STUDIES ON ETHEPHON CONCENTRATION FOR GUM EXUDATION ON *Acacia senegal* (L.) WILLD. IN SOUTH-EASTERN RAJASTHAN

दक्षिण–पूर्वी राजस्थान में *एकेसिया सेनेगल* (एल.) वाइल्ड पर गोंद निःस्त्रवण हेतु इथेफोन की सान्द्रता पर अध्ययन

POOJA KUMARI

THESIS

Master of Science in (Forestry)
Forest Products and Utilization

2024

DEPARTMENT OF FOREST PRODUCTS AND UTILIZATION

COLLEGE OF HORTICULTURE AND FORESTRY,

JHALRAPATAN CITY, JHALAWAR-326023 (RAJASTHAN)

(AGRICULTURE UNIVERSITY, KOTA)

Registration No. **2022-01-02-12-01**

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THESIS

Agriculture University, Kota
Submitted to the

In Partial Fulfillment of the Requirements for the Degree

of

MASTER OF SCIENCE IN (FORESTRY)

FOREST PRODUCTS AND UTILIZATION

BY

POOJA KUMARI

Registration No.
2022-01-02-12-01

Enrolment No.
2022/FORT/42

2024

DEDICATED TO
MY BELOVED
FAMILY

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CERTIFICATE OF ANTI PLAGIARISM
CERTIFICATE-I

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Dated: …………….

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ACRONYMS

%	**:**	Per cent

/	:	Per
@	:	At the rate of
&	:	And
cm^3	:	Cubic centimeter
C.D.	:	Critical difference
CV	:	Coefficient of variation
°C	:	Degree Celsius
d.f.	:	Degree of freedom
et al.	:	And others/ co-workers
etc.	:	Etcetera
E-W	:	East-West
N-S	:	North-South
Fig.	:	Figure
g.	:	Gram
Ha	:	Hectare
kg	:	Kilogram
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
mm	:	Millimeter
No.	:	Number

NS	:	Non-significant
ppm	:	Parts per million
RH	:	Relative humidity
S.Em	:	Standard error of mean
µm	:	Micrometer
YR	:	Hue
V/V	:	Volume/Volume
viz.	:	(*Videlicet*), namely.

CHAPTER – 1

INTRODUCTION

Acacia senegal (L.) Willd commonly known as gum arabic tree belong to the family Leguminosae. It is found in some parts of India mainly in the dry rocky hills of states like Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Orissa, Jharkhand, Bihar and to some extent in Gujarat and Rajasthan. It grows in a range of annual rainfall between 100-800 mm (mainly between 300-400 mm). It is very drought resistant and tolerates dry period of 8-11 months. The species prefers sandy soils, but also grows on slightly loamy sands with optimum pH ranging from 5-8 (Eisa *et al.* 2008). It is medium-sized deciduous tree growing up to 7-15 m in height with a girth of about 1.3 m. The trunk is about 30 cm in diameter and is covered by a grayish-white bark that becomes dark, scaly and thin in old trees. The stem has powerful hooked thorns, 3-5 mm long, with enlarged bases appear at the nodes of the branches, usually in like 3s which have sharp pointed ends. The seeds of *Acacia* are known to be major source of traditional folk vegetable in Rajasthan.

Acacia senegal is considered as a multipurpose species due to its diverse uses which includes gum arabic, fodder and wood production, and soil fertility improvement. As an N_2-fixing species, *Acacia senegal* improves degraded lands and nutrient deficient soils. This species is particularly used in tree improved fallows to replenish soil fertility and intercrops well with sorghum and other grasses (Harmand *et al.* 2012). The wood is valued as fire wood and can be used to produce charcoal. The wood is also used to make utensils, fence-posts, poles and agricultural tools. The bark and the roots provide fiber and make strong ropes and fishing nets. Gum arabic trees provide valuable fodder to sheep, goats and camels.

Acacia senegal trees are major source of gum arabic which is an commercial non-timber forest product (NTFP) and is important source of income for tribals of India. In India, 275 million rural people depends on forests for their source of revenue and livelihood support by selling minor forest produce which tribal collected from the forests. Gum arabic exudates from the duct of the inner bark and is tapped in the hot season (May-June) when the trees are in stress condition. The annual yields start from 188-285 g for young trees and 379-675 g for older trees (7-15 years). Gum production is excellent on poor soils and higher in stressed trees.

As per International trade of gum arabic, the three major gum producers in world includes Nigeria, Chad and Sudan constitutes 95 per cent gum export in world. Sudan produces

80 per cent of the total gum arabic and is largest gum arabic producer in the world. The approximate annual gum production of India is 800 tons. About 400 tons of gum arabic is exported to Bangladesh (26.46 %), Indonesia (14.53 %), and USA (8.88 %), UK (8.03%), Bolivia (6.73%), and Kenya (6.25 %) during 2014-15 (Yogi *et al.* 2017). Gum arabic is a natural or slightly acidic salt of a complex polysaccharide containing calcium, magnesium, and potassium cations. Gum arabic is non-toxic, odourless, and has a bland taste and it does not affect the odour, colour or taste of the system in which is used. The gum is someone yellowish in colour. It is insoluble in oils, and is most organic solvents, but usually dissolves completely in hot or cold water, forming a clear, mucilaginous solution. It is the GRAS (Generally Recognized as Safe) list under the Federal Food, Drug and Cosmetic Act.

The gum arabic is amorphous, white to yellowish, odourless and tasteless which consists of complex polysaccharides and glucosides. The non-toxic and biodegradable property of gum makes it a versatile natural product that can be used in various industrial uses. The excellent-grade gum arabic is usually round, tear shaped and orange-brown in colour which when crushed becomes pale or vitreous in appearance (Musa *et al.* 2018).

Gum tapping is the traditional way of producing gum usually the tapping is done for *Acacia senegal* (gum arabic) tree by using small Axe or using the developed new hand tool called Sonki as bared The Sonki is driven under the bark of the tree without penetrating the wood between the outer bark and inner cambium. A strip of bark (30-40 cm) is then removed causing wounds that stimulate gum exudation (Eltahir *et al.* 2023).Tapping of gum is done to collect gum from the tree. The preferred tapping season is from November to May which affects the oozing of the gum in maximum sense. *Acacia* trees are tapped by means of incisions made in their branches some weeks ahead of time. Usually mature tree, 4.5-6 m height and 5–25 year-old, are tapped by making incision in the branches and stripping away bark. The gum gets accumulated around the wound and in surrounding areas within 15-20 days, depending on the environmental factors. The high temperature favours the gum yield where as increased relative humidity decreases the yield.

Gum arabic, collected from *Acacia* trees, serves various important industrial functions due to its unique features. It is used in the majority for the production of adhesives and glues that are valuable in industries where a consistent adhesive is required, such as in the manufacture of envelopes, postage stamps, and even in the production of plywood. It is extensively used in the textile industry as a binder for colouring and dying fabric printing. The gum arabic is also used as a glazing agent in the production of ceramics and pottery and helps to create a glossy finish on ceramic surfaces making the product aesthetic and more durable. The gum has diverse applications including surface treatment in paper industry, in explosives and fireworks, as binder, adhesive, glazing agent, and surface treatment, which continues to make it a valuable ingredient in numerous industrial processes and applications worldwide.

The gum can be extracted using methods like mechanical injury or chemical application. The chemical applied for artificially inducing the stress condition in plant and is usually applied at the start of summer season to before onset of monsoon i.e. from the month of mid-March to June in hot arid climatic conditions. Therefore, the optimum season of treatment with chemicals is from start of summer to onset of monsoon in hot arid climate condition. The proposed research entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** was conducted with following objectives:

1. To study the physical and morphological characteristics of *Acacia senegal* (L.) Willd.
2. To study the effect of different concentration of Ethephon on gum exudation.
3. To study the quality parameters on gum of *Acacia senegal* (L.) Willd.

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CHAPTER - 2
REVIEW OF LITERATURE

In this chapter, the literature pertaining to **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** carried out by various researchers has been briefly mentioned. The literature on different aspects is reviewed under the following heads:

2.1 To study the physical and morphological characteristics of *Acacia senegal* (L.) Willd.

2.2 To study the effect of different concentration of Ethephon on gum exudation.

2.3 To study the quality parameters on gum of *Acacia senegal* (L.) Willd.

2.1 Physical and morphological characteristics of *Acacia senegal* (L.) Willd

Wekesa *et al.* (2009) assessed the gum arabic yield per tree per picking for different varieties of natural stands *Acacia senegal* (var. kerensis, var. senegal and var. leiorhachis) in Kenyan dry lands for a period of five months. Trees in each sample plot were measured for basal diameter and classified into three diameter classes (3.0-6.0, 6.1-9.0 and 9.0 cm). It was reported that there was a significant difference in gum arabic ($p<0.001$) between tapped and untapped tree as well as affected by soil moisture and soil temperature. The trees with basal diameter of 3.0-6.0 cm produced high quantities of gum then big trees of basal diameter >6.0 cm for *Acacia senegal* varieties senegal and leiorhachis ($p<0.001$).

Ibrahim *et al.* (2013) investigation on eighty *Acacia senegal* trees each from Borno and Yobe states were chosen for study in complete randomized block design. The morphological characters measured were: tree height, bark thickness, canopy cover, and diameter at breast height. The results show that morphological and reproductive characters observed differed significantly ($P<0.05$) among the trees. Performance of trees from Yobe State is significantly higher than those from Borno for all the parameters measured which include; tree height (5.64 m), bark thickness (0.53 cm), canopy cover (7.01 m), and diameter at breast height (8.210 cm), respectively. The variation observed may provide base for genetic improvement of this important multipurpose leguminous tree.

Gupta *et al.* (2017) studies on anatomy of wood of *Acacia senegal*, and reported that gum is formed in cysts in the inner bark of the branches and not in the wood. The gum cysts are formed first in the parenchyma of the phloem. In case of wounding, the gum is transported to the wounded site via new channels formed by degradation of the cells. Macroscopic characters indicate that sapwood is pale to creamy yellow, heartwood pale to dark brown.

Eltahir and Ismaeil (2020) reported that the mean diameter, number of main stems, height, and age crown were of high gum yield *Acacia senegal* trees were (9.2±3.6 cm), (4±1 m), (6.6±3.7 stems) and (11.6±5.0 years) respectively. The largest diameter and the highest trees were recorded in Umhglig Albiraimia village were (13.1±3.2 cm) and (8.3±2.8 m) respectively, while the highest numberof main stems was found in Umgawawa village (5 stems). The average yield of high gum yield trees was 7.6±2.1 kg/tree/season while the highest yield was 10 kg/tree/season as recorded in Eldemokeya area. The study concluded that there was similarity among *Acacia senegal* trees however; high gum yield trees could be phenol typically identified by experience.

2.2 Effect of different concentration of Ethephon on gum exudation

Babu and Menon (1989) studied the effect of 2 ml of ethephon solution into the stem at 1.5 m above ground in *Bombax ceiba* and *Sterculia urens* with the concentration of 0, 240, 480, or 720 mg and 0, 96, 192, 480, 768, and 960 mg, respectively. The 240 mg concentration showed the maximum gum yield. Gummosis from treated holes in *Sterculia urens* began after ten to twelve days in blazedor hole method which was maximum (64.5 g gum) in the 768 mg treatment, while the 960 mg treatment exduated the second-highest yield (38 g gum). The 0 mg treatment produced the least amount of exudation (0.5 g gum).

Bhatt and Ram (1990) conducted the study on 6 trees of *Acacia senegal* growing in Chambalravines, near Bihar, Madhya Pradesh. Five trees were treated with ethephon by inducing 4 ml solution(containing 480, 720 and 960 mg active ingredient) over a hole of 5 cm deep and 2.5 cm wide, inclineddownwards 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 maximum gum exudation (806-950 g/tree) was obtained in the treatment with 960 mg concentration which started 4-8 days after treatment.

Joseleau and Ullmann (1990) reported that the gummosis in *Acacia senegal* and gum yielding species occurs inside the cambial zone of branches and stems and is induced during the stress conditions such as heat, drought, insect attack or systemic wounding in the trees. This progression was examined by a evaluation of polysaccharides released from the inner bark, cambial zone and the xylem of artificially injured (tapped) region, to those present in normal conditions. The three anatomical zones were extracted for water-soluble polysaccharide and alkali-extractable hemi-cellulose which depicted the presence of gum in cambial zone, on the boundary (side) of the scarified region of the tree and also a short distance beyond the limits of the tapping.

Nair (2003) reported that the production of gum in gum karaya (*Sterculia urens*) tree is approximately 10 times higher in April-May when compared with gum production in month of November. Therefore, it is suggested that the gum tapping for commercial production should be doneonly during March to May and the trees may be given rest in the remaining part of the year. The artificial incisions were made in the tree trunk after slashing the bark of 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 or incision made in the tree trunk were treated with ethephon which can be ten times higher than the gum tapped by using traditional method.

Verbeken *et al.* (2003) studied the response of gum karaya (*Sterculia urens*) tree to the incisions or artificial wounds given to tree. The wound certainly gave onset to the gummosis process and the exudate was allowed to solidify on the tree and then removed as large, irregular tears. The yield of gum from a mature tree is 1-5 kg per season and best quality gum was collected from April to June before the monsoon season as the temperature increases.

Nair *et al.* (2004) reported the technique of tapping with substantial increase in the yield by using ethephon to enhance gum yield and wound healing. After 45 days, a thick wound tissue was settled at the injured region which healed the damaged tissue in 60 days after tapping. The yield was 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 variation in the yield among individual trees, due to heterozygosity. The efficient and scientific tapping technique using ethephon as a inducing agent for gummosis or gum rosiness could ensure considerable enhancement and sustainable production. The concentration used for treatment is critical and different for each species as increased concentration may lead to die back and death of the plants.

Ballal *et al.* (2005) found that there was negative correlation of gum yield with tapping time and minimum and maximum temperatures at gum collection, while it was found to be positively correlated with tapping intensity, rainfall, and minimum and maximum temperatures at tapping time.

Mishra (2005) assessed the ecological status of *Sterculia urens* trees and their impact on harvesting of gum in selected districts of Orissa *viz.*, Rayagada, Koraput and Malkangiri. The density of the trees varied from 3 trees/ha in Koraput to 6 trees/ha in Malkangiri. In Koraput district, maximum damage was observed in *Sterculia urens* trees where 17 per cent trees were found entirely damaged and 45.4 per cent trees harshly damaged. Average gum yield per tree was found to be directly proportional with the girth of the trees whereas, it was found to be low (16.5 g/tree/day) in trees with GBH of 21-50 cm in Koraput district whereas, it increased to 155 g/tree/day in the trees of GBH 201-230 cm in Rayagada district.

Fadl and Gebauer (2006) studied the two-factor experiment at umakiran forest reserve on *Acacia seyal* (talha) gum. The Factor-1 was the time of tapping, which was tested in three stages (1-15 November and 1 December). The Factor-2 was intensity of tapping, which was tested in four stages (2, 4, 6 and 8 branches). The tapping date showed the significant effect on the quantity of gum production as the highest gum yield was reported when they were tapped on the 1st November. However, the tapping intensity did not depicted effect on the gum yield. Therefore, a tapping intensity of minimum 2-4 branches is suggested to curtail the likelihood of harmful effect on the tapped trees.

Giri *et al.* (2008) also reported that the trees of *Anogeissus latifolia* showed the maximum gummosis phenomenon during the summer season. However, the trees can be artificially injured occasionally to increase the quantity of gum oozing out from the trees. The harvesting season preferable for *Anogeissus latifolia*is from March to mid-June and, 1200 tones of gum from the tree can be harvested annually.

Adam *et al.* (2009) studied the effect of tapping direction and sun light on the yield of gum from *Acacia senegal* tree at Demokeya Forest Reserve over two seasons (2006/2007 and 2007/2008). The treatments comprised of directions in eastern, western, northern and southern sides of the tree during the tapping process. The tapping direction ($P<=0.001$) showed highly significant results in all pickings, except third picking in first and first picking in the second season. It was also observed that tapping on the eastern and western sides towards direct sun light increased the gum yield by 60 per cent. The combined scrutiny showed highly significant differences ($P<=0.05$ and $P<=0.001$) on total gum yield (g/tree) and the number of trees yielding gum.

Unanaonwi (2009) selected 10 samples from the wild forest and ten from the plantation of *Acacia senegal* from Nigeria by using a multistage sampling procedure. The natural forest showed the higher value (87.7 g) of gum yield when compared to plantation area (85 g) and yield/ha was higheryield of 53.125 kg from plantations while, 18.592 kg from wild forests . 3.62 tone of gum arabic were projected to have been produced overall, or 0.3 per cent of the country's total production.

Madariya *et al.* (2016) evaluated the effect of various concentration of ethephon in 5-10 years of age with trunk girth from 80-100 cm *Acacia senegal* trees with transverse hole of 4-5 cm depth at approximately 1 m height from the ground level with manually operated drill. The treatments with variable ethephon concentration (T_1: control (distilled water), T_2: 100 ppm, T_3: 200 ppm, T_4: 300 ppm, T_5: 400 ppm, T_6: 500 ppm, T_7: 600 ppm, T_8: 700 ppm, T_9: 800 ppm and T_{10}: 900 ppm) was tested for gum yield. The gum yield (g/plant) was positively affected by treatment of ethephon. The maximum gum yield (177.25 g/plant) was observed from treatment with 900 ppm ethephon which was found to be statistically at par with 800 ppm and 700 ppm ethephon treatment when compared to all other treatment and control.

Ngaryo *et al.* (2011) reported that 51 per cent of gum production was directly related to the stem diameter class, the crown diameter class, the date, the height and the depth of tapping. The abilityof tree to produce gum is related to its size and diameter. Furthermore, gum production as found to bepositively correlated with stem diameter, crown diameter and tapping height while, found to be negatively related to its depth.

Abib *et al.* (2013) conducted the experiment to conclude that effect of application of ethephon on the gum yields of *Acacia senegal* under sub-humid conditions in Cameroon. Trees were inducted with 40 or 120 mg ethephon were compared to controls in field experiments at a semi-arid and a sub- humid location in Northern Cameroon, during two seasons. Two selected provenances from drier areas(Sudan) were compared to the local areas. The initial season showed the increase in the gum yield upto 400–600 per cent compared to the untreated trees. Gum yield at the semi-arid location was 77, 313 and 214 g/tree with 0, 40 and 120 mg ethephon/tree, respectively, while at the sub-humid location, it was found to be 30, 186 and 114 g/tree with 0, 40 and 120 mg ethephon/tree.

Garasiya *et al.* (2013) carried out an investigation to assess the effect of ethephon concentration on production of gum in *Acacia senegal* tree in Junagadh Agricultural University. The treatment consisted of T_1 (Control), T_2 (Ethephon 100 ppm), T_3 (Ethephon 200 ppm), T_4 (Ethephon 300 ppm), T_5 (Ethephon 400 ppm), T_6 (Ethephon 500 ppm), T_7 (Ethephon 600 ppm),

T_8 (Ethephon 700 ppm), T_9 (Ethephon 800 ppm) and T_{10} (Ethephon 900 ppm). The gum yield harvested per plant(386 g) was significantly highest in T_{10} (900 ppm ethephon), and it was at par with T_9 (800 ppm ethephon) (379 gm). The lowest gum yield per plant (80.33 g) was collection in T_1 (Control).

Harsh *et al.* (2013) studied 30 trees of *Acacia senegal* of 14 years with average height of 4.9 m and 67.8 cm collar girth with different doses of ethephon and reported that the trees started the process of gummosis 8–10 days after the ethephon treatment. The mean gum yields were 39.9, 67.7 and 140.6 g/tree, under ethephon treatment at 9.75 per cent, 14.62 per cent and 19.5 per cent concentrations, respectively.

Moola *et al.* (2013) reported the technique for gum arabic production and gum tapping in *Acacia senegal* which is wide spread and popular in western part of India particularly in Rajasthan. This technique can help the farmers of western Rajasthan where the gum tappers of this region produced about 23.59 tone gum arabic and earned about 235.9 thousand US$ gross income in 3 years (2009-2011) by sale of gum arabic in local markets and can further help to provide better livelihood option for the community.

Sharma and Prasad (2013) studied 9 trees of *Sterculia urens,* and conducted 2 experiments *viz.,* 3 trees were selected for semicircular blazing and remaining 6 trees through gum inducer technique. Gum was collected from each tree separately once a month, right before the start of the next treatment application, to determine the influence of treatment and its interval on gum yield. It was also found that the tree with higher diameters produced more gum in both gum tapping approaches, while production was maximum in gum inducer. In contrast to the semi-circular flaming method of gum tapping, the gum inducer technology was found to be appropriate for karaya gum tapping from *Sterculia urens* trees in the Jharkhand region, causing less damage (17 times by volume) to the trees and higher gum production (about 200%).

Unanaonwi and Bada (2013) studied the effects of height and girth on yield of gum arabic in the natural forests of *Acacia senegal*. Three heights and girth classes were selected and results concluded that the trees with height less than 2 m and girth more than 50 cm increased he gum yield (163.6-209.7 g). Tree girth significantly influenced the gum yield ($p<=0.05$) i.e. girth higher than 54 cm (maximum of 65 cm) produced the highest mean gum yield.

Li *et al.* (2014) conducted research on the gummosis in Peach, which is caused by *Botryosphaeria* fungi. This study investigated the effects of ethephon application before and after inoculation with *Lasiodiplodia theobromaeon* for gum formation. The ethephon treatment increased the gum exudation before pathogen inoculation, but was inhibited by application after inoculation of pathogen. The results showed that ethephon has a dual function in regulating gum formation by affecting both the peach shoots and the pathogen.

Das *et al.* (2014) studied the effect of temperature and relative humidity on ethephon induced gum exudation in *Acacia nilotica* tree and reported that the gum production was dependent on environmental factors *viz*., girth of tree, relative humidity, and temperature. Gum production was positively correlated with tree girth, tapping intensity, rainfall and temperatures at the time of gum tapping and inversely correlated with low temperatures and high relative humidity.

Kanzaria *et al.* (2015) conducted a research experiment to study the effect of gum-inducing chemical and Ethephon 100 ppm solution on gum yield in gum arabic (*Acacia senegal*) trees. The maximum number of gum tears per plant (9.66 g/plant) was observed in the plants treated with the gum inducing chemical followed by ethephon 100 ppm treatment (8.66 g/plant) and control (1 g/plant) observed least number of gum tears after a week of application. The maximum production (142.33 g/plant) was documented in tree treated with gum-inducing chemical, while (124 g/plant) was observed in treated with ethephon 100 ppm and control produced the least (41.33 g/plant) gum.

Kuruwanshi *et al.* (2017) evaluated the possibility of gum production in *Sterculia urens* Roxbusing three replications and six treatments, namely T_1 control (distilled water), T_2 (2.34%), T_3 (3.12%), T_4 (3.9%) of ethephon concentration, T_5 (400 ppm of IAA), T_6 (800 ppm of IAA). Subsequently, a syringe was used to inject a 4 ml (2 ml per hole) dose of ethephon and IAA gum inducer into the hole. The hole was then closed immediately with damp clay. The T_4 treatment with 3.9 per cent concentration of ethephon resulted in the highest total gum output per plant (239.02), which was followed by treatments with concentrations of T_3, 3.12 per cent (137.51) and T_2, 2.34 per cent (66.88).

Sinha *et al.* (2016) studied the effect of various tapping techniques with slight modification on the oleo-resin gum yield and effect on tree health on 14-year-old *Boswellia serrata* plantation maintained by Gujarati pharmaceutical company. The results predicted that slant cut was more superior when compared to straight cut for oleo-gum resin production. The mechanical methods *viz.*, V-shaped cut method with a hole on the lower side and ethephon treatment; and the hole method treated with ethephon and patched up with clay were found to be most efficient in term of healing in trees.

Kuruwanshi *et al.* (2017) concluded during ICAR Network Project for research work in Chhattisgarh in *Sterculia urens* that the ethephon at the rate of 3.9 per cent in 4 ml in two consecutive doses in 45-60 days intervals at high temperature in month of April to June was found significantly effective for maximum gum production during both the year 2015 and 2016. The quantity of gum was highest in at 3.9 per cent ethephon (239.02 g and 259.15 g) followed by 3.12 per cent ethephon (137.51g and 172.36 g) and 2.34 per cent ethephon (66.80 g and 87.67 g), whereas in 400 ppm IAA (15.84 g and 17.30 g) and minimum exudation was obtained in 800 ppm IAA concentration.

Tewari *et al.* (2017) standardized the ethephon treatment in *Acacia senegal* trees for improved production and recovery of gum arabic trees. The hand or electrical drill was used for making 50^o downward slanted hole of about 14–16 mm in diameter and roughly 4 cm deep was drilled on the tree trunk (35–50 cm above the ground) to check that the trees uptake the CAZRI gum inducers for gum exudation process. The CAZRI gum inducer is applied in a single 4-ml dose and the hole was sealed with clay or natural bee wax that had been dampened. It was discovered that the ideal dosage for the highest production of gum arabic was 4 ml of ethephon solution, which contains 780 mg of the active component.

Vasishth and Guleria (2017) conducted the trial on *Senegalia senegal* trees with gum arabic collections larger than 25 cm dbh in south-east Rajasthan. The two methods i.e. bore hole and V- shaped blazed tapping were investigated in three seasons (January-March, April-June, and September- November) to check the most efficient tapping method. After the first 15 days of spraying, gum was collected three times every 10 days. The minimum output of 53.44 grams/tree achieved from the V- shaped tapping approach was considerably lower than the maximum gum production of 93.44 grams/tree obtained from the borehole tapping method.

Kuruwanshi *et al.* (2018) studied the chemical methods for gum tapping in ghatti (*Anogeissus latifolia*) tree undertaken in ICAR Network Project for research work at village Khargadih, district Raipur (Chhattisgarh) and reported that ethephon at 2.34 per cent in 4 ml in two consecutive doses in 45-60 days intervals at high temperature in month of April to June was found significantly effective for maximum gum production. The quantity of gum was found significantly maximum in 2.34 per cent (662.25 g) followed by 1.56 per cent (394.16 g) and 0.78 per cent (197.66 g), while the minimum exudation was observed in 800 ppm IAA (42.87 g).

Prasad *et al.* (2018) conducted research to standardize the ethephon dose and month suitable for its application to enhance the gum production from *Anogeissus pendula* without compromising the health of tree. The trees of *A. pendula* trees were selected for treatment with three doses of ethephon *viz.*, 390 mg/4ml (10%), 780 mg/4ml (20%) and 1170 mg/4ml (30%) active ingredients at monthly intervals during a complete year (March, 2010 to February, 2011). The gum yield with highest dose of ethephon was recorded to be maximum in March, 2010 (57.18 g/tree) and minimum in August, 2010 (0.17 g/tree).

Ghritlahare and Katiyar (2021) studied the effect of deep incisions at the base of bole madewith an axe in *Soymida febrifuga* trees. The existing harvesting techniques are harmful and conventional, which frequently results in lower-quality crops. Three replications and five treatments: Control (distilled water), Ethephon, H_2SO_4, and Ethephon with H_2SO_4 were utilized in the experiment. HCl was employed to treat any possible gum exudation. The treatment of ethephon with H_2SO_4 was found to be highly effective in increasing the gum yield. The maximum gum exudation (8.10 to 5.54 g) was reported in ethephon @ 3.9 per cent with 1 per cent H_2SO_4 in the month of February and March.

Raj and Jhariya (2022) studied the effects of environmental conditions on the gum production in *Acacia nilotica* (babul gum) trees in Chhattisgarh. Using two different ethephon concentrations (15.6 or 62.4 mg/tree), two girth class levels (≥30.1 to 50.0 cm and ≥50.1 cm), two levels of holes/injuries (single and double), and three levels of season (rainy, winter, and summer), the gum tapping technique was scientifically based. The quantity of gum yield (137.10 mg/tree/day) was found to be higher during summer when compared to rainy season (84.10 mg/tree/day) and lower in the winter season (70.63 mg/tree/day). The production of gum is influenced by different environmental factors such as tree girth class, seasons, and ethephon concentration.

Wiyono *et al.* (2022) studied the combined effect of mechanical and chemical tapping, GIS (Gum Inducer solution) on *Lannea coromandelica* tree without causing any serious damage to the plants. Sample population of 62 trees were selected and gum retrieval method was done by drilling rods, then on each borehole inserted 3 ml GIS. Gum collection was done every 7 days for 3 weeks. The use of GIS concentrations of 1.5 per cent resulted in an average total gum production of 31 g which was higher when compared to 1 per cent GIS treatment concentrations (21.23 g).

2.3 Quality properties of gum

Anderson *et al.* (1990) reported that the trees of gum arabic (*Acacia senegal*) exudes white to yellow-white spherical tears of gum with variable size. It has no odour or flavour and swells when comes in contact with the water to form aqueous solutions that can contain up to 50 per cent of the total weight and is insoluble in organic solvents.

Williams *et al*. (1990) stated that gum arabic (*Acacia senegal*) has a comparatively low viscosity and is highly water soluble when compared with other gums. Majority of gums cannot dissolve in water at quantities more than 5 per cent due to their high viscosity. It was found that 50 percent w/v gum arabic can be dissolved in water to provide a fluid solution with an acidic pH of 4.5. Due to the extremely branched structure of the molecules, gum arabic only becomes a viscous solution at high concentrations due to its compact, comparatively tiny hydrodynamic volume. Less than 10 per cent solutions behave like Newtonian solutions and have low viscosities.

Dziezak (1991) reported that gum arabic (*Acacia senegal*) can dissolve easily in both hot and cold water at concentrations of up to 50 per cent because of its compact, branched structure and small hydrodynamic volume. Due to its low viscosity, the gum arabic solutions can be used in variety of applications. Up to 40 per cent of the solution exhibits Newtonian behavior; at greater concentrations,the solution takes on pseudoplastic characteristics.

Fennema (1996) studied the effect of climate on the colour of gum arabic (*Acacia senegal*) and reported that pure *Acacia* gum has a hue range of light to deep amber, dries hard and transparent in small amounts, and is somewhat hazy and translucent when liquid. Compared to other comparable gum arabic products, gum arabic and arabic spray dry have a higher whiteness index (colour).

Islam *et al*. (1997) evaluated the grading system for gum from Sudan known as gum arabic (*Acacia senegal*). The gum was graded by hand, with the most expensive grade being the cleanest, largest, and lightest colored pieces. The cleaned and sifted grade is made up of whole and broken lumps that are pale to dark amber in colour, the cleaned grade also includes sifting, but the dust is removed; the sifting grade includes a mixture of sand, dirt, and bark; the red grade is dark red gum particles that have been removed from other lumps.

Peter *et al.* (1999) reported that hakea gum exudates from species *Hakea gibbosa*have been shown to comprise of L-arabinose and D-galactose linked in gums to form acidic arabinogalactans (type A). Majority (%) of sugar constituents included glucuronic acid, galactose, arabinose, mannose,xylose in the ratio of 12:43:32:5:8.

Islam *et al*. (2002) surveyed the zoosporicidal activity of the *Aphanomyces cochlioides* and *Lannea coromandelica* and found that motility and viability of zoospores are regulated by secondarymetabolites. Commercial polyflavonoid tannins, Quebracho and Mimosa, also showed identical zoosporicidal activity. Both the tree species were visualized through electron microscopic observation as well as cell membrane fragmentation method and may be useful in the medical treatments.

Williams *et al.* (2000) also reported that the gum of *Acacia senegal* commonly known as gum arabic, is easily dissolved in water to produce highly concentrated solution sup to 55 per cent and is actually soluble in cold water. The structural characteristics of gums, including the presence of a carboxylate group linked to individual monosaccharide units, which have an important role in the variations in solubility of these materials.

Hagybaghercandy *et al.* (2003) examined the quantitative and qualitative characteristics of carbohydrate in the gum of *A. nilotica*, collected from a research farm of medicinal plants in Booshehr province, Iran. The quantitative characteristics of carbohydrates were determined by spectrophotometry (HITACHI 340) at 625 nm. The total carbohydrate percentage in gum arabic was found to be 6.51 per cent. The qualitative analysis by thin layer chromatography revealed the presence of pentoses, hexoses and uronic acid in gum arabic. In this method, the best reagents and solvents were formic acid-tertiary butanol-water and anisidine-phthalic acid-ethanol.

Flindt *et al.* (2005) reported that the gum arabic (*Acacia senegal*) is a slightly acidic complex molecule made up of polysaccharides, glycoproteins, and their calcium, magnesium, and potassium salts. The quality of gum is dependent upon its chemical makeup, which is influenced by the geographical origin, the weather during harvest, the soil, the age and genotype of the tree, and the conditions in which processing was done.

Trommer and Neubert (2005) found that the utilization of gum arabic is prominent in pharmaceutical preparations and as a carrier of drugs due to its harmless physiological GA antioxidant properties.

Sabahelkier *et al.* (2008) investigated the gum derived from *Acacia senegal,* and reported thatit belongs to hydrocolloid group and is water soluble polysaccharide. The major constituents of the gum included protein and arabinogalactan, with trace amounts of mineral components. It is insoluble in most of organic solvents, but it is somewhat soluble in ethylene glycol, glycerol, and ethanol (up to 60%).

Ahmed *et al.* (2009) studied the effect of location on the properties of gum (*Anogeissus leiocarpus*) samples and the analysis of variance showed in significant differences ($p<0.05$) in all properties studied except in ash content which may be due to the differences in the type of clay soil which found in three different locations. The general characteristics of *Anogeissus leiocarpus* were reported as 9.2 per cent moisture, 3.4 per cent ash, 0.72 per cent nitrogen, 4.74 per cent protein, -35.5^{o} specific rotation, 1.68 relative viscosity, 4.2 pH, 1.334 refractive index, 14.3 per cent uranic acid, 0.44 per cent reducing sugar, 1336.0 per cent equivalent weight and 0.68 per cent tannin content.

Akoto *et al.* (2008) examined the physico-chemical properties of gum collected from four cashew growing districts namely; Ghana, Sampa, Wenchi and Jirapa, to promote the use of cashew gum in the food industry. The values for pH (3.8-4.2), total ash (0.5-1.25 %), protein content (1.27-1.80 %), total sugars (0.96-2.10 mg/g), total phenols (0.21-2.26 %), moisture content (9.8-13.2 %), and insoluble matter (1.9-4.8 %) were reported. Except for pH, which was lower in mature tree gum, gum from mature trees was found to have higher levels of protein, moisture, sugars, and phenols than gum from young trees.

Ali *et al.* (2009) described that gum arabic (*Acacia senegal*) is a branched chain, complex polysaccharide, either neutral or acidic found as a mixed calcium, magnesium and potassium salt of a polysccharidic acid. The gum arabic can be used commercially in dentistry because it enhances dental remineralization and possess some antimicrobial activity. It can also be used in inks production, pottery pigments and glazing for colour thickening in watercolors and paints, wax polishes or for giving luster to silk and crepe in textiles and lithography.

Yebeyen *et al.* (2009) conducted study to determine the quality of gum arabic harvested from naturally occurring *Acacia senegal* (L.) trees from Ethiopia. The qualities of gum were compared to those of similar gum that had been reported from well-known locations like Sudan and to international standards. Ten randomly selected *Acacia senegal* (L.) trees were tapped for gum samples, which were then combined into a single large sample by placing them inside a single plastic bag. Colour, odour, moisture content, ash content, viscosity, pH, specific rotation, N and tannin levels, and concentration of several metals were among the attributes that were examined using conventional laboratory techniques. The results yielded moisture content of 15 per cent, ash content of 3.56 per cent, intrinsicviscosity of 1.19 ml g^{-1}, pH on 25 per cent solution of 4.04, specific rotation of 32.5, nitrogen content of 0.35 per cent, protein content of 2.31 per cent and with no tannin content. Mineral contents of the gum arabic (g/100 g) are Ca 0.7, Mg 0.2, Na 0.01, K 0.95, Fe 0.001, P 0.6 and non-detectable traces of Pb, Co, Cu, Zn, Ni, Cd, Cr and Mn.

Lelon *et al.* (2010) evaluated the physical characteristics of gum arabic extracted from two varieties of *Acacia senegal* (L.) (var. kerensis and var. senegal) in Marigat division, Baringo district. Internal energy in gum arabic var karensis (33.4 and 33.76 %) was not significantly different (P > 0.05) from that of variety senegal found in Kapkun and Solit (33.0 and 32.96 %), but moisture content in gum arabic obtained from variety kerensis in Kimorok and Maoi (17.5 ± 1.00 and 15.4 ± 0.50 %) was significantly higher (P < 0.05) than those of variety senegal in Solit and Kapkun (15.0 ± 0.50 and 14.9± 1.80 %). Gum arabic from variety senegal in Solit and Kapkun had an ash content of 2.94 and 3.16 per cent, respectively, greater (P < 0.05) than gum from variety kerensis in Kimorok and Maoi (2.88 and 2.72 %). The amount of volatile matter in gum arabic from variety senegal (64.2 %) in Kapkun was greater (P < 0.05) than the amounts of variety kerensis (63.8, 63.7, and 63.6 %) in Kimorok, Solit, and Maoi.

Yusuf (2011) studied the physico-chemical characteristics of the gum exudates from *Acacia senegal* (Dakwara), *Acacia sieberiana* (Farar Kaya), and *Acacia nilotica* (Bagaruwa). The physico-chemical analysis showed the range of 13.40–16.20 per cent moisture; 38–45 per cent water solubilityat 30°C; pH of 25 per cent solution (4.50-5.00 %); melting temperature (289–320°C); relative viscosity of 1 per cent solution (20.18–24.80 %); total ash (3.30–3.54 %); nitrogen (0.38–0.42 %); protein (2.51-2.77) (77.99–80.41 %). Significant concentrations of cationic elements, including calcium, magnesium,iron, sodium, and potassium, were also present in the gum samples. The physicochemical qualities of the samples under investigation varied significantly, but overall, the values of all the parameters compared well to other studies conducted on *Acacia* gums from different parts of the world.

Rabah (2011) reported in rheological study of gum 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 >45^0C becomes lower than that of water even at low concentration (10 g/l) varies exponentially.

Deshmukh *et al.* (2012) concluded that ghatti gum (*Anogeissus latifolia*) is a light yellow to brown in colour that comes in different grades based on its solubility and viscosity. On an RVT Brookfield Viscometer, the viscosity of a 10 per cent dispersion of gum ghatti soluble grade I, II, III, and IV were measured at 25^0C for 24 hours. The results showed that the viscosity was below 400 cps, 400-500 cps, 1,000-2500 cps, and over 2500 cps, respectively.

Ibrahim *et al.* (2013) evaluated the physico-chemical properties of *Acacia senegal*, and found average specific rotation value of the *A. senegal* var. senegal samples was determined to be (-32) P oPR.R., while the average values of moisture and ash percent were found to be 13.49 per cent and 3.27per cent respectively. The average intrinsic viscosity *of A. senegal* var. senegal samples was found to be 14.61 ml/g, while the average nitrogen content, as evaluated by Kjeldahl, was found to be 0.35 per cent for *A. senegal* var. *senegal* samples. With a conversion factor of 6.6, the average protein value that was determined was 2.31 per cent. It was discovered that the average values of glucuronic acid percentage and acid equivalent weight were 15.2 per cent and 1161, respectively.

Abayomi *et al.* (2014) determined the properties of gum of *Azadirachta indica* (NMG) compared to *Acacia* gum (ACA). The morphological properties were evaluated using the size and shape factors of aspect ratio, roundness, irregularity and equivalent-circle-diameter. The tableting properties of the gums were determined using compressionl characteristics, tensile strength (TS), brittle fracture index (BFI) and crushing strength-friability/disintegration-time ratio (CSFR/DT). The results showed that NMG possesses larger, irregular and more elongated particles than *Acacia* gum. The onset and amount of plastic deformation occurring in NMG was faster and higher, respectively, than in *Acacia* gum. It was also concluded that *Acacia* gum tablets were stronger, and their tendency to cap/laminate was higher than in *Azadirachta indica* gum tablets.

Yadav *et al.* (2015) conducted a study to compare the mucilage extracted from seeds of *Cassia fistula* and gum karaya (*Sterculia urens* Roxb.). The isolated mucilage was evaluated for their solubility using several solvents and the results predicted that the isolated mucilage first swell up in water and then get dissolved. The extract was found to be insoluble in other solvent like ethanol, benzene, ether, and petroleum ether.

Ali and Daffalla (2018) studied the variation in physico-chemical properties of *Acacia senegal* var. from 1968-2016 in the gum belt, Sudan. The data obtained indicated the following values of moisture (14.5 %), ash (2.5 %), protein (2.2 %), nitrogen (0.34%), viscosity (15.2 ml/g) and pH (4.34). The fat content and nitrogen free extract were also analyzed and the values obtained were 0.05 per cent, and 80.75 per cent, respectively.

Azanu (2019) evaluated the utilization of gums obtained from cashew, neem, moringa, and mango trees for industrial by assessing the physicochemical properties of some of the selected plant gum exudates in contrast to *Acacia albida* (acacia gum) as a control. The parameters involved pH, ash, nitrogen content, phosphorus (P), iron (Fe), calcium (Ca), sodium (Na), and potassium (K). The gumshad the following values: pH 4.70–6.54, ash, nitrogen content, P, Fe, Ca, Na, and K; 2.0–4.0 per cent;0.48–2.06 per cent; 0.017–0.028 mg/kg; 0.16-0.35 mg/kg; 0.54–1.44 mg/kg; 0.06-0.10 mg/kg; and 0.22-0.82 mg/kg, in that order. The pH of studied gums ranged from mildly acidic to neutral; the gums from *Anacardium occidentale* (cashew) and *Mangifera indica* (mango) had pH values that were comparable to those of *Acacia* gum. The qualities were strikingly comparable to those of *Acacia* gum, which is frequently utilized in the food processing and related food industries. Therefore, in culinary and medicinal applications, the gums of *Anacardium occidentale* (cashew), *Mangifera indica* (mango), *Moringa oleifera* (moringa), and *Azadirachta indica* (neem plant) may be safely substitutedfor *Acacia* gum.

Jaafar (2019) demonstrated the clinical effects of gum arabic (*Acacia senegal)* and found thatit can be used as emulsifier, film coating and others. Traditionally the gum used for chronic renal failure, digestive discomfort and others. Although gum arabic considered as an inert substance, recent information revealed multiple pharmacological and medical effects, such as weight reduction, antihypertensive, antihyperlipidemic, anticoagulant, antibacterial, antidiabetic, anti-inflammatory, nephroprotective and other effects.

Sahu *et al.* (2019) studied the physico-chemical properties of karaya gum and reported that 17.47 per cent weight-based moisture content, 0.79 g/cm^3 bulk density, 1.50 g/cm^3 true density, 0.90 g/cm^3 tap density, 1.26 g/cm^3 bulkiness, 46.76 per cent porosity, 1.14 0.06 hausner's ratio, and carr's compressibility. According to the results, the following values were found: ash content, pH, refractiveindex, water activity, and water holding capacity (per 100 ml), nitrogen (%), protein (%), and 1.336 per cent, respectively. Karaya gum was found to be insoluble in acetone, chloroform, or ethanol but gets dissolved in hot and cold water. In the spindle rotational speed range of 20 to 100 revolutions perminute at 24 to 26^{0}C, the viscosity of a 1 per cent karaya gum solution varied from 619 to 1286 cp.

Taha *et al.* (2012) analysed the properties of three types of gum grown in Sudan, *Gummi nesina olibanum*, *Guar Cyamopsis teyragonlobus*, and *Combretum Combertacea* and reported per cent moisture content values as 5.35, 6.70, and 9.10; per cent ash as 1.77, 0.63, and 4.33; per cent nitrogen as 0.27, 0.71, and 0.96, and per cent protein of 1.68, 4.18, and 6.45 in 3 species respectively. The main sugars found in olibanum, guar, and combretum were found to be arabinose and galactose while, manose, rhamnoe, and D-glucuronic acid were found in lower concentrations. The FTIR spectra confirmed the presence of 14 a sugar moiety in the gum's composition. The results showed that *Combretum Combertacea* showed the physico-chemical properties of gum hich were in vicinity to properties of gum arabic.

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CHAPTER - 3

MATERIAL AND METHODS

The present investigation entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** was carried out at College of Horticulture and Forestry, Jhalawar (Rajasthan). The laboratory analysis was done in the laboratory of Department of Forest Products and Utilization, College of Horticulture and Forestry, Jhalawar, Rajasthan.

3.1 Experimental site

The experiment for gum exudation was conducted in 10-year-old kumat (*Acacia senegal* L.)block established Herbal Garden, College of Horticulture and Forestry, Jhalawar (Rajasthan) during the year 2023-24.

3.2 Geographical location

The experimental site is situated at $23^0$45' to $24^0$52' North latitude and 75^0 29' to $76^0$56' Eastlongitudes and an altitude of 131.14 meters above mean sea level.

3.3 Climatic conditions

The climate of Jhalawar is typically sub-humid type and is characterized by extremes of temperature in summer and winter with high rainfall and moderate relative humidity. The average rainfall in the region is approximately 954.7 mm. The maximum temperature range during summer is 43℃ to 48 ℃ and minimum 3℃ to 5 ℃ during winter season.

3.4 Soils

The experimental site was composed of black soil with clay loam type and good drainage facility.

3.5 Experimental Details

The *Acacia senegal* L. tree planted in the year 2012-13 were selected based on morphological characteristics and investigated during the year 2023-24 at College of Horticulture and Forestry, Jhalawar (Rajasthan). All trees selected for the experiment were of age 10 years and girth in the range from 35 to 40 cm.

Plate 1. Experimental Site

Location of Experiment	**Herbal garden, CH&F Jhalawar**
Age of tree	**10 years**
Design	**One-way classification**
Number of Replications	**04 (trees)**
Number of Treatments	**06 (01 control)**
Duration of Experiment	**June 2023- May 2024**

3.6 Treatment details

The experiment was conducted in summer season, 2023-24 with following treatment.

Treatment Notation	Treatment Combination
T_0	Control (Distilled water)
T_1	5 % v/v Ethephon in distilled water (4ml/tree)
T_2	10 % v/v Ethephon in distilled water (4ml/ tree)
T_3	15 % v/v Ethephon in distilled water (4ml/ tree)
T_4	20 % v/v Ethephon in distilled water (4ml/tree)
T_5	25 % v/v Ethephon in distilled water (4ml/tree)

3.7 Chemical Gum Tapping Method

The chemical gum tapping of selected trees was initiated using different concentration of gum enhancer in the tree trunk by hand operated drill machine to induce gummosis. The whole treatments were made through a syringe of 4 ml volume. The 4 ml gum enhancer was injected during the whole period of tapping. The treatment was done in month of February, March, April, and June. The slanting hole of about 6 mm with 2.5 cm depth was made using hand operated drill and 4 ml of gum enhancer was injected in hole with the help of syringe and was immediately covered with soil after injection.

Drilling

Injecting chemical inducer

Cover the hole with soil

Gum exudates

Plate 2. Gum exudation by chemical method

FLOW CHART OF CHEMICAL TAPPING METHOD

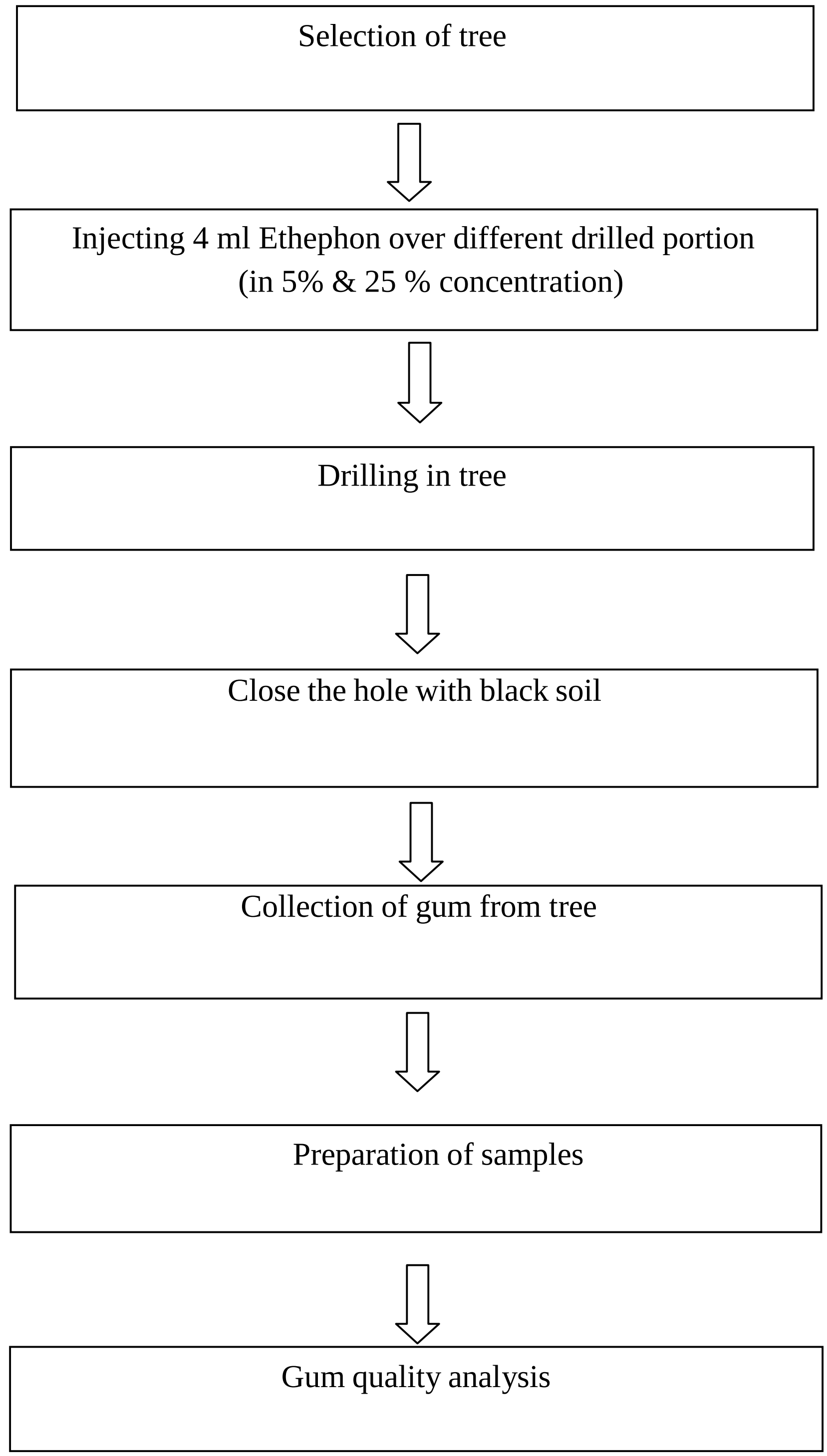


Fig. 3.1 Flow chart of chemical gum extraction method

3.8 Observations recorded

The observations included time of treatment application rate of gum exudation (g/month), time of gum exudation and quantity of gum exudation (g/tree). The details of the observations are described below.

3.8.1 Physical and Morphological characteristics of *Acacia senegal* (L.) Willd.

3.8.1.1 Tree height (m)

The plant height was measured at the beginning and end of experiment. The observations of 4 trees as replicate from each treatment were recorded and its average was calculated. The height was measured from ground level to the tip of the stem with the help of measuring scale.

3.8.1.2 Collar girth (cm)

Collar girth was measured by measuring tape in centimeters of individual tree. The average collar girth per tree was recorded for further statistical analysis.

3.8.1.3 Crown width (m)

The crown width of tree was measured in meter using measuring tape in two directions i.e. East-West and North-South direction. Average values were separately calculated both for East-West and North-South directions.

3.8.1.4 Number of Primary branches

The total number of primary branches per tree was recorded by counting the number of lateral branches of tree per replication from each treatment and average was calculated.

3.8.1.5 Number of secondary branches

The total number of secondary branches per plant was recorded by counting the number of branches of plants per replication from each treatment and average were estimated.

3.8.2 Effect of different concentration of Ethephon on gum exudation.

3.8.2.1 Time of treatment application

The chemical treatment was applied after 11 A.M. during the fourth week of June 2023 and February, March and April 2024.

3.8.2.2 Rate of gum exudation (g/application)

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

3.8.2.3 Quantity of gum exudation (g/tree)

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

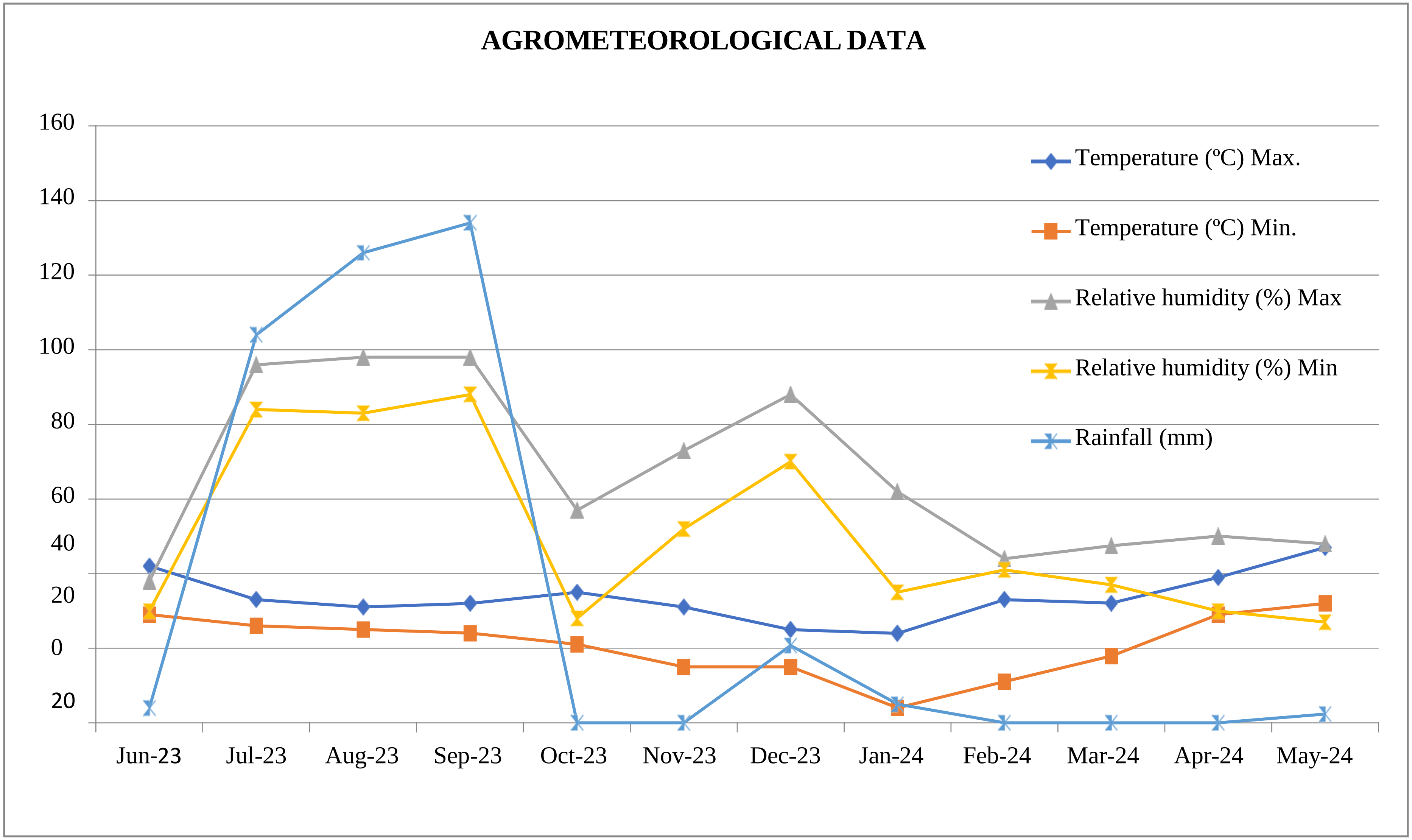
3.8.2.4 Agro-meteorological data

The present research was conducted at the Herbal Garden, College of Horticulture and Forestry, Jhalawar. The climate of Jhalawar is typically sub-humid and characterized by extremes of temperature both summer and winter with high rainfall and moderate relative humidity. Meteorological data showed that during the period of the experiment the mean maximum and minimum temperatures ranged between 42℃ and 4℃ while, the mean relative humidity ranged between 98 and 27 per cent (Irrigation Department Government of Rajasthan, 2023-24). and have been presented in Table 3.1 and Fig. 3.2.

Table 3.1 Mean monthly agro meteorological parameters of Jhalawar for the period of (gum exudation) experimentation (from June, 2023 to May, 2024).

Month	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
June 2023	42.00	29.00	38	30	4.00
July 2023	33.00	26.00	96	84	104.00
August 2023	31.00	25.00	98	83	126.00
Sept 2023	32.00	24.00	98	88	134.00
Oct 2023	35.00	21.00	57	28	0.00
Nov 2023	31.00	15.00	73	52	0.00
Dec 2023	25.00	15.00	88	70	20.70
Jan 2024	24.00	4.00	62.00	35	05.00
Feb 2024	33.00	11.00	44.00	41	00.00
March 2024	32.14	17.85	47.50	37	00.00
April 2024	39	29	50.04	30	00.00
May 2024	47	32	48	27	02.34
Total					**432.04**

Source- Irrigation Department, Government of Rajasthan, Jhalawar



AGROMETEOROLOGICAL DATA
160
140
120
100
80
60
40
20
0
20
Temperature (ºC) Max.
Temperature (ºC) Min.
Relative humidity (%) Max
Relative humidity (%) Min
Rainfall (mm)
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
Dec-23
Jan-24
Feb-24
Mar-24
Apr-24
May-24

3.8.3. Anatomical-section of branch wood of *Acacia senegal* (L.)

The wood samples of 20mm x 20mm x 20mm were preserved in 100 ml of Formalin acetic acid (FAA) solution which consisted of 90 ml of 70 per cent ethyl alcohol, 5 ml of glacial acetic acid and 5 ml formaldehyde (Johanson, 1940). The longitudinal, radial and tangential sections of wood were cut with a sliding microtome at 10–20 µm thickness. These were viewed under the microscope and only the selected 30 sections were used for preparation of permanent slides. For better contrast and tissue identification, sections were stained as per schedule described by Johansen (1940).

Fresh sections in water ⇒	For 2 minutes
⇓ Stain with 2% Safranine ⇒	For 30 minutes
⇓ Washed with running water ⇒	For 5 minutes
⇓ Dehydrated with 30% ethyl alcohol ⇒	For 5 minutes
⇓ Dehydrated with 50% ethyl alcohol ⇒	For 5 minutes
⇓ Dehydrated with 70% ethyl alcohol ⇒	For 5 minutes
⇓ Dehydrated with 95% ethyl alcohol ⇒	For 5 minutes
⇓ Counterstained with 0.5% Fast green ⇒	For 5 minutes
⇓ Absolute Alcohol ⇒	For 5 minutes
⇓ Alcohol: Xylene (3:1)	
⇓ Alcohol: Xylene (1:1)	

Alcohol: Xylene (1:3)

Pure Xylene – I → For 5 minutes

Pure Xylene – II → For 5 minutes

Fig. 3.3 Flow chart showing outline of staining procedure

The stained sections were mounted on glass slide with the help of Canada balsam or DPX mountant (a mixture of distyrene, a plasticizer and Xylene) and covered with the cover slip by avoidingthe air bubbles. 3-4 slides of each sample were prepared for all the planes of symmetry. From these, the best sections were chosen for the measurements.

3.8.3.1 Vessel dimensions

Vessel dimensions were determined by macerating the wood shavings in Jeffery' s solution, i.e. 10 per cent chromic acid and 10 per cent nitric acid, for 48 hours (Pandey *et al.* 1968). Thereafter, the shavings were thoroughly washed, stained with safranine, and teased with the help of needle in 10per cent glycerine prior to mounting on slides. Straight and complete fiber were selected and measured under a stereo microscope equipped with a 10X eyepiece. 4-5 measurements of fiber were made in each slide using an Ocular Micrometer fitted to the eyepiece of a microscope at 10X magnification and standardized with the help of Stage Micrometer.

3.8.3.2 Fiber dimensions

Fiber length was determined by macerating the wood shavings in Jeffery' s solution, i.e. 10 per cent chromic acid and 10 per cent nitric acid, for 48 hours (Pandey *et al*. 1968). Thereafter, the shavings were thoroughly washed, stained with safranine, and teased with the help of needle in 10 percent glycerine prior to mounting on slides. Straight and complete fiber were selected and measured under a stereo microscope equipped with a 10X eyepiece. 4-5 measurements of fiber were made in each slide using an Ocular Micrometer fitted to the eyepiece of a microscope at 10X magnification and standardized with the help of Stage Micrometer.

3.8.3.3 Rays dimensions

Rays dimensions were determined by macerating the wood shavings in Jeffery' s solution, i.e. 10 per cent chromic acid and 10 per cent nitric acid, for 48 hours (Pandey *et al.* 1968). Thereafter, theshavings were thoroughly washed, stained with safranine, and teased with the help of needle in 10 percent glycerine prior to mounting on slides. Straight and complete fiber were selected and measured under a stereo microscope equipped with a 10X eyepiece. 4-5 measurements of ray were made in eachslide using an Ocular Micrometer fitted to the eyepiece of a microscope at 10X magnification and standardized with the help of Stage Micrometer.

3.8.4 Quality Parameters

The study of quality analysis of gum samples was done in the laboratory of Department of Forest Products and Utilization, College of Horticulture and Forestry, Jhalawar. The exudates gum samples were dried and cleaned properly. The clean gum samples were pulverized with the help of a laboratory pulverized to convert the samples in the uniform grit sizes. The weighing of different fractions of the grit samples obtained from the sieve was done using an electronic balance (least count 0.001 g). Determination of different physico-chemical properties such as true density, bulk density, tap density, porosity, bulkiness, hausner's ratio, carr's compressibility index (CCI), swelling index (S.I), moisture content, ash content, pH of gum, colour of gum, and volatile matter. Kumat gums weredetermined using the standard techniques.

3.8.4.1 True density

Among the various methods available for the determination of true density, the liquid displacement method is the simplest method and was used in the present study (Farooq *et al.* 2014). Toluene was selected as the liquid for measurement, because gum is insoluble in toluene. It is expressed in g/cm^3.

$$\text{True density } (\rho t) = \text{Weight of gum/ Displacement volume}$$

3.8.4.2 Bulk density (ρb)

The bulk density (ρb) of arabic gum was determined by slowly pouring the granules into a 10 ml graduated glass cylinder and the excess granules leveled off with a spatula. The bulk density wasobtained by dividing the weight of granules by the volume (Kwakye *et al.* 2010).

$$\text{Bulk density (pb)} = m / v_1$$

Where,

pb = bulk density of the sample, g/cm^3

m = bulk weight of powder taken, g

v_1 = apparent volume of powder, cm^3

Plate 6. Determination of true density

Plate 7. Determination of bulk density

(a) Before taping

(b) After taping

Plate 8. Determination of tap density

3.8.4.3 Tap density (ρt)

The difference between the bulk density and tapped density is only that, in bulk density we have to use the bulk volume where as in the tapped density we have to use tapped volume which can be obtained by switching on the equipment for 100 times tapings (Yadav *et al.* 2015).

$$\text{Tap density } (\rho t) = m / v_1$$

Where,

ρt = tap density of sample, g/cm^3

m = mass of sample, g

v_1= volume of tapped sample, cm^3

3.8.4.4 Porosity

Porosity is defined as the percentage of void space in the bulk material not occupied by the material (Singhal and Samuel, 2003). The porosity is mathematically defined as the ratio of differencebetween true density and bulk density of grits and true density. According to Mohsenin *et al.* (1978), porosity(ε) can be expressed as below.

$$\text{Porosity } (\varepsilon)\ (\%) = \left(1 - \frac{pb}{pt}\right) \times 100$$

Where,

(ε) = Porosity, %

pb = Bulk density, g/cm^3

pt = True density, g/cm^3

3.8.4.5 Bulkiness

The reciprocal of bulk density is called bulkiness (Yadav *et al*. 2015). It was calculated by the following equation:

$$\text{Bulkiness} = 1/\text{Bulk density}$$

3.8.4.6 Hausner's ratio (H)

Hausner's ratio measures cohesiveness of the exudate gum powder. Generally, it may be defined as ratio of tapped density and bulk density. The hausner's ratio was calculated using following formula (Yadav *et al.* 2015).

$$\text{Hausner's ratio} = \text{Tap density} / \text{Bulk density}$$

3.8.4.7 Carr's compressibility index (CCI)

The Carr's index (closely related with Hausner's ratio) is the fast, simple and popular technique of describing the flow property of any powder. It has been proposed as an indirect measure of size and shape, surface area, bulk density, moisture content and cohesiveness of materials, as all these properties can influence the compressibility index. Compressibility is directly related to cohesiveness, particle size and flow rate. Carr's compressibility index was determined using the values of apparent bulk density and tap density with the help of following relationship (Reddy *et al.* 2015).

$$\text{Carr's Compressibility index (\%)} = \frac{\text{Tap density-Bulk density}}{\text{Tap density}} \times 100$$

Where,

ρt = tap density of gum powder, g/cm^3

ρb = bulk density of gum powder, g/cm^3

3.8.4.8 Swelling index (SI)

Swelling index of arabic gum granules was determined by using the method stated by (Gauthami and Bhat, 1992) with slight modification. One gram of gum granules was weighed and transferred to a 100 ml stopper measuring cylinder. The initial volume of the sample was recorded. The volume was made up to 100 ml mark with distilled water. The stopper of the cylinder and shaken lightly and then kept stationery for 24 h. The volume occupied by the gum powder sediment was noted after the lapse of 24 h. Swelling index was determined by following formula (Kumar *et al.* 2011).

$$SI = \frac{Xo-Xt}{Xo} \times 100$$

Where,

SI = swelling index (%)

X_o = initial volume of gum, ml

X_t = volume occupied by swollen gum powder after 24 h, ml

3.8.4.9 Moisture content

The moisture content of arabic gum was determined by the method described by Okalebo *et al.* (2002). A clean crucible was dried in an air oven at 105^{0}C, and cooled in desiccators and weighed. Two grams of finely ground sample was accurately weighed and transferred into crucible. The crucible containing the sample was dried in an oven and weighed regularly till constant weight. The moisture content was calculated using the following expression.

$$\text{Moisture content (\%, db)} = W_1 - W_2 \ / \ W_1 \times 100$$

Where,

W_1 = weight of sample before drying

W_2 = weight sample after drying

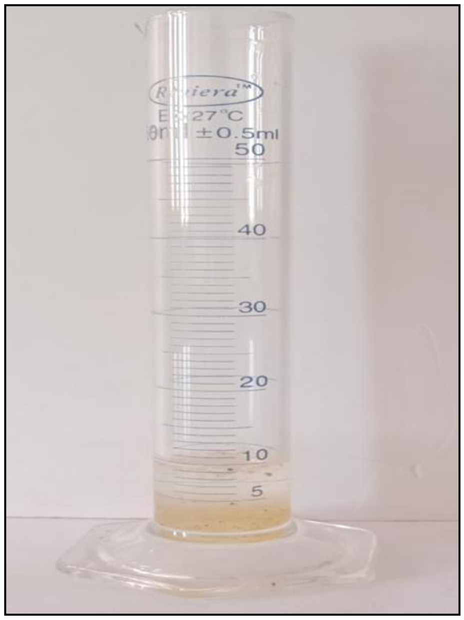


Plate 9. Determination of swelling index

Plate 10. Determination of moisture content

3.8.4.10 Ash content

The content of ash in the arabic gum samples was determined following the method describedby (Malsawmtluangi *et al.* 2014). About 2 g of the powder sample was first heated on a burner in air to remove its smoke. Then it was burnt in a muffle furnace at 550°C for 3 h or till a constant weight ash was obtained. The crucibles were then withdrawn from the furnace and cooled to room temperature in desiccators and weighed. The ash content was expressed as percentage ratio of the weight of the ash to the oven dry weight of the powder. The ash content was calculated using the following expression.

$$\text{Ash content (\%)} = W_1 - W_2 / W_0 \times 100$$

Where,

W_1 = weight of crucible + sample before burning

W_2 = weight of crucible + sample after burning

W_0 = original weight of sample

3.8.4.11 pH of gum

The pH was of gum was determined using a pH meter. It was determined with 1 per cent aqueous solution of gums at room temperature. 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 (Ameh, 2012).

3.8.4.12. Colour of gum

Colour was assessed in each gum sample using Munsell soil color charts. The colour of the gums varies from almost colourless through various shades of yellow, orange to dark brown; some ofthe best gum arabic (*Acacia senegal*) were almost colourless.

3.8.4.13 Volatile matter (%)

To determine the volatile matter, the gum sample was first dried and then ignited in muffle furnace at 575^0C in for one hour. To remove carbon contents, it was allowed to cool and then weighted immediately. It was thereafter calculated by following formula (Okalebo *et al.* 2002)

$$\text{Volatile matter in sample (\%)} = C$$

Where, C is Weight loss in % = (A-B)/A*100;

Gum sample **Ash content**

Plate 11. Determination of ash content

Plate 12. Determination of pH of gum

3.9 Statistical analysis:

The recorded data will be subjected to One way ANOVA for statistical analysis.

Analysis of variance (ANOVA) The analysis of variance table was set up as under:

Source of variation	Degree of Freedom	Mean sum of square	Variance ratio
Treatment **Error**	(t-1) (rt-1)(t-1)	Mt Me	Mt/Me
Total	(rxt)-1	MT	

Where,

r = number of replications

t = number of treatments

Mt = mean sum of square due to treatment

Me = mean sum of square due to error

The critical difference (CD) was calculated as follows:

CD= SE (d) x t0.05

Where,

SE (d) = standard error of difference was calculated

t0.05 = t value at 5 per cent degree of freedom.

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CHAPTER - 4

EXPERIMENTAL RESULTS

The results obtained from the present investigation entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** conducted at Herbal Garden, College of Horticulture and Forestry, Jhalawar, Rajasthan during June, 2023 to May, 2024 are presented in this chapter. The data recorded for selected parameters under study were subjected to statistical analysis for comparison and interpretation of data. The results obtained from the present investigations are described in the chapter under the following headings:

4.1 To study the physical and morphological characteristics of *Acacia senegal* (L.) Willd.

4.2 To study the effect of different concentration of Ethephon on gum exudation.

4.3 To study the quality parameters on gum of *Acacia senegal* (L.) Willd.

4.1 Physical and morphological characteristics of *Acacia senegal* (L.) Willd.

The data related to tree height, collar girth, crown width in East-West and North-South direction, number of primary branches and number of secondary branches for *Acacia senegal* L. tree are hereby presented as under.

4.1.1 Tree height (m)

The tree height is an important factor influencing the gum yield of tree and has positive interaction. The data related to tree height are presented in Table 4.1 (Fig. 4.1). The data pertaining to tree height (m) in *Acacia senegal* L. trees were found to be non-significant which ranged from 3.77 m to 4.05 m.

4.1.2 Collar girth (cm)

The data pertaining to collar girth (Fig. 4.2) in selected trees of *Acacia senegal* L. trees are presented in Table 4.1 which was found to be non-significant and the value ranged between 30.57 cmto 40.37 cm.

Table 4.1 Tree height (m) and Collar girth (cm) of *Acacia senegal* L. trees.

S.No.	Treatments	Tree height (m)	Collar girth (cm)
1.	T_0 Control (Distilled water)	3.82	38.12
2.	T_1 5% v/v Ethephon in distilled water (4ml/tree)	3.92	38.02
3.	T_2 10% v/v Ethephon in distilled water (4ml/ tree)	3.77	30.57
4.	T_3 15 % v/v Ethephon in distilled water (4ml/ tree)	3.90	40.37
5.	T_4 20 % v/v Ethephon in distilled water (4ml/tree)	4.05	38.20
6.	T_5 25 % v/v Ethephon in distilled water (4ml/tree)	3.97	38.12
$C.D._{005}$		**NS**	**NS**
SEm±		**0.17**	**3.14**
C.V %		**8.74**	**16.87**

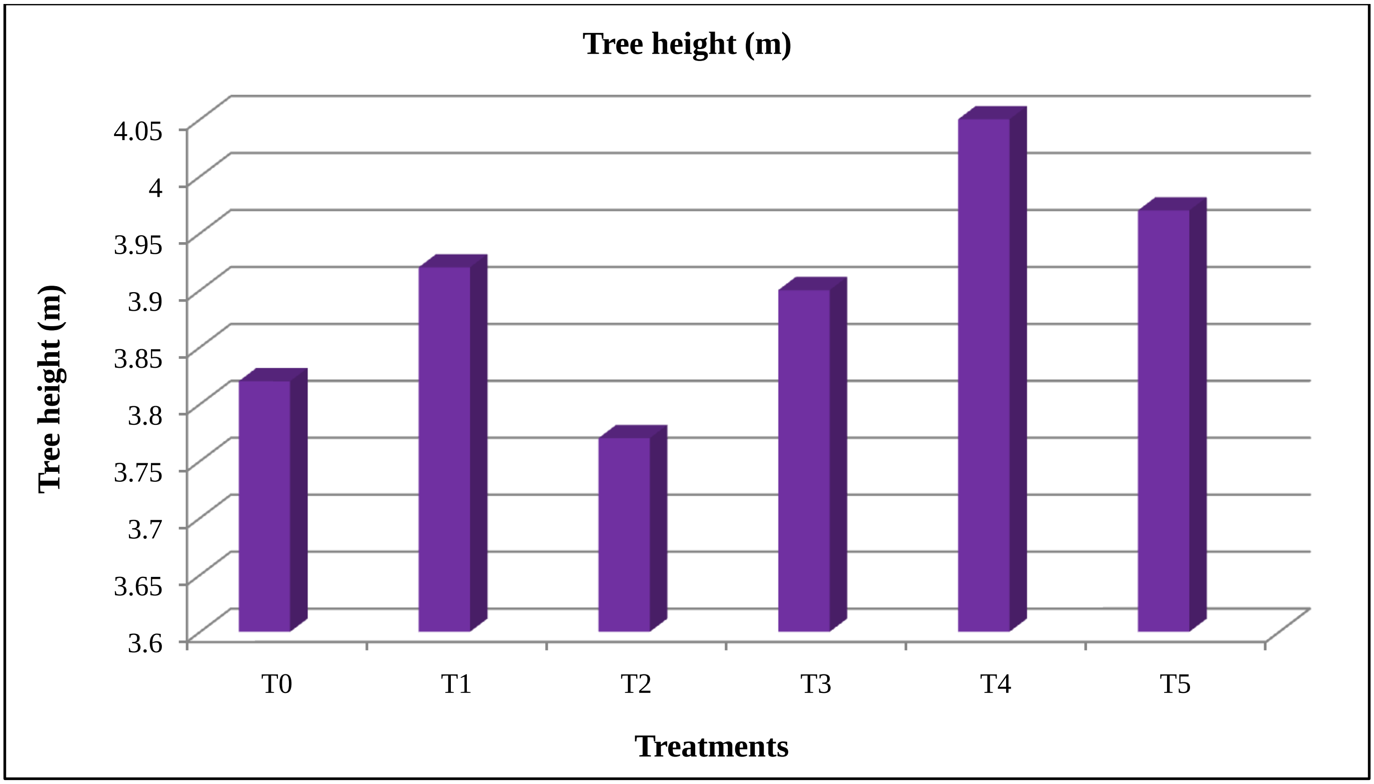

Fig. 4.1 Graph showing tree height (m) of selected trees of *Acacia senegal* L.

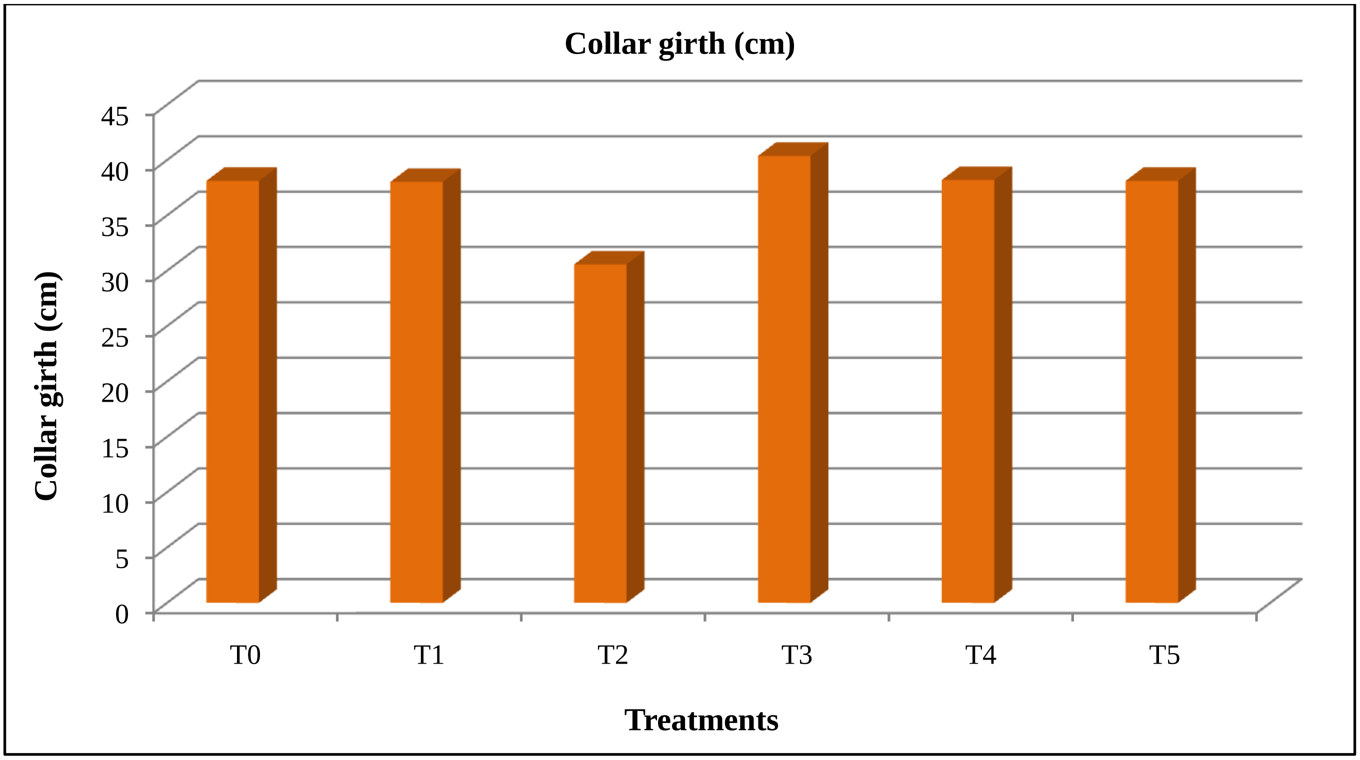

Fig. 4.2 Graph showing collar girth of selected trees of *Acacia senegal* L.

4.1.3 Crown width (E-W) (m)

The data related to crown width (m) (Fig. 4.3) for E-W in selected trees of *Acacia senegal* L. trees in E-W direction presented in Table 4.2 which was found to be non-significant and the values ranged from 3.70 to 4.27 m.

4.1.4 Crown width (N-S) (m)

The perusal of data for crown width (Fig. 4.3) (m) for *Acacia senegal* L. trees in N-S direction are presented in Table 4.2 The analysed data was found to be non-significant and the values ranged from 3.77 to 4.40 m.

4.1.5 Number of primary branches per tree

The observations related to the number of primary branches (Fig. 4.4) in selected *Acacia senegal* L. trees were found to be non-significant and are presented in Table 4.3, ranging from 2 to 3 in number.

4.1.6 Number of secondary branches per tree

The statistically analyzed data related to number of secondary branches (Fig. 4.4) in selected trees of *Acacia senegal* L. were also found to be non-significant as shown in Table 4.3. The values of number of secondary branches per tree ranged from 5 to 8 in number.

Table 4.2 Crown width in E-W and N-S direction (m) in *Acacia senegal* L. trees.

S.No.	Treatments	Crown width (E-W) (m)	Crown width (N-S) (m)
1.	**T_0** Control (Distilled water)	3.70	3.77
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	3.87	3.90
3.	**T_2** 10 % v/v Ethephon in distilled water (4ml/ tree)	4.12	3.92
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	4.27	4.17
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	3.95	4.40
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	3.72	4.27
$C.D._{005}$		**NS**	**NS**
SEm±		**0.219**	**0.263**
C.V %		**11.12**	**12.89**

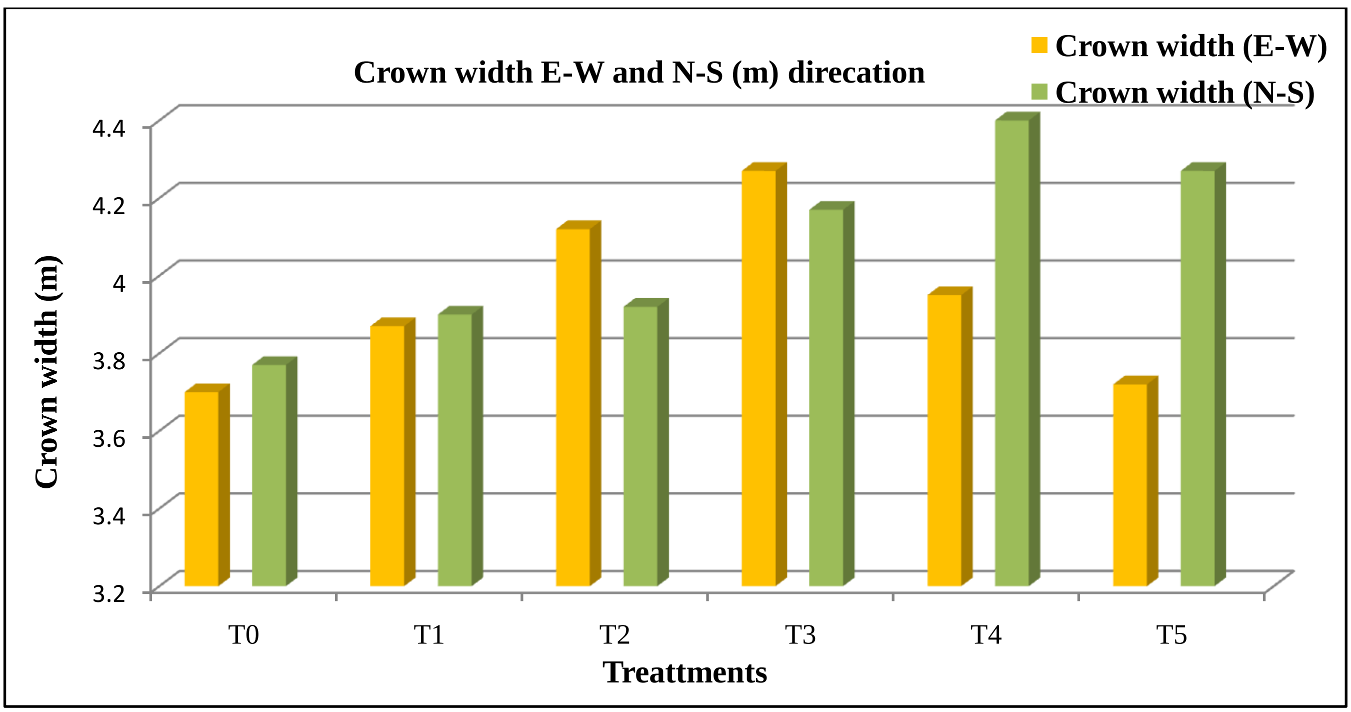

Fig. 4.3 Graph showing crown width E-W and N-S (m) direction of selected trees of *Acacia senegal*

Table 4.3 Number of primary branches and secondary branches of *Acacia senegal* L. tree

S.No.	Treatments	No. of primary branches per tree	No. of secondary branches per tree
1.	**T_0** Control (Distilled water)	2	7
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	3	8
3.	**T_2** 10 % v/v Ethephon in distilled water (4ml/tree)	3	7
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/tree)	3	6
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	3	5
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	3	6
$C.D._{005}$		**NS**	**NS**
SEm±		**2.19**	**0.55**
C.V %		**16.19**	**16.79**

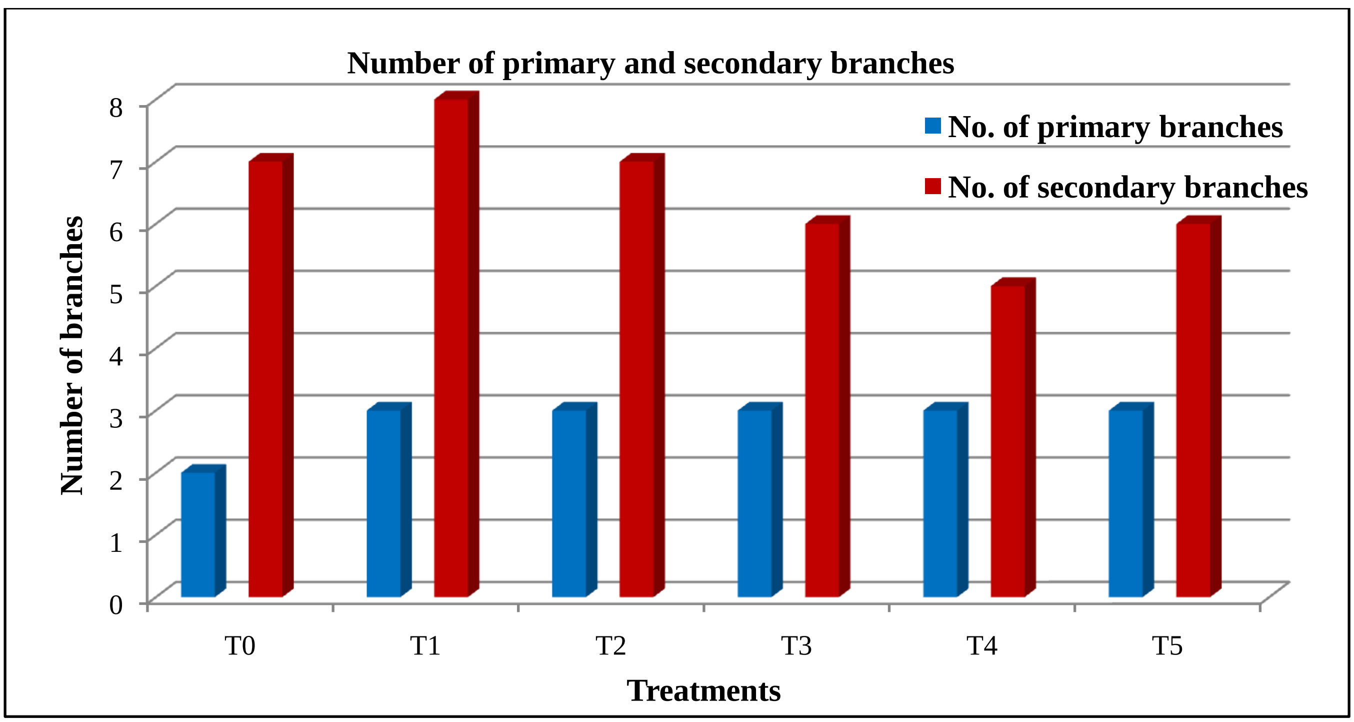

Fig. 4.4 Graph showing number of primary and secondary branches of selected trees of *Acacia senegal* L.

4.2 Effect of different concentration of Ethephon on gum exudation.

4.2.1 Time of treatment application

Gum exudation phenomenon is entirely dependent on the time of application of gum inducing chemical in trees. The environmental factors *viz.*, temperature and relative humidity have an important role for the process of gummosis. The application of gum inducer was performed during summer season in selected trees. The application of different doses of ethephon was done on the first (1^{st} and 2^{nd}) week of each month (June 2023, February, March, April 2024) of summer season.

In treatment, the gum enhancer ethephon with five different concentrations were used in *Acacia senegal* L. trees for tapping purposes. In the experiment, six treatments i.e. T_0 (Control with Distilled water), T_1 (5 % v/v Ethephon), T_2 (10 % v/v Ethephon), T_3 (15 % v/v Ethephon), T_4 (20 % v/v Ethephon), T_5 (25 % v/v Ethephon) were injected as 4 ml in the hole, as gum enhancer to induce the stress condition in the trees to induce the biopolymer exudation. The data related to time of treatment application in *Acacia senegal* L. tree are presented in Table 4.4.

Table 4.4 Time of application of treatment for gum exudation in *Acacia senegal* L. trees (in days)

Treatment	1^{st} Application of Ethephon (2-June-2023)	2^{st} Application of Ethephon (4-Feb-2024)	3^{st} Application of Ethephon (10-March-2024)	4^{st} Application of Ethephon (7-April-2024)
T_0 control	17-18	25-27	20-25	19-21
T_1 5% v/v	12-14	17-18	14-15	15-16
T_2 10% v/v	12-14	17-18	14-15	15-16
T_3 15% v/v	10-12	15-16	12-15	12-15
T_4 20% v/v	7-9	13-14	10-14	10-12
T_5 25% v/v	10-12	14	12-14	13-14

4.2.2 Rate of gum exudation (g/application)

The rate of gum exudation was dependent on the stress factors caused by the effect of temperature, relative humidity percentage, and concentration of chemical, time of treatments, and directions of treatments in tree.

The results obtained for rate of gum exudation observed in the month of June 2023 to May 2024. The rate of gum exudation in different treatments in *Acacia senegal* L. and different time of application of ethephon. The first treatment was applied on *Acacia senegal* L. tree in the first week of June, second treatment on February first week, third treatment second week March and fourth treatment first week of April. The rate of gum exudation was maximum in the 1^{st} application followed by 4^{th} application, 3^{rd} application and 2^{nd} application in *Acacia senegal* L. tree during the year 2023 and 2024. The maximum temperature goes higher in month of June 2023 (42^0C) and minimum in month of February 2024 (33^0C) in temperature and relative humidity (%) was low (38%) in June 2023 as compared to February 2024 (44%).

The data pertaining to rate of gum exudation from *Acacia senegal* L. tree is presented in Table 4.5 (Fig. 4.5). The results obtained were found to be highly significant where the maximum rate of gum was found as 47.35 g when treated with T_4 (20 % v/v Ethephon) whereas, the minimum gum exudation was observed as 6.15 g in control with distilled water (T_0) during 1^{st} application of ethephon. During 2^{nd} application of Ethephon, the rate of gum was found maximum as 12.47 g when treated with T_4 (20 % v/v Ethephon) whereas, the minimum gum exudation was observed as 1.74 g in control with distilled water (T_0). During 3^{rd} application of ethephon, the highest quantity of gum was found as 15.07 g when treated with T_4 (20 % v/v Ethephon) while, the minimum was observed as 4.08 g in control with distilled water (T_0). In the 4^{th} application of ethephon, the quantity of gum was found maximum as 18.20 g when treated with T_4 (20 % v/v Ethephon) whereas, the minimum was observed in control with distilled water (T_0) as 5.73 g.

Table 4.5 Rate of gum exudation (g/application) in *Acacia senegal* L. during year 2023-24.

S.No.	**Treatments**	**1st Application of Ethephon (June 2023)**	**2nd Application of Ethephon (Feb 2024)**	**3rd Application of Ethephon (March 2024)**	**4th Application of Ethephon (April 2024)**
1.	$\mathbf{T_0}$ Control (Distilled water)	6.15	1.74	4.08	5.73
2.	$\mathbf{T_1}$ 5% v/v Ethephon in distilled water (4ml/tree)	20.35	7.68	8.08	9.95
3.	$\mathbf{T_2}$ 10% v/v Ethephon in distilled water (4ml/ tree)	27.65	8.58	10.33	11.01
4.	$\mathbf{T_3}$ 15 % v/v Ethephon in distilled water (4ml/ tree)	35.57	10.13	12.08	15.13
5.	$\mathbf{T_4}$ 20 % v/v Ethephon in distilled water (4ml/tree)	47.35	12.47	15.07	18.20
6.	$\mathbf{T_5}$ 25 % v/v Ethephon in distilled water (4ml/tree)	29.40	9.88	10.88	14.56
C.D.$_{005}$		**1.64**	**0.38**	**0.42**	**0.54**
SEm±		**0.55**	**0.13**	**0.14**	**0.18**

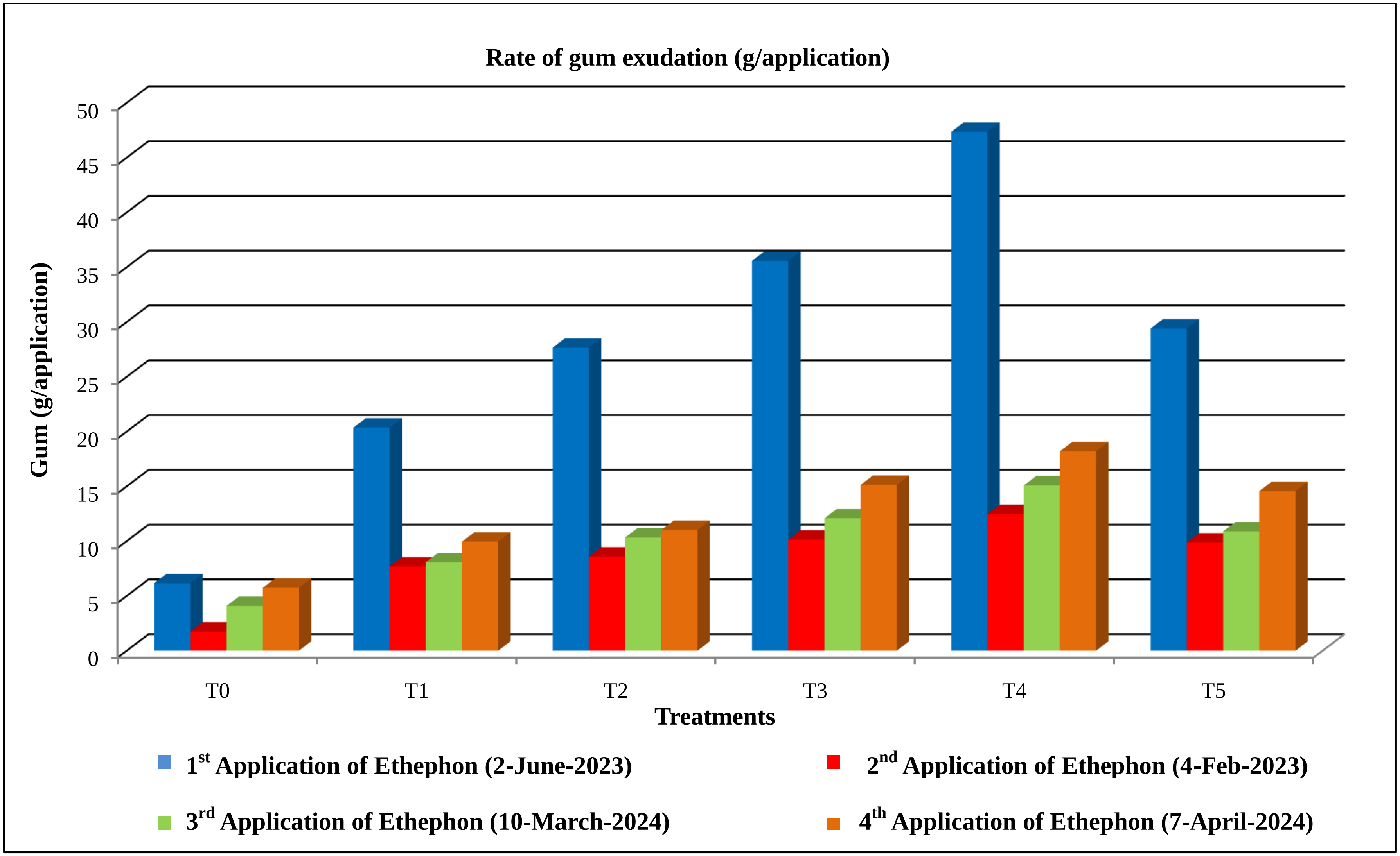

Fig. 4.5 Rate of gum exudation (g/application) in *Acacia senegal* L. during year 2023 and 2024.

4.2.3 Quantity of gum exudation (g/tree)

The data pertaining to the effect of treatment on quantity of gum exudation in *Acacia senegal* L. tree for selected months during 2023-24 are presented in Table 4.6 (Fig. 4.6).

The results obtained for quantity of gum exudation observed in the month of June 2023 to May 2024 were found to be highly significant. The quantity of gum exudation in different treatments in *Acacia senegal* L. exposed that the maximum gum exudation of 93.08 g was found in T_4 (20 % v/v Ethephon) whereas, the minimum exudation was observed as 17.69 g in control with distilled water (T_0).

Table 4.6 Quantity of gum exudation (g/tree) in *Acacia senegal* L. tree.

S.No.	Treatments	Quantity of gum exudation (g/tree)
1.	**T_0** Control (Distilled water)	17.69
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	46.05
3.	**T_2** 10% v/v Ethephon in distilled water(4ml/ tree)	57.56
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	72.90
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	93.08
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	64.71
$C.D._{005}$		**1.85**
SEm±		**0.88**

4.2.4 Agro meteorological data

The gum yield was depending upon the relative humidity and temperature. Gum production was positively correlated with minimum and maximum temperatures at time of treatment. The maximum gum yield was found in high temperature and low humidity. The maximum yield of gum was found as June 2023 in which higher temperature (42℃) and low relative humidity (38%). The minimum yield of gum was found during February 2024 in which low temperature (33℃) and high relative humidity (44%).

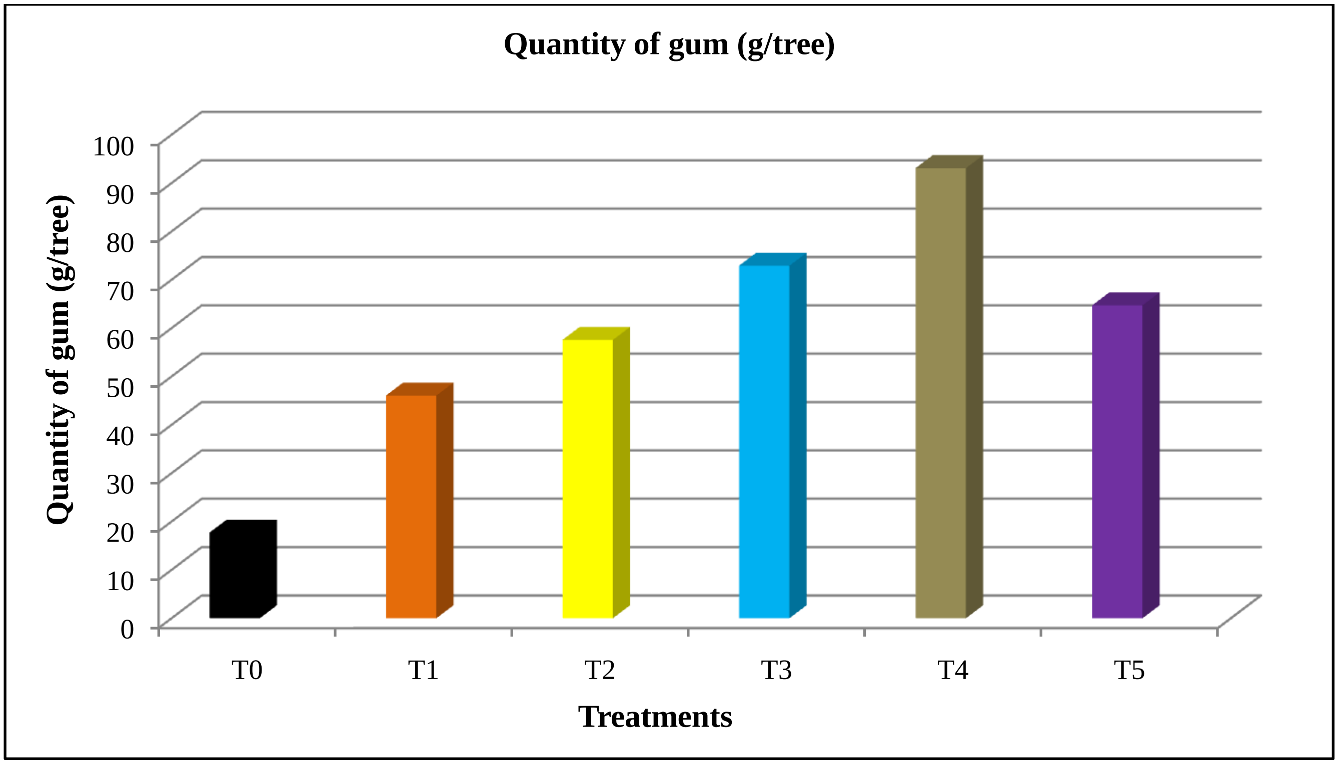

Fig. 4.6 Quantity of gum exudation (g/tree) in *Acacia senegal* L. tree.

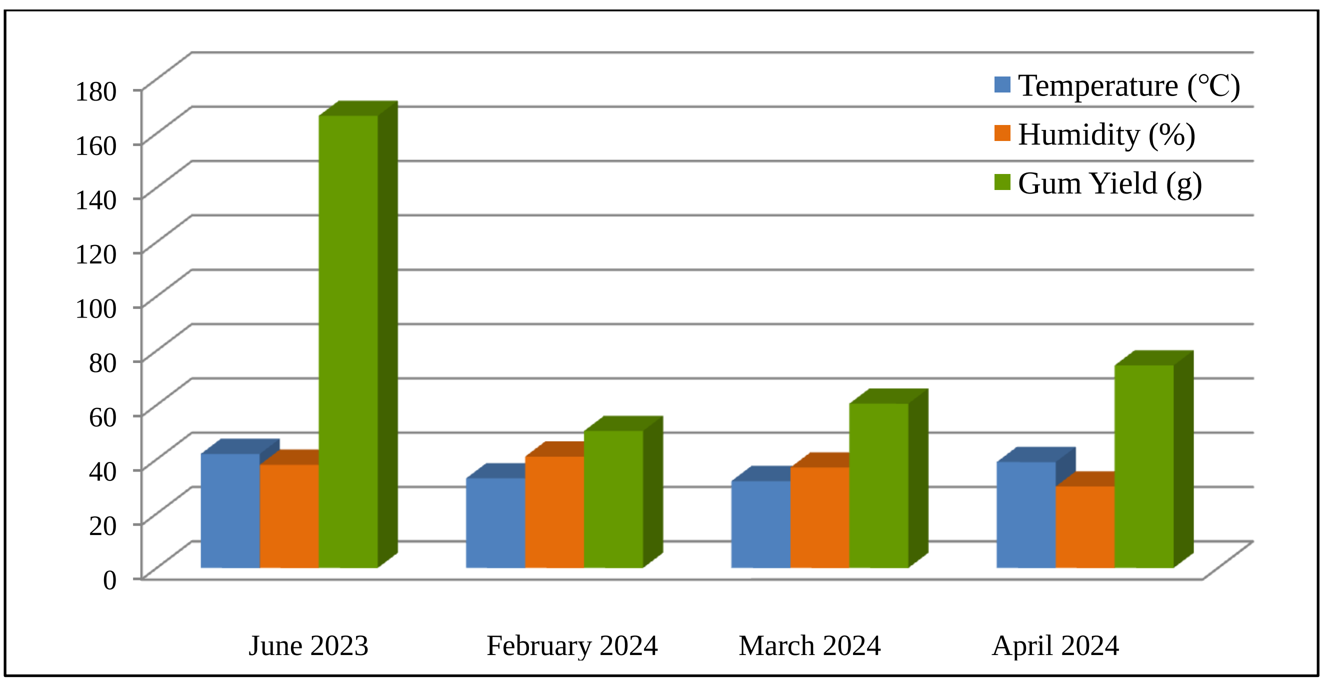

Fig. 4.7 Graph showing the relation between temperature, relative humidity and gum yield in *Acacia senegal* L. (from June 2023 to May 2024).

4.3 Anatomical-section of branch wood of *Acacia senegal* L.

4.3.1 Vessel dimensions

The vessel dimensions of wood of *Acacia senegal* L. tree possess dominant solitary vessels, radial pores ranged from 2-3 and pore clusters 2-4. The vessel shape at transverse plane was circular, oval and cylindrical and arches (Owolabi *et al*. 2021).

4.3.1.1 Vessel Length (mm) and Diameter (mm)

Perusal of data related to vessel length and vessel diameter (mm) in *Acacia senegal* L. wood were depicted in Table 4.7 (Plate 3). The data was found to be non-significance and value of vessel length (mm) ranged from 0.172 mm to 0.184 mm. The data related to vessel diameter (mm) was also non-significance and ranged from 0.136 mm to 0.150 mm.

Table 4.7 Vessel Length (mm) and Vessel Diameter (mm) of *Acacia senegal* L. wood.

S.No.	Treatments	Vessel Length (mm)	Vessel Diameter (mm)
1.	T_0 Control (Distilled water)	0.166	0.136
2.	T_1 5% v/v Ethephon in distilled water (4ml/tree)	0.179	0.150
3.	$T_2$10% v/v Ethephon in distilled water (4ml/tree)	0.172	0.138
4.	$T_3$15 % v/v Ethephon in distilled water (4ml/tree)	0.182	0.145
5.	T_4 20 % v/v Ethephon in distilled water (4ml/tree)	0.184	0.148
6.	T_5 25 % v/v Ethephon in distilled water (4ml/tree)	0.173	0.144
$C.D._{005}$		**NS**	**NS**
SEm±		**0.004**	**0.003**

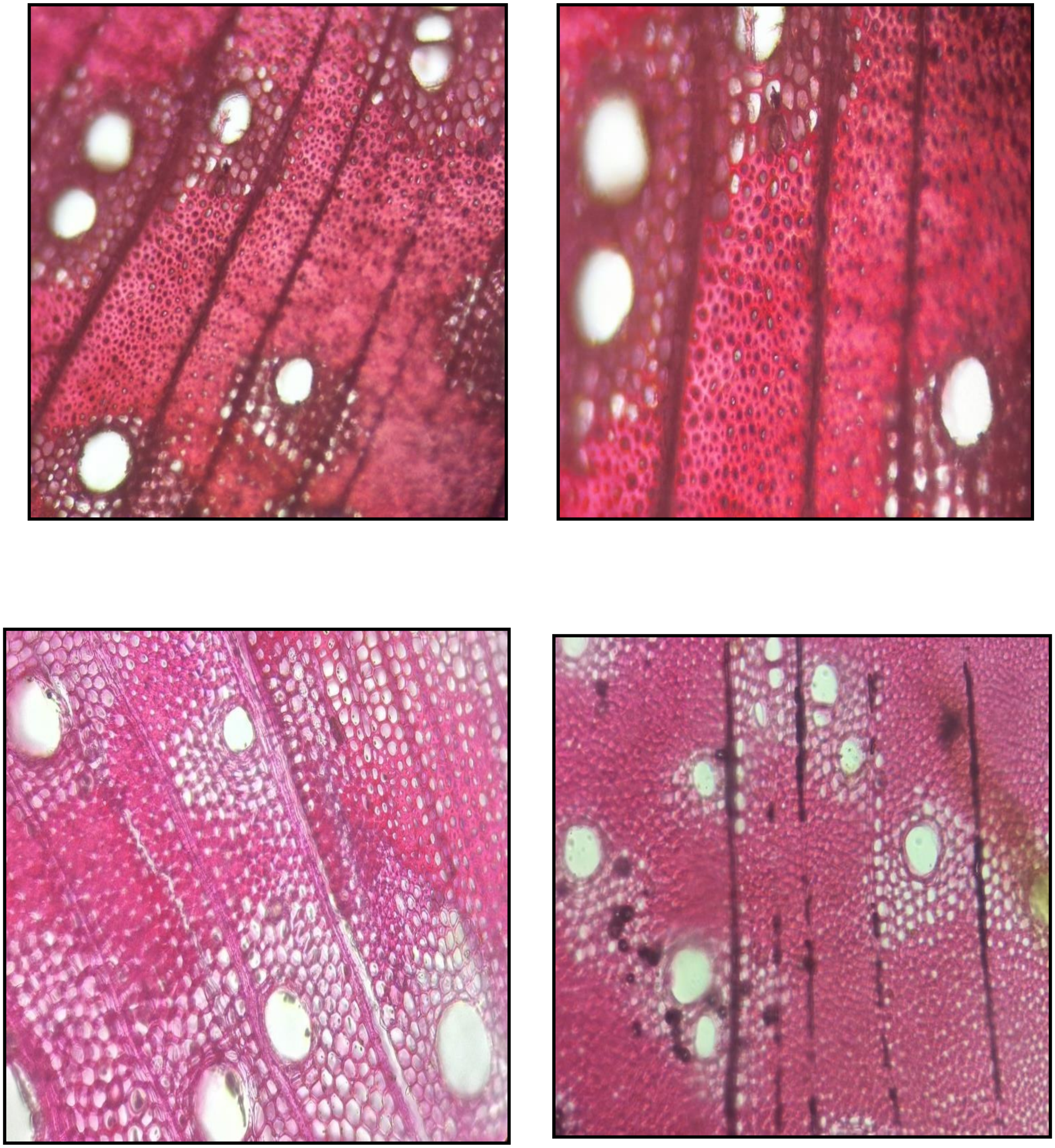

Plate 3. Cross section (C.S) of branch wood of *Acacia senegal* L. tree in showing the vessels lengthand vessels diameter.

4.3.2 Fiber dimensions

The wood of *Acacia senegal* L. have libriform fibers, non-septate. The size and compactness of fibers in wood gives the level of strength and resistance of wood. They are elongated type with much lignified cell wall. The data related to fiber dimensions are given below.

4.3.2.1 Fiber Length (mm) and Diameter (mm)

The data pertaining to fiber length and diameter of *Acacia senegal* L. wood are presented in Table 4.8 (Plate 4). The data related to fiber length and diameter (mm) was found to be non-significant with value ranging from 0.739 mm to 0.779 mm in fiber length and 10.629 mm to 16.359 mm for fiber diameter.

Table 4.8 Fiber Length (mm) and Fiber Diameter (mm) of *Acacia senegal* L. wood.

S.No.	Treatments	Fiber Length (mm)	Fiber Diameter (mm)
1.	**T_0** Control (Distilled water)	0.769	16.359
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	0.757	12.008
3.	**T_2** 10% v/v Ethephon in distilled water (4ml/ tree)	0.739	10.629
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	0.744	14.095
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	0.751	12.314
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	0.779	13.275
$C.D._{005}$		**NS**	**NS**
SEm±		**0.019**	**2.256**

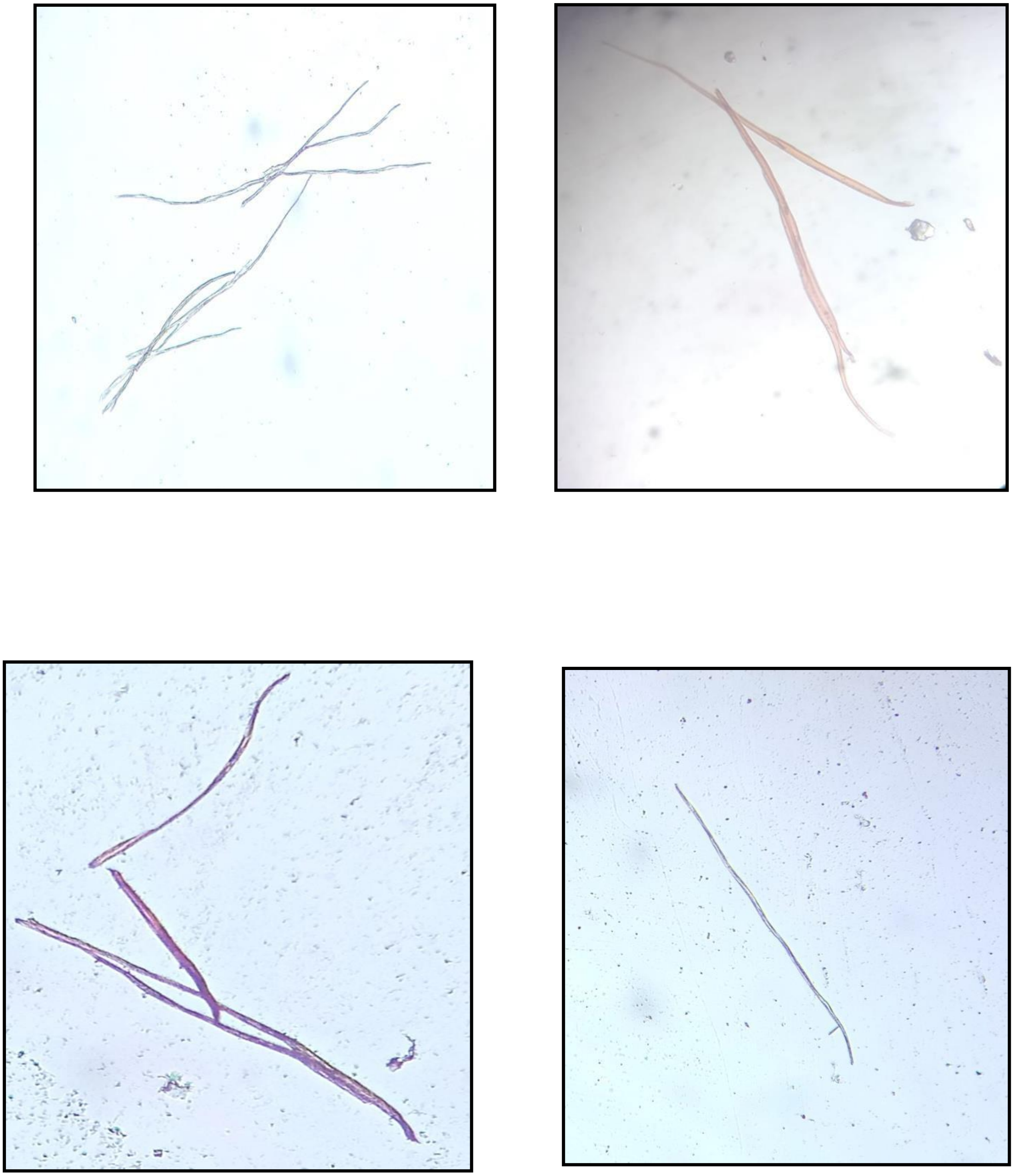

Plate 4. Radial section (R.S.) of branches wood of *Acacia senegal* L. tree in showing the fiberlength and fiber diameter.

4.3 Gum ducts

The anatomy and histology of gum ducts is very important to determine the mechanism of gummosis. The gum exudation is significantly influenced by the gummosis process, which is related to biotic and abiotic stress in trees. The results have shown that ethephon had significantly affected the formation of gum. The sample of sapwood was taken for conducting the anatomical studies. Gum ducts are cylindrical, square and oval at tangential plane and the ray length 309.6±66.4 μm and diameter (36.0±7.0 μm) (Owolabi *et al.* 2021).

4.3.3.1 Ray Length (mm) and Diameter (mm)

The data pertaining to ray length and ray diameter (mm) of *Acacia senegal* L. wood are depicted in Table 4.9 (Plate 5.) which was found to be statistically non-significant. The values of ray length ranged from 0.141 mm to 0.164 mm while, the valued of ray diameter (mm) varied from 0.023 mm to 0.029 mm.

Table 4.9 Ray Length (mm) and Ray Diameter (mm) of *Acacia senegal* L. wood.

S.No.	Treatments	Ray Length (mm)	Ray Diameter (mm)
1.	**T_0** Control (Distilled water)	0.141	0.027
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	0.161	0.024
3.	**T_2** 10% v/v Ethephon in distilled water (4ml/ tree)	0.164	0.023
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	0.151	0.028
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	0.150	0.026
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	0.160	0.029
$C.D._{005}$		**NS**	**NS**
SEm±		**0.009**	**0.003**

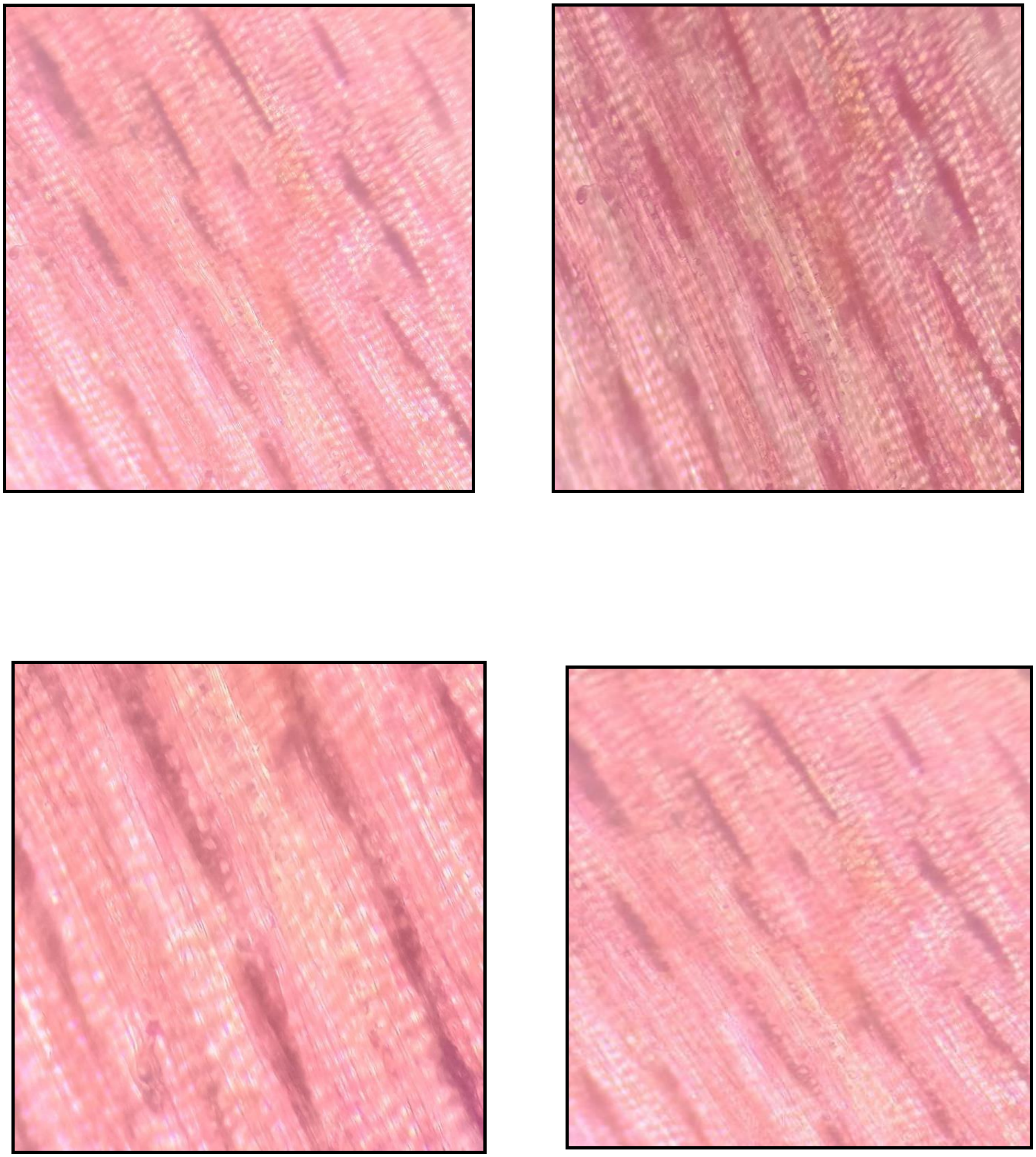

Plate 5 Transverse section (T.S.) of branch wood of *Acacia senegal* L. tree in showing the raylength and ray diameter.

4.4 Quality parameter of gum

The results of various physico-chemical properties i.e. true density, bulk density, tap density, porosity, bulkiness, hausner's ratio, carr's compressibility index, swelling index, moisture content, ash content, pH of gum, colour of gum, volatile matter of gum arabic are presented in the following sub-sections.

4.4.1 True density

True density is the quality parameter which is used to determine the flow properties of gum. The data related true density of gum collected from the trees of *Acacia senegal* L. are presented in Table 4.10. The results obtained were found to be non significant with value ranging from 1.30 g/cm^3 to 1.39 g/cm^3.

Table 4.10 True density of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	True density (g/cm^3)
1.	**T_0** Control (Distilled water)	1.31
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	1.30
3.	**T_2**10 % v/v Ethephon in distilled water (4ml/ tree)	1.35
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	1.39
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	1.39
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	1.34
C.D. $_{0.05}$		**NS**
SEm±		**0.03**

4.4.2 Bulk density

The bulk density of the gum is dependent on particle density which determines the ability of flow ability. The data pertaining to bulk density of gum from *Acacia senegal* L. trees are presented in Table 4.11. The results obtained were found to be non significant. The values of bulk density of gum ranged from 0.78 g/cm^3 to 0.81 g/cm^3.

Table 4.11 Bulk density of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Bulk density(g/cm^3)
1.	**T_0** Control (Distilled water)	0.78
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	0.81
3.	**T_2** 10 % v/v Ethephon in distilled water (4ml/ tree)	0.81
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	0.80
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	0.78
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	0.78
C.D. $_{0.05}$		**NS**
SEm±		**0.02**

4.4.3 Tap density

The statistically analyzed data related to tap density of the gum collected from trees of *Acacia senegal* L. trees are presented in Table 4.12. The results obtained were found to be non significant. The values of tap density ranged from 0.85 g/cm^3 to 0.88 g/cm^3.

Table 4.12 Tap density of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Tap density (g/cm^3)
1.	**T_0** Control (Distilled water)	0.85
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	0.88
3.	**T_2** 10 % v/v Ethephon in distilled water (4ml/ tree)	0.87
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	0.88
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	0.85
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	0.87
C.D. $_{0.05}$		**NS**
SEm±		**0.02**

4.4.4 Porosity

The porosity is dependent on the values of bulk and true density. The porosity value increased with the increase in bulk density value. The data related porosity of gum collected from the selected trees of *Acacia senegal* L. are presented in Table 4.13. The results obtained were found to be non significant. The values of porosity ranged from 6.50 per cent to 10.25 per cent.

Table 4.13 Porosity of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Porosity (%)
1.	$\mathbf{T_0}$ Control (Distilled water)	8.75
2.	$\mathbf{T_1}$ 5% v/v Ethephon in distilled water (4ml/tree)	8.25
3.	$\mathbf{T_2}$10% v/v Ethephon in distilled water (4ml/ tree)	6.50
4.	$\mathbf{T_3}$15 % v/v Ethephon in distilled water (4ml/ tree)	10.25
5.	$\mathbf{T_4}$ 20 % v/v Ethephon in distilled water (4ml/tree)	8.75
6.	$\mathbf{T_5}$ 25 % v/v Ethephon in distilled water (4ml/tree)	9.25
C.D. $_{0.05}$		**NS**
SEm±		**1.41**

4.4.5 Bulkiness

The data pertaining to bulkiness of gum from trees of *Acacia senegal* L. are presented in Table 4.14. The results obtained were found to be non significant. The values of bulkiness ranged from 1.23 g/cm^3 to 1.28 g/cm^3.

Table 4.14 Bulkiness of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Bulkiness(g/cm^3)
1.	**T_0** Control (Distilled water)	1.28
2.	**T_1** 5 % v/v Ethephon in distilled water (4ml/tree)	1.23
3.	**T_2** 10 % v/v Ethephon in distilled water (4ml/ tree)	1.23
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	1.26
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	1.28
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	1.28
$C.D._{0.05}$		**NS**
SEm±		**0.03**

4.4.6 Hausner's ratio (H)

The hausner's ratio of *Acacia senegal* L. gum powder was noted to be dependent on tapped and bulk density of the powders. The data related hausner's ratio of gum from trees of *Acacia senegal* are presented in Table 4.15. The results revealed were found to be non significant. The values of hausner's ratio ranged from 1.06 g/cm^3 to 1.11 g/cm^3.

Table 4.15 Hausner's ratio of gum collected from *Acacia senegal* L. trees

S.No.	Treatments	Hausner's ratio
1.	**T_0** Control (Distilled water)	1.08
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	1.09
3.	**T_2** 10% v/v Ethephon in distilled water (4ml/ tree)	1.06
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	1.11
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	1.09
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	1.11
$C.D._{0.05}$		**NS**
SEm±		**0.02**

4.4.7 Carr's compressibility index (CCI)

The carr's compressibility index denotes the compression characteristics and flow properties. The data related carr's compressibility indexof gum from *Acacia senegal* L. tree are depicted in Table 4.16. The results obtained were found to be non significant. The values of carr's compressibility index ranged from 6.06 to 8.27.

Table 4.16 Carr's compressibility index of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Carr's compressibility index
1.	**T_0** Control (Distilled water)	8.27
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	7.94
3.	**T_2**10% v/v Ethephon in distilled water (4ml/ tree)	6.06
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	7.94
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	8.27
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	8.10
$C.D._{0.05}$		**NS**
SEm±		**0.58**

4.4.8 Swelling index (SI)

The swelling index of gum is important property for determining the adoption of different unit operation particularly in pharmaceutical and food industries. The data related swelling index of gum collected from trees of *Acacia senegal* L. are presented in Table 4.17. The results obtained were found to be non significant. The values of swelling index ranged from 2.50 to 4.33.

Table 4.17 Swelling index of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Swelling index
1.	**T_0** Control (Distilled water)	2.50
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	3.13
3.	**T_2**10% v/v Ethephon in distilled water (4ml/ tree)	3.63
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	3.32
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	4.33
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	3.39
$C.D._{0.05}$		**NS**
SEm±		**0.38**

4.4.9 Moisture content (%)

The moisture content of gum collected from *Acacia senegal* L. was determined using hot air oven. The data related moisture content of gum of *Acacia senegal* L. are presented in Table 4.18. The moisture content of gum was found to be statistically significant because affect of collection time, available moisture in gum sample, relative humidity and temperature in air. The maximum moisture content of gum 15.10 per cent was found in T_4 (20% v/v Ethephon). The collection of gum in month of March 2024 was used for found the moisture content of gum and at time atmospheric temperature (32.14°C) and relative (37%) humidity whereas, minimum was recorded as 12.45 per cent in T_1(5% v/v Ethephon).

Table 4.18 Moisture content of gum collected from *Acacia senegal* L. trees

S.No.	Treatments	Moisture content (%)
1.	$\mathbf{T_0}$ Control (Distilled water)	13.00
2.	$\mathbf{T_1}$ 5% v/v Ethephon in distilled water (4ml/tree)	12.45
3.	$\mathbf{T_2}$10% v/v Ethephon in distilled water (4ml/ tree)	13.55
4.	$\mathbf{T_3}$15 % v/v Ethephon in distilled water (4ml/ tree)	14.00
5.	$\mathbf{T_4}$ 20 % v/v Ethephon in distilled water (4ml/tree)	15.10
6.	$\mathbf{T_5}$ 25 % v/v Ethephon in distilled water (4ml/tree)	13.00
$C.D_{0.05}$		**0.79**
SEm±		**0.27**

4.4.9 Ash content (%)

The ash content was determined by using muffle furnace. The data related to ash content of gum collected from *Acacia senegal* L. trees are presented in Table 4.19. The results obtained were found to be non significant. The values of ash content ranged from 3.40 per cent to 3.65 per cent.

Table 4.19 Ash content of gum collected from *Acacia senegal* L. trees.

S.No.	Treatments	Ash content (%)
1.	**T_0** Control (Distilled water)	3.60
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	3.65
3.	**T_2**10% v/v Ethephon in distilled water (4ml/ tree)	3.43
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	3.60
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	3.40
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	3.55
$C.D._{0.05}$		**NS**
SEm±		**0.07**

4.4.11 pH of gum

The data pertaining to pH value in gum from *Acacia senegal* L. was found to be non significant are presented in Table 4.20. The value of pH ranged from 6.58 to 6.65.

Table 4.20 pH of gum collected from *Acacia senegal* L. trees

S.No.	Treatments	pH range of gum
1.	**T_0** Control (Distilled water)	6.57
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	6.62
3.	**T_2**10% v/v Ethephon in distilled water (4ml/ tree)	6.62
4.	**T_3**15 % v/v Ethephon in distilled water (4ml/ tree)	6.65
5.	**T_4**20 % v/v Ethephon in distilled water (4ml/tree)	6.62
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	6.55
C.D. $_{0.05}$		**NS**
SEm±		**0.02**

4.4.12 Colour of gum

Colour of the *Acacia senegal* L. gum samples were matched with Munsell Soil Colour Chart for identification purpose. The data related to colour of gum of *Acacia senegal* L. are presented in Table 4.21 (Plate 13). The value of T_0 control (Distilled water) in showed the chroma value 7/8 and reddish brown colour with the hua 5YR, T_1 (5 % v/v Ethephon) in showed the chroma value 6/4 and light brown colour with the hue 7.5 YR and T_2 (10 % v/v Ethephon) show chroma value 5/8 and coloure yellowish red hue 7.4 YR. The T_3 (15 % v/v Ethephon) in showed chroma value 8/8 and yellow colour hue 7.5 YR, T_4 (20 % v/v Ethephon) in chroma value 6/8 and it is brownish yellow colour with the hue 10 YR other the T_5 (25 % v/v Ethephon) reddish yellow colour with the hue 5 YR and chroma value is 7/8.

5 YR 7/8
Reddish Yellow

7.5 YR 6/4
Light brown

7.4 YR 5/8
Yellowish red

7.5 YR 8/8
Yellow

10 YR 6/8
Brownish yellow

5 YR 7/8
Reddish Yellow

Plate 13. Colour of *Acacia senegal* L. gum matching with Munsell Soil Colour Chart.

Table 4.21 Colour of gum collected from *Acacia senegal* L. trees

S.No.	Treatments	Colour of gum
1.	$\mathbf{T_0}$ Control (Distilled water)	5 YR (7/8) Reddish Yellow
2.	$\mathbf{T_1}$ 5% v/v Ethephon in distilled water (4ml/tree)	7.5 YR 6/4 Light Brown
3.	$\mathbf{T_2}$10% v/v Ethephon in distilled water (4ml/ tree)	7.4 YR 5/8 Yellowish Red
4.	$\mathbf{T_3}$15 % v/v Ethephon in distilled water (4ml/ tree)	7.5 YR 8/8 Yellow
5.	$\mathbf{T_4}$ 20 % v/v Ethephon in distilled water (4ml/tree)	10 YR 6/8 Brownish Yellow
6.	$\mathbf{T_5}$ 25 % v/v Ethephon in distilled water (4ml/tree)	5 YR (7/8) Reddish Yellow

4.4.13 Volatile matter (%)

The volatile matter was determined by using the ash content present in the gum of *Acacia senegal* L. The data related to volatile matter of gum from *Acacia senegal* L. are presented in Table 4.22. The results obtained were found to be non significant. The values of volatile matter ranged from 43.50 per cent to 46.00 per cent.

Table 4.22 Volatile matter of gum collected from *Acacia senegal* L. trees

S.No.	Treatments	Volatile matter (%)
1.	**T_0** Control (Distilled water)	45.00
2.	**T_1** 5% v/v Ethephon in distilled water (4ml/tree)	46.00
3.	**T_2** 10% v/v Ethephon in distilled water (4ml/ tree)	43.50
4.	**T_3** 15 % v/v Ethephon in distilled water (4ml/ tree)	45.00
5.	**T_4** 20 % v/v Ethephon in distilled water (4ml/tree)	45.50
6.	**T_5** 25 % v/v Ethephon in distilled water (4ml/tree)	45.00
C.D.$_{005}$		**NS**
SEm±		**0.58**

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CHAPTER – 5
DISCUSSION

This chapter depicts the discussion of the investigation entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** in the light of scientific reasoning, logical explanations and experimental evidences observed under following headings:

5.1 To study the physical and morphological characteristics of *Acacia senegal* (L.).

5.2 To study the effect of different concentration of Ethephon on gum exudation.

5.3 To study the quality parameters on gum of *Acacia senegal* (L.).

5.1 Physical and morphological characteristics of *Acacia senegal* (L.) Willd.

The physical and morphological characteristics *viz*: tree height, collar girth and crown width (E-W) and (N-S) direction and number of primary branches, number of secondary branchesin *Acacia senegal* trees did not show any variable difference. The ethephon treatment did not deteriorated the health of the trees. This is supported by Prasad *et al.* (2018) the ethephon application to optimize gum yield from *Anogeissus pendula* without deteriorating tree health. Similar studies have been conducted by Tewari *et al.* (2017) in *Acacia senegal* and Garasiya *et al.* (2013) on *Acacia senegal* tree.

5.2 Effect of different concentration of Ethephon on gum exudation.

5.2.1 Time of treatment application

The exudation of gum depends upon different factors *viz*: temperature, humidity, and time of treatment application in trees where the temperature and relative humidity played a significant role for the process of gummosis and gum exudation.

The rate of gum exudation varied accounting to the time of application and treatment of ethephon used. The first treatment which was applied in the first week of June showed the maximum rate of gum exudation which may be due to the higher atmospheric temperature (42℃) and low relative humidity (30%) as compared to second treatment in February (with atmospheric temperature 33℃ and relative humidity 41%). Das *et al.* (2014) also supported that the gum yieldupon relative humidity and temperature. Gum production was depends tapping intensity and directly related to temperatures during tapping time and negatively correlated with low temperatures and high relative humidity. Raj *et al.* (2015) also reported similar finding while working on *Acacia nilotica* with application of different doses of ethephon. Giri *et al*. (2008) reported that the natural gummosis was prevalent in trees of *Anogeissus latifolia* mostly in summer season. Nair (2003) on *Sterculia urens* tree and also reported similar findings Kuruwanshi *et al.* (2017) on *Sterculia urens*, *Anogeissus latifolia* and *Acacia nilotica.*

5.2.2 Rate of gum exudation (g/application)

The gummosis process in gum yielding species depends entirely upon the stress condition in trees. The phenomenon of gum oozing initiates either by the external wound on the internal stress due to environmental condition. The maximum rate of gum exudation of 47.35 g during 1st application was found in T_4 (20% v/v Ethephon) whereas, the minimum was reported as 6.15 g in control. The maximum rate of gum exudation 12.47 g during 2nd application was found in T_4 (20% v/v Ethephon) whereas, the minimum was reported as 1.74 g in control. The maximum rate of gum exudation 15.07 g during 3rd application was found in T_4 (20% v/v Ethephon) whereas, the minimum was reported as 4.08 g in control. The maximum rate of gum exudation 18.20 g during 4th application was found in T_4 (20% v/v Ethephon) whereas, the minimum was reported as 5.73 g in control. Similar results were reported by Madariya *et al.* (2016) on *Acacia senegal* while using variable ethephon concentration. The gum yield (g/plant) was significantly influenced by ethephon treatments where gum yield was 177.25 g/plant while using 900 ppm ethephon. Abib *et al.* (2013) while working on *Acacia senegal* tree also reported that application of ethephon cause the effect of water stress in plant. Kanzaria *et al.* (2015) also reported increased gum exudation in *Acacia senegal* by using ethephon upto 200 per cent more over control and naturally grown trees. Raj *et al.* (2015) also reported the higher gummosis in *Acacia nilotica* when tapping was done in high temperature and low relative humidity.

5.2.3 Quantity of gum exudation (g/tree)

The maximum quantity of gum of *Acacia senegal* L. was found by the treatment with 20 % v/v Ethephon in distilled water 4ml/tree (T_4) as 93.083 g. It can be concluded that the quantity of gum increases with the increasing concentration of ethephon (from 20 to 25%). This study was also reported by Harsh *et al.* (2013) where the ethephon treatment at 9.75 per cent, 14.62 per cent and 19.5 per cent concentrations, respectively increased the gum exudation upto 780 mg/tree (19.5% solution) in *Acacia senegal* tree. Prasad *et al*. (2018) also found that the gum yield was increased significantly with the increase in concentrations of ethephon in *Anogeissus pendula* trees.

5.3 Anatomical-section of branch wood of *Acacia senegal* (L.)

5.3.1 Vessel dimensions

5.3.1.1 Vessel Length (mm) and Diameter (mm)

The value of vessel length and vessel diameter in *Acacia senegal* L. ranged from 0.172 mm to 0.184 mm and 0.136 mm to 0.150 mm respectively. Similar results were found by Owolabi *et al.* (2021) in *Acacia senegal* where average vessel length was 214.0±48.9 µm and diameter vessel was found 178.8±43.6 µm.

5.3.2 Fiber dimension

5.3.2.1 Fiber Length (mm) and Diameter (mm)

The fiber length as certain the suitability of wood for pulp and paper industries. The fiber length and diameter were found to be in range of 0.739 mm to 0.779 mm and 10.629 mm to 16.359 mm respectively. The results were found to be in conformity with Owolabi *et al.* (2021) with range of 805.6±153.5 µm and 19.8±3.7 µm respectively in *Acacia senegal* tree.

5.3.3 Ray dimension

5.3.3.1 Ray Length (mm) and Diameter (mm)

The value of ray length and diameter (mm) in *Acacia senegal* L. was found in ranged of 0.141 mm to 0.164 mm and 0.023 mm to 0.029 mm respectively. Owolabi *et al.* (2021) showed similar results in *Acacia senegal* with length of ray 309.6±66.4 µm and diameter 36.0±7.0 µm.

5.4 Quality parameters of gum

The ethephon concentration did not showed any variable change on quality parameters of gum. The moisture content of gum was found to have variation which may be due to the impact of collection time, available moisture in gum sample, relative humidity and temperature in air.

5.4.1 True density

The value of true density for *Acacia senegal* L. tree gum ranged from 1.30 to 1.39 g/cm^3. Rosland *et al.* (2020) while working on *Acacia senegal* reported the value of true density in the range of 1.48 to 1.49 g/cm^3 which is affected by the size of particles. The results were found to be in conformity with Sahu *et al.* (2019) on *Sterculia urens*, Shah *et al.* (2011) in *Moringa oleifera,* Tiwari (2021) in *Moringa oleifera* gum and Sinha (2017) on *Acacia nilotica* gum.

5.4.2 Bulk density

The values of bulk density for *Acacia senegal* gum ranged from 0.78 to 0.81 g/cm^3. Similar results were reported by Rosland *et al.* (2020) on *Acacia senegal* where the bulk density obtained was found to be slightly higher as compared to the commercial gum. Sahu *et al.* (2019) also studied value of physico-chemical properties of karaya gum (*Sterculia urens*) and found bulk density value of

0.79±0.02 g/ml. The work is also conformity with Tiwari (2021) on *Moringa oleifera* gum the mean values of bulk density for moringa gum powder granules were obtained as 0.72 and 0.73 g/cm^3. Sinha (2017) on *Acacia nilotica* tree gum reported the value of bulk density of babul gum powder 0.78±0.06 g/cm^3.

5.4.3 Tap density

The value of tap density of gum ranged from 0.85 to 0.88 g/cm^3. Rosland *et al.* (2020) also reported the tap density of *Acacia senegal* were significantly affected by the particle size. Sahu *et al.* (2019) also reported the value of tap density 0.90 g/cm^3. Similar studies have been conducted by Shah *et al.* (2011) in *Moringa oleifera* and Bhushette *et al.* (2017) in *Acacia nilotica*.

5.4.4 Porosity

The porosity of gum ranged from 6.50 per cent to 10.25 per cent. Similar results were reported by Tiwari (2021) on *Moringa oleifera* gum. Sinha (2017) on *Acacia nilotica* tree gum reported value of porosity of babul gum powder determined to be 54.82±3.55 per cent.

5.4.5 Bulkiness

The value of bulkiness in the *Acacia senegal* gum ranged from 1.23 g/cm^3 to 1.28 g/cm^3. Similar results were reported by Sinha (2017) while work on *Acacia nilotica* tree. The results were in conformity with Yadav *et al.* (2015) in *Cassia fistula* and *Sterculia urens* gum where bulkiness was found to be 1.68 ± 0.06 g/cm^3 and 1.75 ± 0.051 g/cm^3 respectively.

5.4.6 Hausner's ratio (H)

The value of hausner's ratio ranged from 1.06 to 1.11 in *Acacia senegal* gum. These results are in conformity with the findings of Rosland *et al.* (2020) on *Acacia senegal* where the hausner's ratio was significantly affected by size of particle and where in the range of 1.18 to 1.24. Bhushette *et al.* (2017) also reported the Hausner's ratio value of *Acacia senegal* to be 1.287±0.01. Similar results were reported by Yadav *et al.* (2015) and Sinha (2017).

5.4.7 Carr's compressibility index (CCI)

The value of Carr's compressibility index of gum arabic for *Acacia senegal* gum ranged from 6.06 to 8.27. These similar results are in conformity with the findings of Rosland *et al.* (2020) in *Acacia senegal* gum. Yadav *et al.* (2015) in *Cassia fistula* and *Sterculia urens* gum and Shah *et al.* (2011) in *Moringa oleifera* gum.

5.4.8 Swelling index (SI)

The observations related to the swelling index of *Acacia senegal* gum powder ranged from 3.13 to 4.33. Similar results were reported by Rosland *et al.* (2020) on *Acacia senegal* where the swelling index of the gum ranged from 1.56 to 4.00. Yadav *et al.* (2015) in *Cassia fistula* and *Sterculia urens* gum reported the swelling index in karaya gum and *Cassia fistula* gum granules to be 381.66±2.88 and 72.24±3.395. Similar results were reported by Tiwari (2021) on *Moringa oleifera* gum.

5.4.9 Moisture content (%)

The observations related to the moisture content of *Acacia senegal* gum powder. The maximum moisture content of gum 15.10 per cent was found in T_4 (20% v/v Ethephon) whereas, minimum was recorded as 12.45 per cent in T_1 (5% v/v Ethephon). Rosland *et al.* (2020) while working on *Acacia senegal* reported the moisture content in range of 11.1 to 11.7 per cent. The results were found to be conformity with Ibrahim *et al*. (2013) in *Acacia senegal* reported the moisture content of samples 11.76 per cent and 14.80 per cent. Yusuf (2011) on *Acacia senegal* gum, Tiwari (2021) on *Moringa oleifera* gum.

5.4.10 Ash content (%)

The value of ash content of gum arabic for *Acacia senegal* gum ranged from 3.40 to 3.65 per cent. The ash content shows the presence of inorganic elements existing in the form of salt. Total ash content is used to determine the acid insoluble matter, critical levels of inert matter, salt of calcium, magnesium and potassium. Rosland *et al.* (2020) on *Acacia senegal* gum also reported the ash content gum arabic range from 3.6 to 3.9 per cent. Similar results were reported by Yadav *et al.* (2015) in *Cassia fistula* and *Sterculia urens*. Bhushette *et al.* (2017) in *Acacia senegal* gum and Sinha (2017) on *Acacia nilotica* tree gum.

5.4.11 pH of gum

The value of pH of gum arabic for *Acacia senegal* gum were found to be slightly acidic gum from range 6.550 to 6.650. These similar results are in conformity with the findings of Yaumi *et al.* (2016) on *Acacia senegal* gum also reported the pH of gum arabic is slightly acidic pH range from 4.81 to 6.41. This range is in good agreement with reported pH values for gum arabic and other *Acacia* gums by several authors.

5.4.12 Colour of gum

The colour of gum due to extract by Munsell soil colour chart were found yellow to reddish yellow colour. Similar results were found by Raj (2015) in *Acacia nilotica* tree collected gum sample was orange-brown in colour.

5.4.13 Volatile matter

The data related volatile matter of gum of *Acacia senegal* were found to be in range of 43.50 to 46.00 per cent. Similar results were reported by Lelon *et al.* (2010) on *Acacia senegal* gum it can be seen that the average volatile matter of gums which range from 51 to 65 per cent.

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CHAPTER – 6
SUMMARY AND CONCLUSIONS

The present research entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** carried during June, 2023 to May, 2024 at Herbal Garden at College of Horticulture and Forestry, Jhalawar, Rajasthan. The salient findings of the study during the investigation have been summarized as below:

The physical and morphological characteristics of *Acacia senegal* L. tree *viz.,* tree height, collar girth, crown width in East-West, North-South direction, number of primary branches and number of secondary branches did not show any negative effect of application of gum inducer and were not being influenced by variable concentrations of ethephon used in the study.

The process of gummosis is entirely dependent upon the natural factors such as temperature and relative humidity, while the anthropogenic factors which cause the stress conditions in trees can affect the gum exudation. The time required for gum exudation varied from 7 to 18 days which may be contributed to the high temperature and low relative humidity. The maximum rate of gumexudation was high in the first week of June when the atmospheric temperature and relative humidity were 44℃ and 18.57 per cent respectively as compared to month of February (with atmospheric temperature 27℃ and relative humidity 55.84%).

The artificial condition to induce gummosis includes chemical and mechanical methods. Itwas evident through the research that the rate of gum exudation was significantly influenced by the application of Ethephon which causes the stress condition and further opening of gum canals in trees. The rate of gum exudation was found maximum by the application of T_4 (20% v/v Ethephon) during the Ist application of ethephon (June 2023) when compared to the lower concentration of ethephon T_1 (5% v/v) and T_0 Control (Distilled water).

The higher concentrations of ethephon (20% v/v Ethephon) has shown increased amount of gum exudation when compared to the other treatments. The quantity of gum exudation in *Acacia senegal* L. trees was reported to be in the range of 17.69 to 93.08 g.

The anatomical-section of branch wood of *Acacia senegal* L. tree showed the values for vessel length, vessel diameter, fiber length, fiber diameter, ray length and ray diameter to be 0.172 to 0.184 mm, 0.136 to 0.150 mm, 0.739 to 0.779 mm, 10.629 to 16.359, 0.141 to 0.164 mm and 0.023 to 0.029 mm respectively.

The application of different concentration of ethephon did not showed any significant change on quality parameters of gum show the value for true density, bulk density, tap density, porosity, bulkiness, Hausner's ratio, Carr's compressibility index, swelling index, ash content, volatile matter, pH of gum range and colour of gum to be 1.30 to 1.39 g/cm^3, 0.78 to 0.81 g/cm^3, 0.85 to 0.88g/cm^3, 6.50 to 10.25 per cent, 1.23 g/cm^3 to 1.28 g/cm^3, 1.06 to 1.11, 6.06 to 8.27, 3.13 to 4.33, 3.40 to 3.65 per cent, 43.50 to 46.00 per cent, 6.55 to 6.65, yellow to reddish yellow respectively. But a significant change can be seen in the moisture content of gum because of collection time, available moisture in gum sample, relative humidity and temperature in air. The maximum moisture content of gum 15.10 per cent was found in T_4 (20% v/v Ethephon) whereas, minimum was recorded as 12.45 per cent in T_1 (5% v/v Ethephon).

CONCLUSION

- This study was conducted to evaluate the ethephon concentration for gum exudation on *Acacia senegal* L. tree with five different concentrations were used for tapping purposes.
- The measured physical and morphological characters *viz*: tree height, collar girth, crown width East-West and North-South direction and number of primary and number of secondary branches of the tree were non-significant due to the trees were selected from similar age.
- The time of treatment had significantly impacted the gum exudation in tree. The maximum gum exudation was noticed in the June month due to higher temperature (44°C) and low relative humidity (18.57 %).
- The ethephon concentration had shown remarkable variation in rate of gum exudation. During Ist application (02 June 2023) the maximum rate of gum exudation of 47.35 g was found in T_4 (20% v/v Ethephon) due to the combined effect of temperature and ethephon whereas, the minimum rate of gum exudation was observed as 6.15 g in control.
- The maximum quantity of gum of *Acacia senegal* L. was found in treatment T_4 (20 % v/v Ethephon in distilled water 4ml/tree) i.e. 93.08 g due to maximum recommended concentration of ethephon above which, the gum ducts get clogged.
- It is concluded that the quantity of gum when treated with ethephon increased up to 25 per cent as compared to no treatment.

- There was non-significant effect of ethephon concentration on all quality parameters of gum except moisture content. The moisture content of gum were found to be statistically significant because of the impact of collection time, available moisture in gum sample, relative humidity and temperature in air.

Based upon the research work, it can be concluded that *Acacia senegal* L. trees can be tapped after the age of 10 years where they attain girth of 35-40 cm, the tapping of the gumdone with the help of chemical at 20 % v/v. The season most favorable for tapping was summer season where temperature was high and lower relative humidity. The commercial tapping of gum can be used in pharmaceutical as well as in print industries.

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STUDIES ON ETHEPHON CONCENTRATION FOR GUM EXUDATION ON *Acaciasenegal* (L.) WILLD. IN SOUTH-EASTERN RAJASTHAN

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Dr. Kanica Upadhyay ** — **Chairperson**

ABSTRACT

The present research entitled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** was carried out in CRD (One way classification) during June, 2023 to May, 2024 at Herbal Garden, under the Department of Forest Products and Utilization, College of Horticulture and Forestry, Jhalawar, Rajasthan. The experiment involved five different concentrations of Ethephon i.e. T_0 (Control with Distilled water), T_1 (5 % v/v Ethephon), T_2 (10 % v/v Ethephon), T_3 (15 % v/v Ethephon), T_4 (20 % v/v Ethephon), T_5 (25 % v/v Ethephon) used for gum tapping in *Acacia senegal* L. trees., as gum enhancer to induce the stress condition in the trees to induce the biopolymer exudation.

Among all the trees, physical and morphological characteristics of *Acacia senegal* L. tree did not show any effect of application of variable concentrations of ethephon used in the study. The time required for gum exudation ranged from 7 to 18 days which may be contributed to the high temperature and low relative humidity. The maximum rate of gum exudation was high in the first week of June as compared to month of February. The results revealed that application of T_4 (20% v/v Ethephon) showed maximum rate of gum exudation in June, 2023 as compared to the T_1 (5% v/v) and T_0 Control (Distilled water). The maximum quantity of gum was observed as 93.083 g in T_4 (20 % v/v Ethephon) whereas, minimum as 17.693 g in control (T_0). The higher concentrations of Ethephon (20% v/v Ethephon) showed highest amount of gum exudation as compared to other treatments. The anatomical-section of branch wood of *Acacia senegal* L. tree did not show the significant values. The data pertaining to the application of different concentration of ethephon did not showed any significant change on quality parameters of gum. But a significant change can be seen in the moisture content of gum. The maximum moisture content of gum 15.10 per cent was found in T_4 (20% v/v Ethephon) whereas, minimum (12.45 %) was recorded in T_1 (5% v/v Ethephon). Based upon the current investigation, the gum tapping in *Acacia senegal* L. can be enhanced by using considerable concentration (20%) of ethephon without deteriorating the health of the trees.

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दक्षिण - पूर्वी राजस्थान में एकेसिया सेनेगल (एल.) वाइल्ड पर गोंद निःस्त्रवण हेतु इथेफोन की सान्द्रता पर अध्ययन

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वर्तमान शोध "**दक्षिण - पूर्वी राजस्थान में एकेसिया सेनेगल (एल.) वाइल्ड पर गोंद निःस्त्रवण हेतु इथेफोन की सान्द्रता पर अध्ययन**" जून 2023 से मई 2024 के दौरान वन वानिकी महाविद्यालय, झालावाड़ राजस्थान के हर्बल गार्डन में सीआरंडी (केन्द्रीय याद्रच्दीकृत डिजाइन) में किया गया था प्रस्तुत परीक्षण में वृक्षों को बायोपॉलीमर निःस्त्रवण हुते तनाव बढ़ाने के लिए गोंद वर्धक के रूप में इथेफॉन की पाँच विभिन्न सांद्रताए टी० (आसुत जल के साथ नियंत्रण), टी, (5 प्रतिशत वी/वी इथेफोन), टी (दस प्रतिशत वी/वी इथेफोन), टी (पन्द्रह प्रतिशत वी/वी इथोफोन), टी (बीस प्रतिशत वी/वी इथेफोन), टी (पच्चीस प्रतिशत वी/वी इथेफोन) शामिल की गई। सभी पेंडो में एकेसिया सेनेगल एल. पेड़ की भौतिक और संरचनात्मक विशेषताओं में अध्ययन में उपयोग किए गए इथेफोन की विभिन्न सान्द्रमा के अनुप्रयोग का कोई प्रभाव नही दिखाया। गोंद निकलने के लिए आवश्यक समय सात से आठ दिनों तक पाया, जिसका संभावित कारण उच्च तापमान और कम सापेक्ष आर्द्रता हो सकता है। फरवरी महीने की तुलना में जन के पहले सप्ताह में गोंद निःस्त्रण से पता चला कि टी, (पाँच प्रतिशत वी/वी/इथेफोन) और टी० कट्रोल (आसुत जल) की तुलना में टी (बीस प्रतिशत वी/वी इथेफोन) के 2023 जून में अनुप्रयोग में हर अधिकतम दिखाई गोंद की अधिकतम मात्रा (93. 083ग्रा.) टी (बीस प्रतिशत वी/वी इथेफोन) मे जबकि न्यूनत मात्रा (17.693 ग्रा) टी० कट्रोल में दर्ज की गई। इथेफोन के अधिक सांद्रता (बीस प्रतिशत वी/वी इथेफोन) ने अन्य उपचारो की तुलना में अधिक गोंद निःस्त्रवण की दर प्रदर्शित की। एकेसिया सेनंगल एल. पेड़ की शाखीय काष्ठ के संरचनात्मक खंड ने सार्थक मूल्य नही दिखाए। इथेफोन की विभिन्न सांद्रता के अनुप्रयोग से संबंधित आंकडो ने गोद के गुणवत्ता मापदंडो पर महत्वपूर्ण परिवर्तन नही दिखाया। लेकिन गोंद की नमी में सार्थक बदलाव देख जा सकता है। गोंद में अधिकतम नमी की मात्रा (15.10 प्रतिशत) टी (बीस प्रतिशत वी/वी इथेफोन) में पाई गई, जबकि न्यूनतम (12.45 प्रतिशत) टी, (पाँच प्रतिशत वी/वी इथेफोन) में दर्ज की गई। वर्तमान जांच के आधार पर पेडों के स्वास्थय को खराब किए बिना इथेफोन की शथेष्ट सांद्रता (बीस प्रतिशत) का उपयोग करके एकेसिया सेनेगल (एल.) में गोद दोहन को बढाया जा सकता है।

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APPENDICES

APPENDIX-I

Analysis of variance table for tree height (m) of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.198333	0.03966667	0.34	0.88332514	Non Sig.
Error	18	2.1	0.11666667			
Total	23	2.298333				

APPENDIX-II

Analysis of variance table for collar girth (cm) of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	229.4187	45.88375	1.162305	0.35739801	Non Sig.
Error	18	710.5775	39.47653			
Total	23	939.9963				

APPENDIX-III

Analysis of variance table for crown width (E-W) of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.938333	0.187667	1.269925	0.31046377	Non Sig.
Error	18	2.66	0.147778			
Total	23	3.598333				

APPENDIX-IV

Analysis of variance table for crown width (N-S) of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	1.195	0.239	1.172207	0.35282968	Non Sig.
Error	18	3.67	0.203889			
Total	23	4.865				

APPENDIX-V

Analysis of variance table for number of primary branches of *Acacia senegal* (L.) tree

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	2.375	0.475	2.630769	0.05060374	Non Sig.
Error	18	3.25	0.180556			
Total	23	5.625				

APPENDIX-VI

Analysis of variance table for number of secondary branches of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	14.70833	2.941667	1.283636	0.30490287	Non Sig.
Error	18	41.25	2.291667			
Total	23	55.95833				

APPENDIX-VI

Analysis of variance table for 1st application (June, 2023) of ethephon for gum exudation in *Acaciasenegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	3877.772	775.5544	639.5592	7.0537E-24	Significant
Error	18	21.8275	1.212639			
Total	23	3899.6				

APPENDIX-VII

Analysis of variance table for 2nd application (March, 2024) ofeEthephon for gum exudation in *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	266.5351	53.30703	821.267	4.0581E-25	Significant
Error	18	1.168349	0.064908			
Total	23	267.7035				

APPENDIX-VIII

Analysis of variance table for 3rd application (April, 2024) of Ethephon for gum exudation in *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	278.6088	55.72175	683.0971	3.327E-24	Significant
Error	18	1.4683	0.081572			
Total	23	280.0771				

APPENDIX-IX

Analysis of variance table for 4th application (April, 2024) of Ethephon for gum exudation in *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	392.3172	78.46343	600.3627	1.4511E-23	Significant
Error	18	2.352481	0.130693			
Total	23	394.6696				

APPENDIX-X

Analysis of variance table for quantity of gum exudation (g/tree) in *Acacia senegal* (L.) tree

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	13051.19	2610.237	1689.632	1.0503E-28	Significant
Error	18	27.8074	1.544856			
Total	23	13078.99				

APPENDIX-XI

Analysis of variance table for vessel length of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.000892	0.000178	2.329489	0.07515572	Non Sig.
Error	18	0.001379	7.66E-05			
Total	23	0.002271				

APPENDIX-XII

Analysis of variance table for vessel diameter of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.000589	0.000118	2.501326	0.05992501	Non Sig
Error	18	0.000848	4.71E-05			
Total	23	0.001438				

APPENDIX-XIII

Analysis of variance table for fiber length of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.004244	0.000849	0.676926	0.64523681	Non Sig.
Error	18	0.022572	0.001254			
Total	23	0.026817				

APPENDIX-XIV

Analysis of variance table for fiber diameter of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.004244	0.000849	0.676926	0.64523681	Non Sig.
Error	18	0.022572	0.001254			
Total	23	0.026817				

APPENDIX-XV

Analysis of variance table for ray length of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.001504	0.000301	2.538732	0.05705962	Non Sig.
Error	18	0.002133	0.000119			
Total	23	0.003638				

APPENDIX-XVI

Analysis of variance table for ray diameter of branch wood of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.000178	3.55E-05	1.12781	0.37371805	Non Sig.
Error	18	0.000567	3.15E-05			
Total	23	0.000745				

APPENDIX-XVII

Analysis of variance table for true density of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.028988	0.005798	1.891346	0.13499088	Non Sig
Error	18	0.055175	0.003065			
Total	23	0.084163				

APPENDIX-XVIII

Analysis of variance table for bulk density of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.005921	0.001184	0.915789	0.48827885	Non Sig.
Error	18	0.023275	0.001293			
Total	23	0.029196				

APPENDIX-XIX

Analysis of variance table for tap density of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	1.353871	0.270774	1.660498	0.18423144	Non Sig.
Error	18	2.935225	0.163068			
Total	23	4.289096				

APPENDIX- XX

Analysis of variance table for porosity of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	30.875	6.175	0.778634	0.57522676	Non Sig.
Error	18	142.75	7.930556			
Total	23	173.625				

APPENDIX-XXI

Analysis of variance table for bulkiness of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.014529	0.002906	0.916462	0.48787635	Non Sig.
Error	18	0.057072	0.003171			
Total	23	0.071601				

APPENDIX-XXII

Analysis of variance table for hausner's ratio of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.007102	0.00142033	1.350909	0.27892702	Non Sig.
Error	18	0.018925	0.00105138			
Total	23	0.026027				

APPENDIX-XXIII

Analysis of variance table for carr's compressibility index of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	14.34162	2.868324	2.134181	0.09745701	Non Sig.
Error	18	24.19188	1.343993			
Total	23	38.5335				

APPENDIX-XXIV

Analysis of variance table for swelling index of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Singnificant
Treatment	5	7.1844	1.43688	2.506672	0.05950646	Non Sig.
Error	18	10.318	0.573222			
Total	23	17.5024				

APPENDIX-XV

Analysis of variance table for moisture content of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	17.65333	3.530667	12.3642	6.7557E-06	Significant
Error	18	5.14	0.285556			
Total	23	22.79333				

APPENDIX-XVI

Analysis of variance table for ash content of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.095	0.019	2.630769	0.05060374	Non Sig.
Error	18	0.13	0.007222			
Total	23	0.225				

APPENDIX-XVII

Analysis of variance table for pH of gum of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	0.028333	0.005667	2.04	0.1105514	Non Sig.
Error	18	0.05	0.002778			
Total	23	0.078333				

APPENDIX-XVIII

Analysis of variance table for volatile matter of *Acacia senegal* (L.) tree.

Sources of variation	Degree of freedom	Sum of square	Mean sum square	F Calculated	F tab.	Significant
Treatment	5	3810.875	762.175	1.800945	0.15246759	Non Sig.
Error	18	7617.75	423.2083			
Total	23	11428.63				

CERTIFICATE

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **"Studies on Ethephon concentration for gum exudation on *Acacia senegal* (L.) Willd. in South-Eastern Rajasthan"** submitted for the award of degree of Master of Science in (Forestry) of Department of Forest Products and Utilization, College of Horticulture and Forstry, Jhalrapatan city, Jhalawar (Raj.) is original and bonafide record of research work carried out by me under the supervision of Dr. Kanica Upadhyay, Assistant Professor, Department of Forest Products and Utilization, College of Horticulture and Forestry, Jhalawar. The content of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or University for the award of any degree or diploma.

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