_2SO_4 @ 1% in between April to May 5.5-2.72 g/tree. Its result was represented in Table 4.15.

4.1.4 Quantity of gum/tree

The gum yield per tree was quantity on the basis of average of three replicates in mechanical and chemical methods of tapping in all four experimental trees *via* collection of the gum samples of various time intervals and expressed, in gum yield g/tree (Fig.). It was observed that the average gum/plant was maximum in Rohina (*Soymida febrigufa* Roxb.) followed by Dhawara (*Anogeissus latifolia*), Saja (*Terminalia tomentosa* Roxb.) and minimum gum was obtained in Chirounji (*Buchanania lanzan* Spreng.)

The chemical method of exudation was found to be superior in almost all the experimental trees except in Saja are represented in Fig. 4.3.

4.2 Rate of gummosis

The mechanism of gummosis plays pivotal role in biopolymer exudation and the depth of bark forms due to environmental stress or internal process of ethylene formation due to stress in controlled genetically and the mechanism is trigger by any cause while artificially or naturally induce the signal of ethylene production inside the sap wood. Hence, ethylene is the major function responsible for the induction of gummosis.

Ethephon (2-chloroethyl-phosphonic acid) is ethylene releasing compounds and it is eco-friendlly and bio safe and used in agriculture and forest crop for various purposes.

Abiotic (drought, salinity, high temp., low RH %, abrasion, wound) and biotic stress (insect, pest, infestation, wound etc.) induce ethylene production.

In some crops like mung bean and pea seedlings IAA stimulate ethylene production by inducing ACC (1 amino cyclopropene-1-carboxylic acid) SAM (Yang & Hoffman), 1984).

Gummosis induced by NAA in peach trunk is probably associated with ethylene production. NAA and IAA substantially stimulate ethylene production in tulip stemp (Saniewski *et al.*, 2003b). Ethephon is used to stimulate latex flow in para rubber (Hevea brasiliensis), resin enhancement in pines (Peters *et al*., 1978), gum production in *Acacia senegal* (Bhatt and Mohan Ram, 1990), *Anogeissus latifolia* (Bhatt, 1987), *Azadirachta indica* (Nair *et al.,* 1980, 1985). It also increases gum resin in *Mangifera indica* (Bhatt and Shah, 1985) and Commiphora wightii (Bhatt *et al.,* 1989).

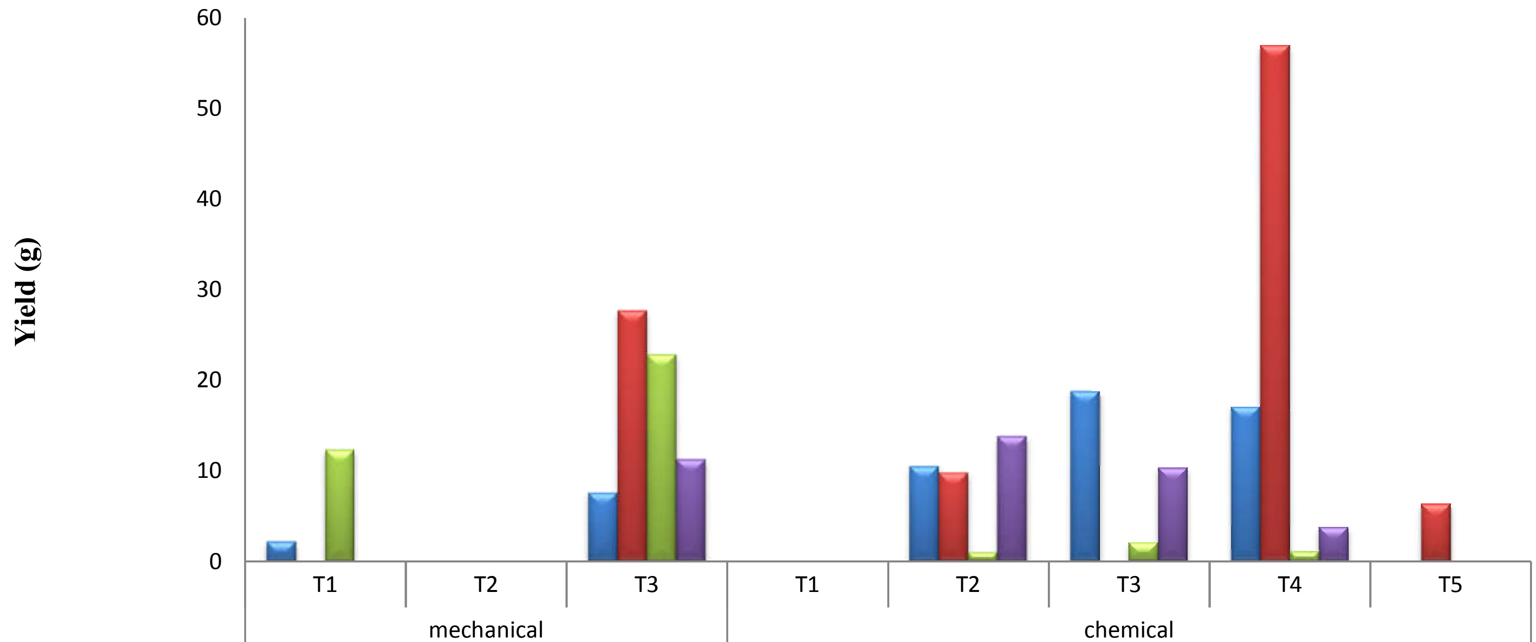
4.3 Quality parameters and Biochemical study

4.3.1 Effect of tapping techniques on solubility of gum of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda Roxb.*), Saja (*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng) in mechanical and chemical methods.

The results related to solubility of Dhawara, Rohina, Saja and Chirounji in different mechanical (semi arc) and chemical methods ((ethephon @3.9% + H_2SO_4 @1%) of tapping depicted in table 4.1 and fig. 4.3 and described below:

The mechanically and chemically tapped (ethephon @3.9% + H_2SO_4 @1%) gum sample of various experimental trees were more and hence it was evaluated for their solubility to analyze the quality and physic-chemical properties. The average overall solubility percent was maximum (127.60, 2% w/v) in Rohina (*Soymida febrifuga* Roxb.), followed by Chirounji (*Buchanania lanzan* Spreng) (112.40) then Dhawara (*Anogeissus latifolia*) and minimum in Saja (*Terminalia tomentosa* Roxb.) are depicted in table 4.17 to 4.18.

In Dhawara the solubility was maximum in hot water 92.40% (2% w/v) and only (0.20%) in ethanol and it was insoluble in acetone. However the solubility was slightly decreased in gum sample extracted by chemical methods as compared to mechanical methods. Hence it was 5% decreased in hot water as compared to



	mechanical T1	mechanical T2	mechanical T3	chemical T1	chemical T2	chemical T3	chemical T4	chemical T5
Anogeissus latifolia	2.22	0	7.61	0	10.475	18.76	17.075	0
Soymida febrifuga Roxb.	0	0	27.69	0	9.78	0	56.97	6.37
Terminalia tomentosa Roxb.	12.31	0	22.84	0	1.02	2.08	1.12	0
Buchanania lanzan Spreng.	0	0	11.28	0	13.8	10.33	3.77	0

Fig.4.3 Effect of mechanical and chemical methods on tapping and quantity of gum exudation (g) in Dhawara (*Anogeissus latifolia)*, Rohina (Soymida febrifuga Roxb.), Saja (*Terminalia tomentosa* Roxb.) and Chirounji *(Buchanania lanzan* Spreng.) during year 2016-17 (Elevation- 333 m).

Table 4.15 Effect of mechanical methods on tapping and rate of gum exudation (g) in Chirounji *(Buchanania lanzan* Spreng.) during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi.

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2		-	-	-	-	-	-	-
T_3		-	11.28	-	-	-	-	11.28
Total								11.28

T_1 (Control one cut with axe), T_2 (Double cut with axe), T_3 (Semi arc method)

Table 4.16 Effect of chemical methods on tapping and rate of gum exudation (g) in Chirounji *(Buchanania lanzan* Spreng.) during year 2016-17 (Elevation- 333 m) at Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi.

Treatment		Dec	January	February	March	April	May	Total
	Temp.(^{0}C)	27.40	28.03	31.40	33.93	41.17	42.17	
	RH (%)	87.60	84.90	76.78	63.25	49.22	46.3	
T_1		-	-	-	-	-	-	-
T_2		2.42	-	6.88	-	1.67	2.83	13.8
T_3		-	-	2.11	-	5.5	2.72	10.33
T_4		-	-	3.77	-	-	-	3.77
T_5		-	-	-	-	-	-	-
Total								27.90

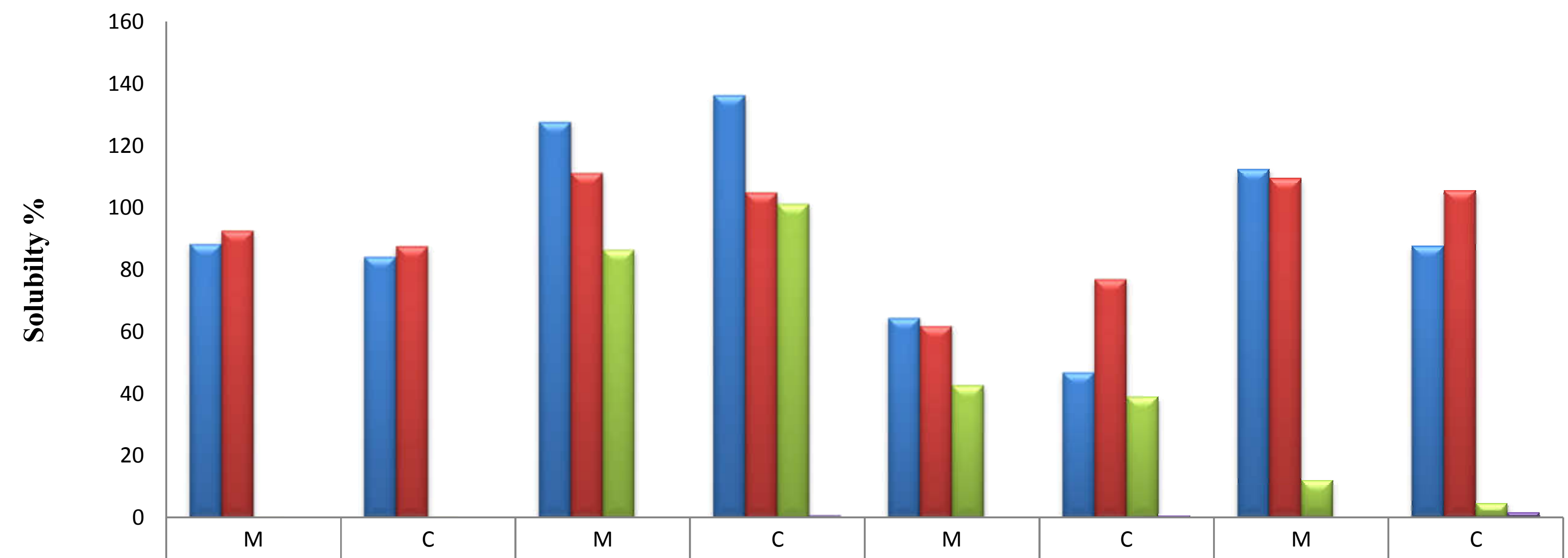
T_1 (Control, Distilled water), T_2 (Ethephon 3.9%), T_3 (H_2SO_4 1%), T_4 (Ethephon @ 3.9% + H_2SO_4 @ 1%), T_5 (HCl @ 1%)

Table 4.17: Average solubility (%) of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga*), Saja (*Terminalia tomentosa*) and Chirounji (*Buchanania lanzan*) in mechanical methods.

	Anogeissus latifolia		***Soymoda febrifuga***		***Terminalia tomentosa***		***Buchanania lanzan***	
	Mean	**2 % (w/v)**	**Mean**	**2 % (w/v)**	**Mean**	**2 % (w/v)**	**Mean**	**2 % (w/v)**
Cold water	0.441	88.20	0.638	127.60	0.321	64.20	0.562	112.40
Hot water	0.462	92.40	0.556	111.20	0.308	61.60	0.528	105.6
Ethenol	0.001	0.20	0.432	86.40	0.213	42.60	0.060	12.00
Acetone	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00

Table 4.18: Average solubility (%) of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga*), Saja (*Terminalia tomentosa*) and Chirounji (*Buchanania lanzan*) in chemical methods.

	Anogeissus latifolia		***Soymoda febrifuga***		***Terminalia tomentosa***		***Buchanania lanzan***	
	Mean	**2 % (w/v)**	**Mean**	**2 % (w/v)**	**Mean**	**2 % (w/v)**	**Mean**	**2 % (w/v)**
Cold water	0.420	84.00	0.681	136.20	0.234	46.80	0.438	87.60
Hot water	0.437	87.40	0.524	104.80	0.384	76.80	0.328	65.60
Ethanol	0.001	0.20	0.506	101.20	0.195	39.00	0.023	4.60
Acetone	0.000	0.00	0.004	0.80	0.003	0.60	0.008	1.60



	Anogeissus latifolia M	Anogeissus latifolia C	Soymida febrifuga M	Soymida febrifuga C	Terminalia tomentosa M	Terminalia tomentosa C	Buchanania lanzan M	Buchanania lanzan C
Cold water	88.2	84	127.6	136.2	64.2	46.8	112.4	87.6
Hot water	92.4	87.4	111.2	104.8	61.6	76.8	109.4	105.6
Ethanol	0.2	0.2	86.4	101.2	42.6	39	12	4.6
Acetone	0	0	0	0.8	0	0.6	0	1.6

Fig. 4.4 Average solubility of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga*), Saja (*Terminalia tomentosa*) and Chirounji (Buchanania lanzan) in mechanical and chemical methods at 2% w/v.

mechanical about 4% is solubility in cold water as compared to mechanical methods.

In Rohina (*Soymida febrifuga* Roxb.) the maximum solubility was obtained in gum sample of chemical method (ethephon @ 3.9% + H_2SO_4 @ 1%) as compared to mechanical method.

The solubility as maximum in cold water (136.20) followed by hot water (104.80), ethanol (101.20) and minimum was obtained in acetone (0.80). However, it was not soluble in acetone when extracted by mechanical method. The solubility was slightly decreased in gum sample of mechanically extracted methods.

In Saja (*Terminalia tomentosa* Roxb.) the solubility was maximum in cold water (64.20%) followed by hot water (61.60%) and ethanol (42.60%) and it was not soluble in acetone. However, the chemically extracted sample was showing maximum solubility in hot water.

In Chirounji (*Buchannaia lanzan* Spreng.) maximum solubility was obtained in cold water (112.40%) followed by hot water (105.6%) then ethanol (12.00%) and it was insoluble in acetone. However, there values were slightly decreased in chemically extracted gum samples.

The gum ghatti was not completely soluble in water and insoluble in 90 % alcohol. Gum ghatti forms a viscous dispersion in water when in concentrations of 5 % or greater. The dispersion is thixotropic and non-Newtonian in behaviour (Sao, 2012). Dell and McComb (1978a) reported that the natural gum is soluble in cold or hot water (or at least it swells to form a gel), but insoluble in organic solvents such as hydrocarbons, ether or alcohols. Similar results were also reported by Davidson (1980).

The good solubility gum indicated the absence of cross linking between polymeric chains. This is because gums having cross linked polymeric chains only swell in water without dissolving. Murwan and Asma (2008) reported that the gum from *Acacia senegal* is a water soluble polysaccharide of the hydrocolloid group and comprised mostly of arabino galactan and protein, in addition to some mineral elements. It is insoluble in most organic solvents; however, limited solubility can be also obtained in ethanol (up to 60 %) glycerol and ethylene glycol. Similar results were also reported by Williams *et al*. (2000).

4.3.2 Impact of tapping techniques on viscosity of gum of different tree species.

The gum sample of Dhawara, Rohina, Saja and Chirounji obtained through mechanical and chemical tapping techniques were analyzed for their viscosity using distilled water and adjust the temperature of the solution to 30^0c at 10, 20 and 30 rpm/min used spindle no. 64, 63, 61 and 62. The unit of Dynamic viscosity is cP (centi poise).

The mechanical and chemically tapped gum sample of Dhawara (*Anogeissus latifolia* Roxb.), Rohina (*Soymida febrifuga* Roxb.), Saja (*Terminalia tomentosa Roxb.*) and Chirounji (*Buchannaia lanzan* Spreng.) were analyzed by using spindle no. 64, 63, 61 and 62 respectively at 30^0c temperature. The results related to viscosity of different mechanical and chemical gum tapping techniques in gum trees are depicted in Table. 4.19 and 4.20 and Fig. 4.5 and described below:

The mechanically tapped gum sample in Dhawara, Rohina, Saja and Chirounji showed slightly lower values as compared to chemically tapped gum samples. However, the value of viscosity was greater at low rpm/min and decreased gradually with increase in rpm 10, 20, 30 rpm/min value was obtained at 10 rpm/min (1240 cP) in Dhawara, 522.33 cP in Rohina, 408.67 cP in Saja and 340 cP in Chirounji and it was minimum at 30 rpm/min, 84.33 cP in Rohina, 360.33 in Saja and 285 cP in Chirounji.

However, there values were slightly higher in chemically tapped gum samples in Saja. The viscosity was to lower in chemically tapped gum samples in saja as compared to mechanically tapped gum. However, in Chirounji it was almost same.

Anogeissus latifolia forms viscous solutions at concentration of about 5 % or higher and exhibits non-newtonian behavior. It is a moderately viscous gum lying between gum arabic and karaya gum. The viscosity value obtained in gum ghatti indicated that its molecules are either solvated or asymmetric or both when compared to gum arabic. Deshmukh *et al*. (2012) investigated that the viscosity of 10% dispersion of gum ghatti soluble grade I, II, III and IV were observed below 400 cps, 400-500 cps, 1000-2500 cps and above 2500 cps respectively at 25^0C on

Table 4.19: Average viscosity (cP) of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga*), Saja (*Terminalia tomentosa*) and Chirounji (*Buchanania lanzan*) in mechanical methods.

rpm/min	*Anogeissus latifolia*	*Soymoda febrifuga*	*Terminalia tomentosa*	*Buchanania lanzan*
10	1240	522.33	408.67	540
20	336	486.00	254.67	328
30	317.00	84.33	360.33	285

Table 4.20: Average viscosity (cP) of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga*), Saja (*Terminalia tomentosa*) and Chirounji (*Buchanania lanzan*) in chemical methods.

rpm/min	*Anogeissus latifolia*	*Soymoda febrifuga*	*Terminalia tomentosa*	*Buchanania lanzan*
10	3115.33	730	289.67	524.33
20	1500.00	542	259.67	478
30	650.00	88	306.33	295

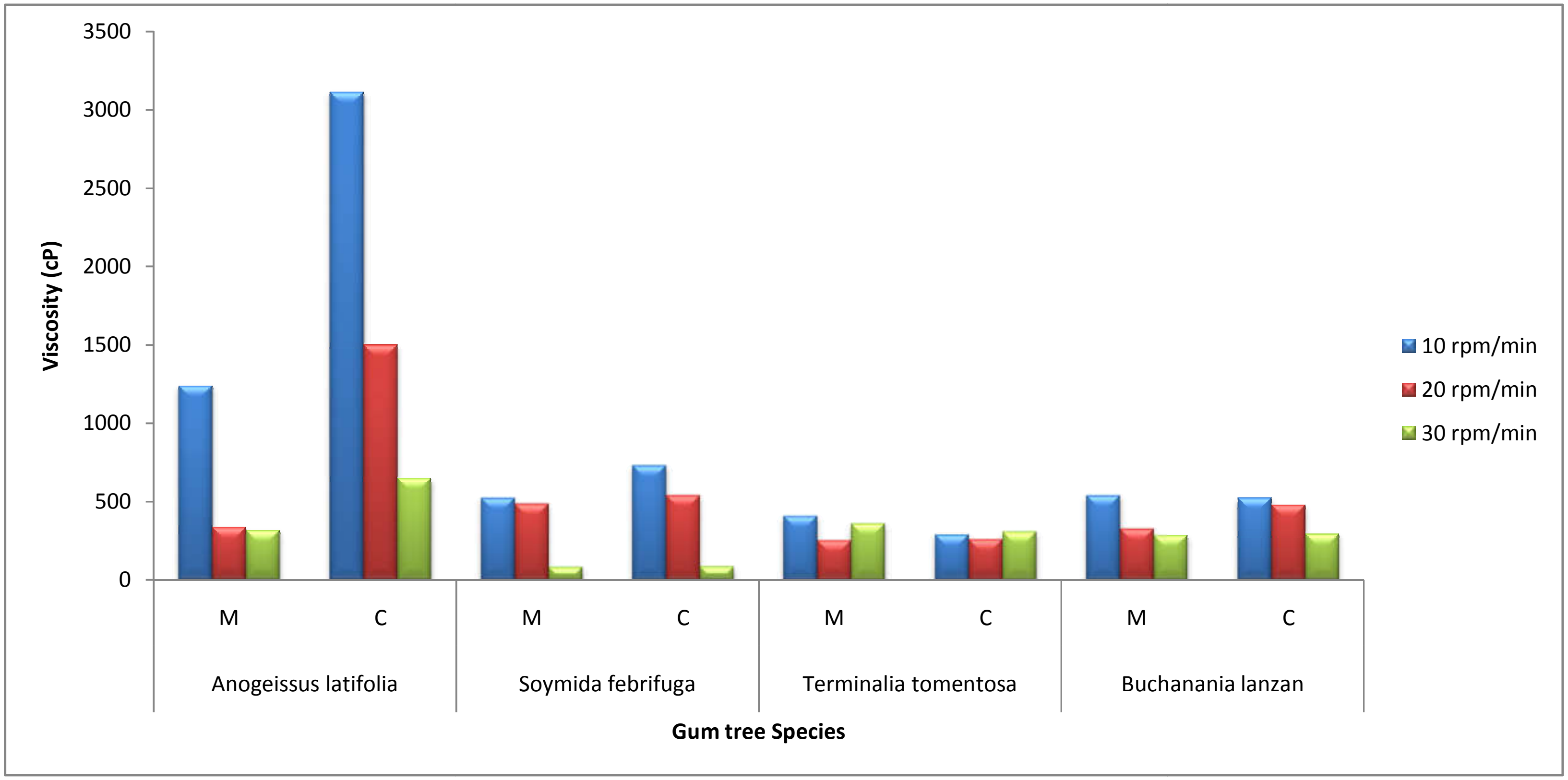


Fig. 4.5: Average viscosity (cP) of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga* Roxb.), Saja (*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) mechanicalandchemical methods.

RVT Brookfield Viscometer at 24 hrs. Sao (2012) also reported that the viscosity of gum ghatti grade I, II, and III in 5 % solution found 30-440cPs, 30-350 cPs and 30-300 cPs respectively. Similar findings were also reported by Jefferies *et al.* (1977) and Meer and Davidson (1980).

4.3.3 pH Value

The value of pH of gum of various experimental trees was analyzed in gum sample collected in winter and summer season by mechanical and chemical method in Dhawara, Rohina, Saja and Chirounji.

The pH value of all gum samples indicated the slightly acidity in Dhawara (*Anogeissus latifolia*) because of its higher acid content and its plays significantly role in dispersion stability. The pH value was significantly higher (5.76) in gum sample collected from semi arc method while the minimum pH (5.66) was obtained in control (1 blaze with axe, traditional method). However, the impact of seasonal variation was non-significantly on gum sample of mechanical tapped methods depicted in table 4.21.

The range of pH was obtained 4.49 to 5.65 in chemically tapped gum in Dhawara. However, the significantly lowest value of pH was observed in gum sample 4.49 obtained by HCl 1%, while maximum pH value was observed in T_4 (ethephon 3.9% + H_2SO_4 1%) is 5.75. The seasonal variation in pH of chemically tapped gum was non-significant depicted in table 4.22.

The range of pH of gum obtained by mechanical method of tapping was 6.14 to 6.19 while in chemically tapped gum sample it was 4.89 to 5.94 in Rohina (*Soymida febrifuga* Roxb.). The chemically tapping method reduced the pH and made the sample acidic.

However, in mechanically tapped gum maximum pH was obtained in semi arc method (6.20) and there was non-significant impact on seasonal variation as well as method of mechanical tapping in pH of gum in Rohina (Table 4.23) However, in chemically tapped sample lowest pH obtained in T_5 HCl @1% (4.88) and maximum in T_2 (ethephon @ 3.9%) 5.94 is depicted in Table 4.24.

In Saja (*Terminalia tomentosa* Roxb.) gum pH ranged from 5.73 to 5.75 in mechanically tapped gum and 5.65 to 5.77 in chemically tapped gum samples. There was non-significant variation in mechanically tapped gum. The maximum pH 5.77 was obtained in T_4 (ethephon @3.9% + H_2SO_4 1%). however it was significantly minimum in T_2 (ethephon @3.9%) treated trees 5.65. depicted in Table 4.25 and 4.26.

In Chirounji the pH of gum sample collected from mechanical method ranged from 5.65 to 5.76, the significantly high pH was obtained in T_2 (double cut with axe) and minimum 5.65 obtained in T_1 control (1 blaze with axe). Where are, in chemically extracted lower than mechanically extracted gum. It was ranged from 5.26 to 5.42. However, it was significantly lower in T_3 (H_2SO_4 @3.9%) 5.26 and significantly maximum in T_5 (HCl @1%) 5.42 treatment and results obtained are presented in Table 4.27 and 4.28.

The pH value of all gum samples noticed acidic in *Anogeissus latifolia* gum which might be due to the presence of acidic sugars. It is composed of Larabinose, D-galactose, D-mannose, D-xylose and D-glucoronic acid. Similar results were also reported by Ahmed *et al.* (2009) in *Anogeissus leicarpous*.

4.3.4 Effect of mechanical and chemical tapping techniques on protein % of experimental trees.

The protein content of gum samples of all experimental trees was analyzed *via* taking the representative samples of mechanical and chemical methods. It was observed that average protein content of gum samples of Dhawara (*Anogeissus latifolia*) was higher (5.86%) and followed by Chirounji (*Buchanania lanzan* Spreng.) 3.69% and Rohina (*Soymida febrifuga* Roxb.) 1.78% and minimum protein percent was observed in gum sample of Saja (*Terminalia tomentosa*) 0.83%. in general the protein content by mechanical method of tapping as compared to chemical methods in all the experimental trees.

Al-Assaf *et al.* (2008) studied on the characterization of gum ghatti and comparison with gum arabic found that the protein content of gum ghatti (3.4%) was higher as compared to protein content of gum arabic (2.1%). Similar results were also reported by Ahmed *et al.* (2009) in *Anogeissus leiocarpus.* The protein was observed 4.7% in Dhawara in mechanically tapped gum and 4.49 to 4.96 in chemically tapped trees (Kuruwanshi 2017).

4.3.5 Ash content

The ash content of gum of experimental trees was analyzed in the gum extracted by mechanical method and chemical methods of gum tapping the ash content was higher in Chirounji (*Buchanania lanzan* Spreng.) 4.90 g followed by Dhawara (*Anogeissus latifolia*) 4.65 g, Rohina (*Soymida febrifuga* Roxb.) 4.53 g and Saja (*Terminalia tomentosa*) 4.17 g.

The ash content was comparatively lower in mechanical method in gum of all the experimental trees are represented in Fig. 4.6.

4.3.6 Time of treatment application

The exudation was significantly higher in the month of May-June in almost all the experimental trees along with mechanical treatment.

4.3.7 Grade of gum

The collected gum of Dhawara (*Anogeissus latifolia*), Rohina (*Soymida febrifuga*), Saja (*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) in mechanical and chemical gum tapping techniques were analyzed visually on the basis of colour and purity are depicted in Fig. 4.7.

Table 4.21: The pH of gum sample of collected by mechanical methods in Dhawara *(Anogeissus latifolia)*.

Treatment		Winter	Summer	Average
T_1	**Control (1 blaze with axe)**	5.667	5.673	5.670
T_2	**Double cut with axe**	5.717	5.710	5.713
T_3	**Semi arc method**	5.763	5.733	5.748

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.001	-	-	-
Seasons	1	0.001	0.001	0.360	0.56198
Treatment	2	0.019	0.009	5.751	0.02176
Interaction (Seasons x Treatment)	2	0.001	0.000	0.286	0.75695
Error pooled	10	0.016	0.002		
Total	17	0.037			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.019	0.013
Treatment	0.052	0.023	0.016
Interaction (Season x Treatment)	N/A	0.033	0.023

Table 4.22: The pH of gum sample of collected by chemical methods in Dhawara *(Anogeissus latifolia)*.

Treatment		Winter	Summer	Average
T_1	**Control (Distilled water)**	0.000	0.000	0.000
T_2	**Ethephon 3.9%**	5.663	5.653	5.658
T_3	**H_2SO_4 1%**	5.723	5.697	5.710
T_4	**Ethephon+ H_2SO_4**	5.743	5.763	5.753
T_5	**HCl**	4.497	4.487	4.492

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.008			
Seasons	1	0.000	0.000	0.155	0.69838
Treatment	4	146.817	36.704	20,378.375	0.00000
Interaction (Season x Treatment)	4	0.002	0.000	0.233	0.91615
Error pooled	18	0.032	0.002		
Total	29	146.859			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.015	0.011
Treatment	0.052	0.025	0.017
Interaction (Season x Treatment))	N/A	0.035	0.025

Table 4.23: The pH of gum sample of collected by mechanical methods in pH of Rohina (*Soymoda febrifuga*)

Treatment		Winter	Summer	Average
T_1	**Control (1 blaze with axe)**	6.133	6.160	6.147
T_2	**Double cut with axe**	6.193	6.153	6.173
T_3	**Semi arc method**	6.197	6.193	6.195

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.015			
Seasons	1	0.000	0.000	0.147	0.70930
Treatment	2	0.007	0.004	2.800	0.10820
Interaction (Seasons x Treatment)	2	0.003	0.002	1.304	0.31383
Error pooled	10	0.013	0.001		
Total	17	0.038			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.017	0.012
Treatment	N/A	0.021	0.015
Interaction (Seasons x Treatment)	N/A	0.029	0.021

Table 4.24: The pH of gum sample of collected by chemical methods in pH of Rohina (*Soymoda febrifuga*)

Treatment		Winter	Summer	Average
T_1	Control (Distilled water)	0.000	0.000	0.000
T_2	Ethephon 3.9%	5.947	5.927	5.937
T_3	H_2SO_4 1%	5.900	5.900	5.900
T_4	Ethephon + H_2SO_4	4.937	4.947	4.942
T_5	HCl	4.897	4.880	4.888

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.000			
Seasons	1	0.000	0.000	0.717	0.40841
Treatment	4	146.886	36.722	94,161.710	0.00000
Interaction (Seasons x Treatment)	4	0.001	0.000	0.554	0.69853
Error pooled	18	0.007	0.000		
Total	29	146.894			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.007	0.005
Treatment	0.024	0.011	0.008
Interaction (Seasons x Treatment)	N/A	0.016	0.011

Table 4.25: The pH of gum sample of collected by mechanical methods in pH of Saja (*Terminalia tomentosa*)

Treatment		Winter	Summer	Average
T_1	**Control (1 blaze with axe)**	5.757	5.743	5.750
T_2	**Double cut with axe**	5.757	5.737	5.747
T_3	**Semi arc method**	5.740	5.727	5.733

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.007			
Seasons	1	0.001	0.001	1.347	0.27269
Treatment	2	0.001	0.000	0.581	0.57708
Interaction (Seasons x Treatment)	2	0.000	0.000	0.000	0.99963
Error pooled	10	0.008	0.001		
Total	17	0.018			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.014	0.010
Treatment	N/A	0.017	0.012
Interaction (Seasons x Treatment)	N/A	0.024	0.017

Table 4.26: The pH of gum sample of collected by chemical methods in pH of Saja (*Terminalia tomentosa*)

Treatment		Winter	Summer	Average
T_1	**Control (Distilled water)**	0.000	0.000	0.000
T_2	**Ethephon 3.9%**	5.647	5.647	5.647
T_3	**H_2SO_4 1%**	5.753	5.770	5.762
T_4	**Ethephon+ H_2SO_4**	5.767	5.767	5.767
T_5	**HCl**	5.703	5.690	5.697

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.003			
Seasons	1	-0.000	-0.000	-0.301	0.00000
Treatment	4	156.993	39.248	86,698.880	0.00000
Interaction (Seasons x Treatment)	4	0.001	0.000	0.477	0.75238
Error pooled	18	0.008	0.000		
Total	29	157.004			

Factor	C.D.	SE(d)	SE(m)
Seasons	0.016	0.008	0.005
Treatment	0.026	0.012	0.009
Interaction (Seasons x Treatment)	N/A	0.017	0.012

Table 4.27: The pH of gum sample of collected by mechanical methods in pH of Chirounji (*Buchanania lanzan*)

Treatment		Winter	Summer	Average
T_1	**Control (1 blaze with axe)**	5.647	5.653	5.650
T_2	**Double cut with axe**	5.760	5.750	5.755
T_3	**Semi arc method**	5.743	5.730	5.737

Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.001			
Seasons	1	0.000	0.000	0.164	0.69414
Treatment	2	0.038	0.019	32.380	0.00004
Interaction (Seasons x Treatment)	2	0.000	0.000	0.353	0.71111
Error pooled	10	0.006	0.001		
Total	17	0.045			

Factor	C.D.	SE(d)	SE(m)
Seasons	N/A	0.011	0.008
Treatment	0.031	0.014	0.010
Interaction (Seasons x Treatment)	N/A	0.020	0.014

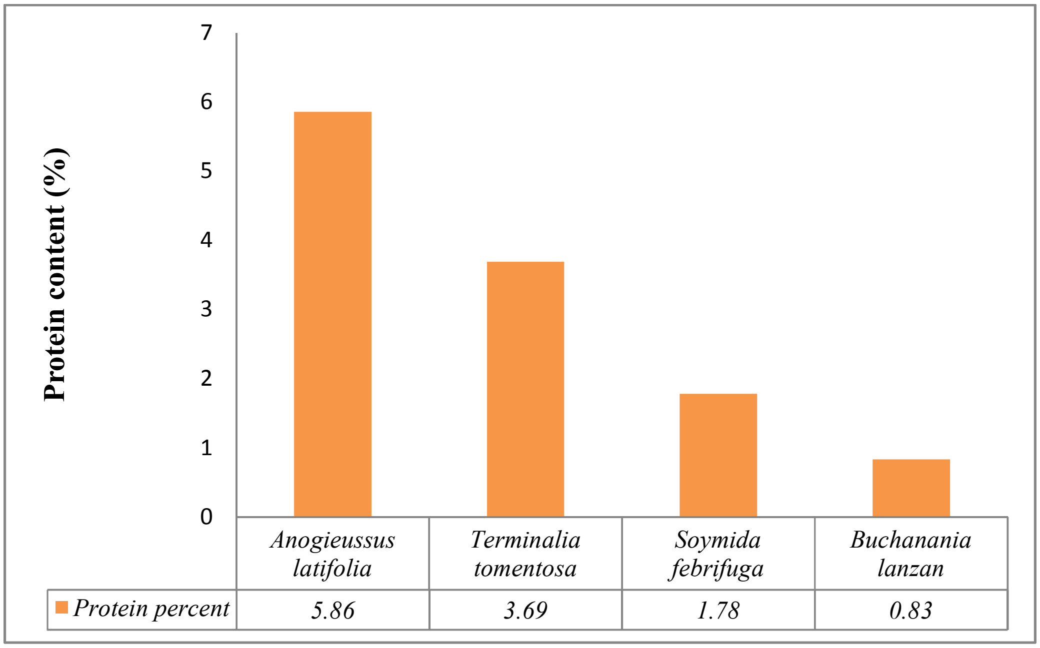
Table 4.28: The pH of gum sample of collected by chemical methods in pH of Chirounji (*Buchanania lanzan* Spreng.)

Treatment		Winter	Summer	Average
T_1	**Control (Distilled water)**	0.000	0.000	0.000
T_2	**Ethephon 3.9%**	5.313	5.333	5.323
T_3	**H_2SO_4 1%**	5.253	5.267	5.260
T_4	**Ethephon + H_2SO_4**	5.403	5.407	5.405
T_5	**HCl**	5.410	5.437	5.423

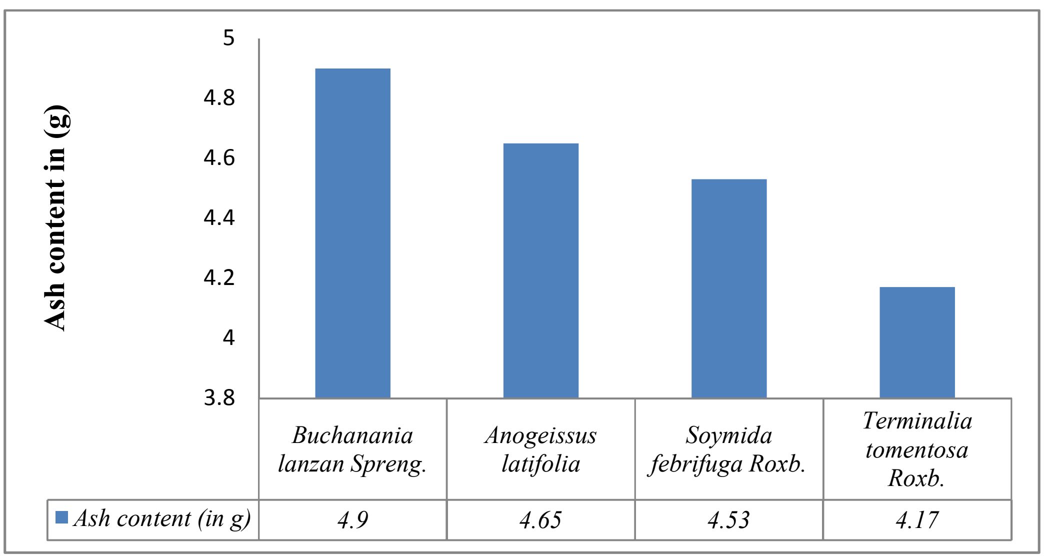
Analysis of variable table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significant
Replication	2	0.000			
Seasons	1	0.001	0.001	4.862	0.04070
Treatment	4	137.641	34.410	139,033.271	0.00000
Interaction (Seasons x Treatment)	4	0.001	0.000	0.723	0.58741
Error pooled	18	0.004	0.000		
Total	29	137.648			

Factor	C.D.	SE(d)	SE(m)
Seasons	0.012	0.006	0.004
Treatment	0.019	0.009	0.006
Interaction (Seasons x Treatment)	N/A	0.013	0.009



A) **Protien % Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga Roxb.*), Saja (*Terminalia tomentosa*) *Roxb.*) and Chirounji (*Buchanania lanzan Spreng*) in mechanical and chemical methods.**



B) **Ash content of Dhawara (*Anogeissus latifolia*), Rohina (*Soymoda febrifuga Roxb.*), Saja (*Terminalia tomentosa*) *Roxb.*) and Chirounji (*Buchanania lanzan Spreng*) in mechanical and chemical methods. (in 5 g of sample).**

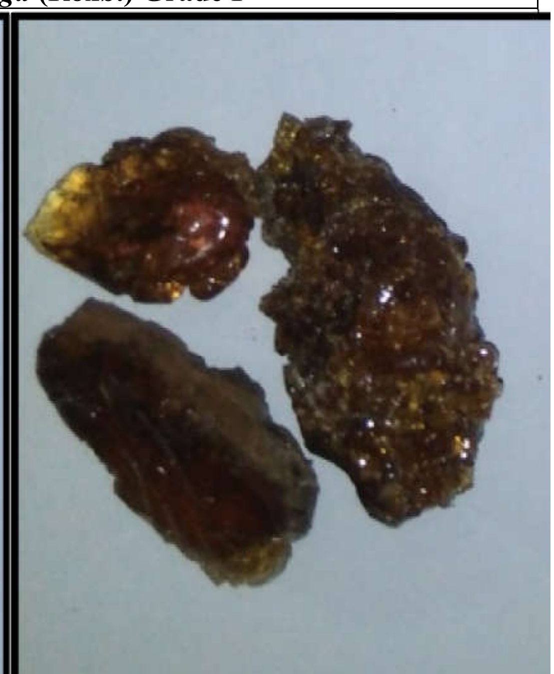
Fig. 4.6: Protein % and ash content present in gum samples of all experimental trees.

	
***Anogeissus latifolia* Grade I**	***Anogeissus latifolia* Grade II**
	
***Buchanania lanzan* (Spreng.) Grade II**	***Buchanania lanzan* (Spreng.) Grade III**

Fig. 4.7: Grading of exudates gum samples on the bases of colour in Dhawara (*Anogeissus latifolia*) and Chirounji (*Buchanania lanzan* (Spreng.).

***Soymida febrifuga* (Roxb.) Grade I**

***Soymida febrifuga* (Roxb.) Grade II**



***Soymida febrifuga* (Roxb.) Grade III**

Fig. 4.8: Grading of exudates gum samples on the bases of colour in Rohina (*Soymida febrifuga* Roxb.)

CHAPTER – V

SUMMARY AND CONCLUSIONS

The present investigation entitled **"Development of tapping techniques for sustainable extraction of biopolymers from major gum producing trees of Mungeli region of Chhattisgarh"** was carried out at village Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi, Dist. Mungeli (Chhattisgarh) whereas, laboratory work was done in Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, IGKV, Raipur (Chhattisgarh) during the year 2016-17. The salient findings of the experiment are summarized below:

Industrial applications of natural gums have been expending tremendously, so gum collection from tress provide an important livelihood for local dwellers. Traditional gum tapping is crude and unscientific, deep incisions make severe injury to trees and ultimately population of trees are decreasing day by day. To overcome this problem, development of proper tapping method and standardizing them for potential production and safe tapping is needed. Therefore, the present investigation was aimed to compare the traditional method of tapping with mechanical and chemical methods and their standardization for safe potential tapping techniques for its sustainable gum production. Hence, the study was done on experimental trees *i.e.* Dhawara (*Anogeissus latifolia*), Rohina (*Soymida febrifuga* Roxb.), Saja (*Terminalia tomentosa* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) abundantly present in the forest of Sanwatpur, under the ATR (Achanakmar Tiger Reserve) Lormi, Dist. Mungeli (Chhattisgarh).

Dhawara (*Anogeissus latifolia*), gum is important of the Indian gums, recognized by the British Pharmacopoeia (drug making), grown extensively all over the country, more commonly in dry deciduoudus forests in the western ghat, and dry plateaus of Vindhyanchal, Satapura and Western Ghats range of mountain, extending to Maharastra, MP, Chhattisgarh, Bihar and Orissa. Dhawara is known as gum ghatti from the fact that it is transported through ancient transport router mountain pass or ghats.

Dhawara (*Anogeissus latifolia*), the different part of the plant contains tanins, ellagic acid, steroids, betasitosterol, glycoside and flavonoids. Its bark is effective in anaemic conditions and urinary discharge, piles, diarrhoea, dysuria, cough, colic liver complaints, snakebite and skin disorders.

Rohina (*Soymida febrifuga* Roxb.) is an important medicinal tree distributed in tropical areas of Asia. The decoction of the bark is extensively used for the treatment of wound, dental disease, uterine bleeding, haemorrhage, stomach pain and as anticancer agent considered to be as good as the Cinchona bark for the treatment of malaria. Phytochemical investigation of the plant yielded an array of structurally diverse limonoids (13), coumarin, flavones and homoisoflavons. Its leaves also using as botanical insecticides for to the pest management. Methanol extract of leaves of *Soymida febrifufa* could have great potential for the control of pests (insect anti-feedents and toxicants) against the third instar larvae of *Spodopatera litura* and *Achaea janata*.

Saja (*Terminalia tomentosa* Roxb.) also possess many pharmacological properties *i.e.* antioxidant, hyperglycaemic, antifungal, anti-diarrhoeal and leucorrheal.

Chirounji (*Buchanania lanzan* Spreng.) trees produce gum benzoin similar but inferior to that form styrax benzoin also known as 'Pyar'. Bark yield tannin (upto 13%). Tannin/resin used in diarrhoea etc. Therefore to meet increasing industrial demand by improving upon unscientific and traditional extraction and eliminate injury to trees and ultimately sustain trees population, via the experimentation analyzed tapping methods, chemical treatments (use of various gum enhancer ethephon, H_2SO_4, HCl) and the best time and season to tsp for maximum yield. For mechanical treatments, *i.e.* T_1, single cut with axe (traditional), T_2, (double cut with axe), T_3, semi arc (12cm length x 6cm width x 4cm deep) were used for chemical treatments (gum enhancer) *i.e.,*T_1, (distilled water 4ml),T_2 (ethephon @ 3.9% 4ml), T_3 (H_2SO_4 @ 1% 4ml), T_4 (HCl @ 1% 4ml), were applied by making a hole on the tree trunk at 1m DBH (distance at breast height) by hand girmit (2 cm diameter) and injected gum enhancer by injection and closed the hole with clay.

The treatment applied on 1st Dec. 2016 and second on 29 Jan 2017. Two concomitant doses of gums enhancer were injected on all observations were recorded *i.e.*, Time of exudation, time of treatment application, quantity of gum (g), physical and physicochemical properties were analyzed during the investigation. The factorial RBD with three replications was applied in some physicochemical properties of gum samples.

The salient finding of the experiment are summarized below:

1. The process of gummosis and exudation started within week in traditional, mechanical as well as chemical methods of tapping in all experimental trees when treatment were applied on 1st Dec. 2016.
2. The rate of exudation was greater in chemical treatment as compared to mechanical and traditional methods of tapping in all the experimental trees excepted in Saja (*Terminalia tomentosa* Roxb.)
3. The temperature and relative humidity play significantly role on quantity of gum exudation in experimental trees. Amongst the traditional methods of tapping T_1 (single cut with axe) to other mechanical methods *i.e.*, T_2 (double cut with axe) and T_3, semi arc method it was observed that the T_3, semi arc method was found to be best as compared to other mechanical methods in yield point of view in all four experimental trees. The maximum yield observed in Rohina (27.69 g) followed by Saja (22.84 g), Chirounji (11.28 g) and minimum in was obtained in Dhawara (7.61 g).
4. The flow rate of biopolymers was significantly higher within month (Dec–Jan) in all experimental trees except in Saja (Dec-Feb). The rate of gum exudation in mechanical methods (semi arc method) was significantly higher within month (Dec–Jan) in all experimental trees except in Saja (Dec-Feb).
5. The semi arc method was found to be suitable in gum tapping in winter season also. However, the mechanism of gummosis have significantly affected by high temperature and low relative humidity. But in these experimental trees, the biopolymers might be synthesizing as end product or bi-product of the metabolic pathways of secondary metabolites throughout the year.
6. The comparative studies of using various gum enhancers in all four experimental trees indicated that in Dhawara. Treatment $T_{3,}$ H_2SO_4 @ 1% 4ml

(18.76 g) and T_4, ethephon @ 3.9% + H_2SO_4 @ 1% 4ml (17.08 g) was superior over individual effect ethephon @ 3.9% (T_2) and T_5, HCl @ 1%.

However, in Rohina the combined effect of H_2SO_4 and ethephon T_4, ethephon @ 3.9% + H_2SO_4 @ 1% 4 ml was found to be superior (56.97 g) over other treatments. In Chirounji T_2, ethephon @ 3.9% 4 ml was significantly superior (13.8 g) followed by T_3, H_2SO_4 @ 1% 4 ml (10.33 g).

In Saja also T_3, H_2SO_4 @ 1% was found to be superior (2.08 g) over other chemical methods.

7. The gum yield per plant was found to be significantly superior in chemical methods in Dhawara, Rohina and Chirounji except in Saja.

   The overall production of gum was significantly higher in Rohina (56.97 g) followed by Dhawara (18.76 g) and Chirounji (11.28 g/tree) in chemical method of tapping.

8. Physical properties of gums indicated that the size of lump of gum *i.e.* length, width was significantly higher in Dhawara gum over others. However in remaining gums length and width was more in Rohina gum followed by Chirounji gum (Pyar) and minimum length of gum lump was obtained in Saja.

9. However, the maximum thickness of gum lumps was obtained in gum of Saja but it contains minimum length and width of gum particles and remaining three gums (Dhawara, Rohina and Chironji) having almost similar thickness. The physico-chemical properties *i.e.* pH, solubility, viscosity, protein %, ash content were analyzed in all the gum samples of experimental trees.

   The solubility was measured in the representative samples of mechanical method (semi arc method) and chemical method T_4 (ethephon @ 3.9% + H_2SO_4 @ 1%) and observed that maximum solubility was obtained in cold water in Rohina, Saja and Chirounji except in Dhawara.

   In Dhawara maximum solubility was obtained in hot water. However the solubility decreased in gum samples obtained through chemical methods of tapping.

10. The solubility in organic substances indicated the availability of resin content and it was observed that gum samples of Rohina containing more resin amount followed by Saja and Chirounji.

Viscosity was determined in representative samples of gum obtained by mechanical and it was determined in distilled water at 30^0c at 10, 20, 30 rpm/min used spindle no. for Dhawara (64), Rohina (63), Saja (61) and Chirounji (62). In general the viscosity decreased with increase in rpm/min in all the experimental trees. It depends on climate, time of harvest, storage conditions including temperature and humidity.

11. The pH of gum samples was analyzed in gum collected in January (winter) and summer (May) in mechanical and chemical methods of tapping in all experimental trees and it was observed that the pH was higher in mechanical method (semi arc) and it was almost same in chemical method of exudation, T_4 (ethephon @ 3.9% + H_2SO_4 @ 1%) 3.9, in Dhawara (5.74-5.75) and Saja (5.73-5.76). while in Rohina it decreased in chemical method T_4, ethephon @ 3.9% + H_2SO_4 @ 1% (6.19-4.94) and in Chirounji (5.75-5.40).
12. The average protein content was higher in gum of Dhawara (5.86 %) followed by 3.69% in Chirounji than Rohina (1.78%) and minimum protein content was obtained in Saja gum 0.83%. however, the mechanically tapped gum samples having higher protein percent as compared to chemically obtained gums.
13. The ash content was higher in Chirounji (4.90 g) and followed by Dhawara (4.65 g), Rohina (4.53 g), and minimum ash content was analyzed (4.17 g). However, the ash content was lower in gum sample of mechanically obtained techniques as compared to sample of gum obtained in chemical methods.
14. The chemically tapped gum was superior in quality and grade as compared to mechanical method of tapping in all experimental trees grade wise.

CONCLUSIONS

The finding based on the experimental investigation

- The all four experimental trees seem to have the capacity to exudates gum throughout the winter and summer. They might be tapped through the use of chemical gum enhancer, it might be safe ensure sustainable yield as compared to traditional and mechanical methods.
- In addition plants (trees) also responded very well to healing of small hole made by hand girmit or drill machine to inject the gum enhancer. Whereas, in mechanical method the healing of cut portion (made by axe) taken more time in healing.
- The application of gum enhancer technique in simple needs no specialized skill and can be taught to unskilled people living in the forest fringes. Gum tapping can be done in winter (Dec to Feb) and summer (March to May) to ensure sustainable supply of gum and good economic return.
- Traditional way of tapping is not standardized, it done by blazing, peeling or by making deep cuts at the base of bole an axe or sickle. This method often leads to the death of the tapped trees.

SUGGESTIONS FOR FUTURE RESEARCH WORK

- The need to standardize the bio safe scientific tapping techniques for sustainable harvesting of gum producing trees for improvement of socio-economic status of tribal and gum dependent communities as well as to generate revenue of the state.
- Gum industry needs concerted effort for tapping, collection, processing, value addition, grading, classification and marketing.
- More gum enhancer and their levels in different locations (elevation, temperature, RH %) should be tested for more precise information.

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Appendix A

Weekly meteorological data of experimental site during the period of December 2016 to May 2017.

WEEKS	MAXT(°C)	MINT(°C)	RF (mm)	RH I (%)	RH II(%)	SS(hr)
49	28.40	13.70	0.00	86.80	42.30	7.40
50	28.90	11.80	0.00	84.10	28.40	8.20
51	27.60	7.90	0.00	84.30	24.60	9.10
52	27.40	10.70	0.00	87.60	29.90	8.20
1	27.70	0.00	0.30	90.60	38.00	7.80
2	26.20	11.20	7.40	82.40	36.10	7.50
3	28.60	12.30	0.00	84.80	30.40	8.30
4	29.60	13.10	0.00	81.80	30.30	8.20
5	30.20	12.10	0.00	77.00	24.70	9.90
6	31.60	13.60	0.00	79.00	28.70	9.10
7	30.30	15.20	0.20	77.10	32.10	8.00
8	33.50	14.80	0.00	74.00	21.70	10.20
9	34.20	14.80	0.00	69.50	17.80	9.90
10	32.90	18.10	0.00	63.10	30.00	7.60
11	32.3	15.9	0	54.1	18.6	9.7
12	36.3	17.2	0.1	66.3	17.1	9.7
13	40.8	20.1	0	52.1	12.7	9.8
14	41.5	22.8	0	47	14.1	9.3
15	40	19.5	0	47	14.1	9.3
16	42.4	23.2	0	50.8	16.1	9.4
17	41.9	21.9	0	37.4	11.3	10.3
18	41.9	24.9	0	45.4	19.6	8.5
19	40.9	23.9	0	51.8	27.3	7.1
20	44	26.2	0	50.6	22.1	9.7

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