STANDARDISATION OF GUM-OLEORESIN EXTRACTION TECHNIQUE IN MATTI (*Ailanthus triphysa* (Dennst.) Alston.)

by

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.) Alston.)"** is a bonafied record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or society.

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This is to certify that the project entitled, entitled **"Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.) Alston.)"** is a record of research work done independently by **Ms. Dipti Choudhury** (2016-17-008) under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of advisory committee of **Ms. Dipti Choudhury (2016-17-008)** a candidate for the degree of **Master of Science in Forestry** agree that this thesis entitled **"Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.) Alston.)"** may be submitted by **Ms. Dipti Choudhury (2016-17-008),** in partial fulfilment of the requirement for the degree.

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Finally, I bow my head before the ALMIGHTY

Dchoudhury

Dipti Choudhury

Dedicated to Sai Baba and my parents . . .

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Non-Timber Forest Products (NTFPs) play a crucial role in daily life and welfare of the people all over the world. NTFP gained global attention in recent times through its contributions to food security, income and employment for indigenous communities, enabling forest-based enterprise, potential for export market and biodiversity conservation. Most of the NTFPs are collected to support livelihood of indigenous people as supplementary foods during food scarcity and to generate additional income during off–farm seasons. NTFP species can have both consumptive and non-consumptive benefits at household level. The forest products that are edible add colour, flavour and ensures that the nutrient and dietary requirements. The rhizomes, leaves, tuber, nuts and fruits will make the diet perfect. The medicinal plants, resins, tans, dyes, oils and gums have their own significant contribution to the life of people.

Natural Gums and Resins (NGRs) are low volume and high value product that occupy a prime place among Non-wood Forest Produce (NWFP/NTFP) and are used by humankind around the world since time immemorial. It still serves as an irreplaceable unique raw material in human society. Because of their bio-compatibility, non-toxic, low cost, environment friendly processing and local availability, these are preferred over synthetic polymers in food, pharmaceutical and cosmetic industries. Its immense contribution to the economical, industrial and cultural development of the country cannot be compared with any other material. NGRs are the precious non-timber forest products in India and world having varied uses in food product and pharmaceuticals industries etc. In 1993 about US $ 10 billion of gums are used only as food additives (FAO, 2003).

India is rich in plant biodiversity having more than 15,000 plant species including about 120 gum yielding plants. Indonesia, Sudan India and China are the major producers of gums and resins (FAO, 2003). India produces annually about 2,81,000 tons of gums and resins and about 1500 tons of gum-resins.

Production of NGRs are promoted mainly in drought, poor soil, and other hostile situations. People all over world, particularly in developing countries their livelihood depends on collection of resin, gums, and latex. NGRs demand is increasing now days as the recent trend, people are giving more emphasis to natural products that are environment friendly. So, there is an urgent need to increase the gum resin yield and as well improve its quality. The only solution for this appears to be developing sustainable tapping techniques for sustainable extraction of gums and resin which will uplift the poor and maintain required forest cover or vegetation and conserve wild germplasm.

Tree based farming system are getting wider recognition in tropics on account of multitude of benefits they provide, apart from the invaluable direct benefits such as timber, firewood, fodder, food etc. Trees offer substantial indirect benefits such as soil and water conservation, nutrient cycling, climatic amelioration, site fertility improvement and eco-restoration etc. Among these trees, fast growing MPTs are of great relevance. Early returns and product diversification are the key factors that endear such trees among the farmer. Many multipurpose trees species are known for quality timber production and high Mean Annual Increament (MAI). Nowadays indirect benefits are getting much more attention than what they used to get few decades back. Among these are the ability to sequester atmospheric carbon-dioxide in the biomass and there by abating greenhouse gas emission and mitigating associated climate change. Trees, especially fast growing MPTs have high potential for carbon sequestration. In this context emission reduction strategies such as tree based CDM projects are getting wider scope in national and international sector. This has opened up renewed prospects for the expansion of tree farming as a profitable enterprise.

Ailanthus is a most suitable species for tree-based farming as this is a deciduous tree with cylindrical trunk attaining a height of about 30 meter characterized by small compact crown with deep root system. Ailanthus is thought to be less competitive with associated crops, consequently many field crops /tree crops such as ginger can be cultivated in association with Ailanthus (Kumar *et al.*, 2000). It is a prominent MPT (Multipurpose Tree Species) in traditional land use system of Kerala. Ailanthus wood is consider as best wood for match splint. It produces a viscous aromatic resin which is used for making high value incense sticks and its bark is used for many medicinal formulations by local Vaidya (local people who give herbal medicine). Ailanthus is also a fast growing tree species that can be successfully incorporated in agroforestry systems, mixed plantation, boundary plantations etc.

Anatomical properties of trees also play a major role for sustainable extraction of NGRs from different trees species, as some trees poses inbuilt special structure called "gum ducts" or "resin canal" in different alignment or direction inside the tree. In some trees it appears only after giving injuries or various kind of stresses. Anatomical studies will also help to select best extraction techniques by studying the cell types and cell arrangements.

The unscientific methods of harvesting of NGRs not only affect its resource base but also hamper the quality of the products. Due to un-sustainable tapping practices, populations of NGRs tree species are fast disappearing. Furthermore, the local collectors also carry out no grading and value addition, which adversely affects the pricing of the products. Coincidentally, the societies offer very low prices to the local people, making NGRs collection highly unremunerative. The net result is a non-availability of quality NGRs required by the industries. Thiscalls for bringing scientific methods in the extraction which are sustainable in nature means, without harming tree it will extract the product with safe and less effort compare to traditional tapping methods. It will also provide quality product which can be readily utilized by the industries, therefore it fetches good profit to farmer for their quality NGRs.

Natural Gums and Resins yielding trees are also not grown in plantation which again causing a concern for losing the wild germplasm. So in order to get continuous supply of NRGs there is urgent need for development of sustainable extraction techniques that ensure good yield as well as the production of quality gums and resins. Therefore, the present study was conducted with the following objectives:

1. To develop an appropriate technique for extraction of gum-oleoresin from *Ailanthus triphysa*.
2. To study the correlation between tree dimension with gum-oleoresin yield.
3. To study the anatomical features with gum-oleoresin production in *Ailanthus triphysa* (Dennst.) Alston.).

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The relevant literature on study entitled "Standardisation of gum-oleoresin extraction technique in matti (*Ailanthus triphysa* (Dennst.) Alston.)" have been reviewed here. However, sufficient literature is not available on the tapping techniques followed in this tree species.

2.1 *AILANTHUS TRIPHYSA* AN OVERVIEW

2.1.1. Taxonomy and distribution

Ailanthus triphysa (Dennst.) Alston. (Syn. *Ailanthus malabarica* DC. also locally called as Matti belongs to the family *simarubaceae* which is widely distributed over North Australia and Asia (Kandu and Laskar, 2010). In India it occurs mainly in natural evergreen forest of Western Ghats (PID, 1948). It is a prominent MPT (Multipurpose Tree Species) in traditional land use system of Kerala and occurs in all physiographic provenances except in high hills and it tolerates wide range of soils (Kumar *et al.,* 1994). Earlier *A. triphysa* was grown as mixed plantation along with bombax, teak, and evodia. However, since 1980, this species is being raised as pure plantations. Anon, (1991) reported that in Kerala, there are about 2500 ha of mixed plantations and 533 ha of pure plantations of *Ailanthus triphysa*,

2.1.2 Botanic description

Ailanthus triphysa (Dennst.) Alston. is a deciduous tree with cylindrical trunk attaining a height of about 30 meter and diameter of 1.2 meter and leaves pinnate, crowded at branch ends, large 45-60 cm long, leaflets 5-10 pairs, ovate, sickle-shaped, oblong and tapering from the base, 7.5-15 x2.5-5 cm thin, glabrous shining, and very oblique at the base, petioles 1 cm long. Flowers white, polygamous, pedicels short, calyx lobes minute, triangular, acute. Petals about 0.4 cm long, oblong-lanceolate, glabrous. Fruit is samara, 5-7.5 cm long, membranous and flat, reddish-brown in colour. Seed circular and compressed, bark rough and grey, inner bark, 1.3 cm thick, fibrous and yellow. Flowering in India and Nepal is between February and March, fruiting follows in April-May (Orwa *et al.*, 2009: Chandrasekar, 1996).

2.1.3 Suitability for agroforestry

Ailanthus triphysa is characterised by small compact crown. Considering the crown architecture, growth, leaf phenology and branching pattern, ailanthus could be classified into the KORIBA's architecture model (Chandrasekar, 1996). Owing to the small crown, moderate root spread and deep rooting tendency, ailanthus is thought to be less competitive with associated crops (Mattew *et al.*, 1992; Thomas *et al.*, 1998). Consequently, many field crops /tree crops such as ginger are frequently grown in association with ailanthus (Kumar *et al.*, 2000).

2.1.4 Utilization

Ailanthus triphysa species has been consider as best matchwood species as it produces a highly viscous aromatic gum-oleoresin that avert the necessity of dipping the splints in the wax (Indira, 1996). The light soft wood is utilized for making packing cases, toys, catamarans, and drums (Kumar *et al.*, 2000). Ailanthus is a popular support tree for pepper vines and is important component of silvipastoral and agrisilvicultural systems in Kerala (Kumar *et al.*, 1994; Kumar, 2001). The Oleoresin oozes out from the wounded trunk of the tree is aromatic and is called halmaddi in Kannada (Karnataka) and Mattipal in Malayalam (Kerala). Because of its fragrance, it is used in the manufacture of high value incense sticks (Nagchampa) which is used nationally as well as in other countries like USA, UK, Tibet etc. (Joshi *et al.*, 1985). Several chemicals compounds belonging to different classes such as triterpenoids, nortriterpenoids, alkaloids, quassinoids and have been previously reported from different parts of *Ailanthus malabarica* (Aono *et al.,* 1994; Hitotsuyanagi *et al*., 2001). It is claimed to be useful in bronchitis and dysentery (Dury, 1978). The bark of *Ailanthus* has anthelmintic, expectorant, febrifuge, and antispasmodic properties, it is used against bronchitis, asthma and dysentery (ANONYMOUS, 1972). Therefore, *Ailanthus* trees are often debarked by Vaidyas (local people who prepare and provide herbal medicine).

2.2 RESINS AND GUMS -AN OVERVIEW

Gums and Resins are classified mainly into four classes which are True gums, Hard resin and Oleo-resins and Gum-resins (FRI, 1972). Gums usually obtained from plants, are solids consisting of mixtures of polysaccharides (carbohydrates) which are either water-soluble or absorb water and swell up to form a gel or jelly when placed in water. They are insoluble in oils or organic solvents such as ether, alcohol and hydrocarbons, Gums exudation, usually from the stem of a tree but in a few cases from the root. Gums are also isolated from the endosperm portion of some seeds of marine algae (FAO, 1995). Commercial exploitation of Gum is restricted to members of the Combretaceae, Leguminosae, and Sterculiaceae (Nair, 2003). Approximately 1200 tons per annum of gum from *Anogeissus latifolia* is harvested in India (Giri *et al.,* 2008).

Prasad *et al.* (2015) reported that all the natural resins are of vegetable origin with the exception of lac and similar insect exudations that harden on exposure to air. They are insoluble in water but usually dissolve readily in alcohol, ether, carbon bi-sulphite and certain other solvents. Nair (2000) reported that resins are mainly obtained from members of Pinaceae (rosin, amber), Umbelliferae (asafoetida, galbanum), Leguminosae (copal), Burseraceae (elemi, frankincense, guggul), and Dipterocarpaceae (dammar).

Gum-oleoresin is a resin of a high content of volatile oil also called as soft resins. (FAO, 1995). Gum-oleoresins are mixtures of both gums and resin and combine the characterics of both groups. They also contain small amounts of essentials oils. Plants of dry arid regions, especially species of Umbelliferae and Burserceae, usually produce them. These plants are abundant in Iran and Afghanistan. Important gum-resin include asafoetida, gamboge, myrrh, galbanum, and frankincense (FRI, 1972).

2.2.1 Resin yielding trees of Kerala

Natural dammars are the important minor forest products of Kerala. In Kerala, dammars obtained from two main species viz. from *Canarium strictum* (Burseraceae) and *Vateria indica* (Dipterocarpaceae). They are locally known as black dammar and white dammar respectively. Dammars, both *Canarium strictum*, and *Vateria indica* are the most important hard resins being collected and marketed from the Kerala forests by the tribal people through tribal societies. Dammars are used mostly for the manufacture of paints, varnish and lacquers. In traditionally it is used against skin and other diseases (Vidyasagaran *et al.*, 2015).

2.2.2 Utilization of Gums and Gum-oleoresin

Natural Gums and Resins are used by people from times immemorial. It is reported that before 4500 years ago Gum Arabic has been used (Davison, 1980). Ancient inscriptions mentioned `Karni' (Gum Arabic) which had been used as painting and in textile adhesives. Gum Arabic was being used for wrapping mummies by Egyptian in 2650 B.C. About 5000 years ago, Guggal was used as medicine. In Atharva Veda therapeutic and medicinal properties of Guggul is mentioned. A detailed description of Guggul as medicine is given in the Charaka (1000 B.C), Sushruta (600 B.C), Vagbhata (17 century AD) and in India during 12th to 14th centuries in various Nighantus, the properties of Guggal are mentioned (Kumar & Shankar, 1982; Satyawati, 1991). Frankincense is being used as source of incense mention in Bible. Trade as medicine and spicy resins like galbanum, ammoniacum and asafoetida which were practiced by ancient people (Howes, 1950).

Nair (2003) reported varied uses of Natural Gums and Resins (NGRs) and its applications in industries have expanded tremendously in recent years. Some important uses of NRGs are found in paper industries, textiles industry, in petroleum industries for removing calcareous deposits as gums are used as lubricant, in pharmaceuticals industries gums are used as suspending agent, emulsification, for making tablets it acts as binder, and also used in jelly lubricants, and to mask the bad smell and taste of syrups. In Cosmetics it is used in lotions, cream for its good spreading properties which add smoothness to the skin and forms a thin protective coating. NGRs are used for production of liquid soaps, facial masks, mouth wash, protective creams, tooth paste, face powder, and hair cream,. Gum Tragacanth etc. in food industries used for thickening and gelling properties, Gums extend the shelf life of bakery products. These are also used in bevarages, dairy product, meat products. Gums are also used for making toys, air fresher gels, paints, metal cutting fluids, cleaners crayon, inks, ceramics, welding rods, and in mining, used in polymerization aide, stabilizing insecticides, polish, lithography, adhesive surface coating of wood and plastics, leather industry, and explosives. (FAO, 2003). Gum-oleoresins have been used in industry such as perfumery, incense, spices, medicine and other cosmetics, Resins are now days mainly used in paints, lacquers, varnishes, sizing paper, manufacture of soap, linoleum, ink, sealing wax, adhesives, medicines, etc. (Nair, 2003).

2.3 TRADITIONAL METHOD OF TAPPING

The traditional tapping methods are used from the ancient time for extraction of NGRs that are adopted by subsequent experience which were merely confined to quantity of resin not quality. And the ancient people are adopted many unsustainable extraction method which are destructive, unproductive, injurious and brutal to plants, often leading to their death. (Siddiqui *et al.*, 2016). Due to this, the natural germplasm of tree of the semi-arid regions of India has declined (Bhatt *et al.*, 1989). Many of the NGRs trees species comes under critically endangered, endangered, vulnerable, threatened categories. Innovations are essential for sustainable yield and quality control. (IUCN, 2017).

There are three main types of resin collection (mainly Dammars) in Kerala, each practiced within a different region. The first type involves the collection of resin formed naturally through fissures on the tree. The second type involves making incisions to promote resin flow. This method is largely employed by harvesters in the Kotagiri region of Kerala. Harvesters collect the resin that exudes from the incisions which were made with help of curved iron knives. The third type of involves a strategy i.e., setting a low fire followed by incisions and resin collection. Harvesters in Nilambur region (Kerala state) use this method. To promote the flow of resin, a low fire is lit at the base of the tree once it has been judged to be a resin-yielding tree (Anita and Tamara, 2008). The commercial tapping of *Sterculia urens* is done by blazing or peeling or by making deep cuts at the base of the tree by using an axe. These methods often lead to the death of the tapped tree (Nair, 2003).

Tenure regimes over *Canarium strictum* trees and harvest frequency varied from village to village as well. Generally, harvesters in Coonoor and Kotagiri region of Kerala, all harvester used natural fissures or incisions without fire to extract resin, collect throughout the year except during the monsoons. The Kattunaikens harvest the resin only one full year after "preparing" the trees. Whereas the Cholanaikens of Alakal harvest the resins after 3 months (Kannan, 1992; Augustine and Krishnan, 2006). Ravikumar and Ved, (2000) reported that due to un-sustainable tapping practices populations of *C. strictum* are fast disappearing, and this tree is considered to be vulnerable in southern India

For extracting resin from *Pinus roxburgii* in Himachal Pradesh, French and Lip method was used during the ancient times, later on it was replaced by rill method by the Britishers (Sharma and Dutt, 2016)

In karaya (*Sterculia urens*), the gum is collected by tapping by removal of sections of bark from the trunk of the tree. Guidance rules have been laid down by the Forest Research Institute, Dehra Dun, in India, but in practice the rules are not adhered to and the dimensions of the "blaze" are often exceeded. Tapping which involves deep and wide wounds to the tree to maximize gum yields is damaging to tree (FAO, 1995).

Torquebiau (1984) gives a good description of tapping practised on *S. javanica* in Sumatra. Traditional methods of tapping trees involve removal of wood from the stem in order to obtain dammar (whether wild or cultivated trees). Cuts made into the trunk have a triangular form but become circular with age and are arranged in vertical rows around the trunk. When the trees attend approximately 25cm in diameter (about 20 years old) first cut is made which is several centimetres wide at first and becomes enlarged at every tapping and eventually becomes a hole of 15-20 cm in depth and width. The average number of holes for a tree about 30 m high and 60-80 cm diameter is 9-11 in each of 4-5 vertical rows. For the higher holes, the tapper climbs the tree supported by a rattan belt and using the lower holes as footholds.

2.4 IMPROVED TAPPING TECHINQUE AND GUM YIELD

The first systematic study on improvement of resin tapping was done during World War II because of the urgent need of oleoresin. By using improved methods in tapping technique with the help of ''Mitchie Golledge'' knife can enhance production over that obtained from control and rapid wound healing (Bhatt *et al.*, 1989; Bhatt and Ram, 1990). By using these improved methods in tapping of the gum/gum resins, sustained yield, regeneration and survival of the tapped trees were observed by several authors (Bhatt *et al.*, 1989). Kathe *et al.* (2010) also reported that a new "rill method" for obtaining *Ailanthus triphysa* resin involving specially designed tools to increase resin production. This method was highly successful and resulted in sustainably produced resin of exceptional quality in Karnataka which gives more quantity from traditional method of tapping.

Kuruwanshi (2017) experimented four mechanical method of tapping (March to May 2016) i.e., T1-Control, T2-Blazes equally spaced with axe, T3-Semiarch method and T4 -Die method. For standardising a method of tapping in *Sterculia urens, Anogesssius latifolia* and he found out Die method was significantly different from other tapping method. As it produces 110.60 gm of gum whereas the controlled yield was 29.38 gm in *Sterculia urens*. In *Anogessius latifolia*. again the die method was proved to be best as it produced 90.32 gm whereas only 28.82 gm in controlled. Nair (2003) reported that artificial incisions are made in the tree trunk and the bark is slashed in Gum karaya (*Sterculia urens*). The debarked area is freshened at the regular interval of 5-6 days. However, the quantity of gum increases when the holes made in the tree trunk is treated with ethephon. It can be ten times higher than the gum tapped by using traditional method.

Ghritlahare (2017) also had a similar kind of studied for four experimental trees i.e. Dhawara (*Anogeissus latifolia),* Rohina (*Soymida febrifuga),* Saja (*Terminalia tomentosa)* and Chirounji *(Buchanania lanzan*) in two season winter and summer. The three mechanical T1 (traditional, single cut with axe), T2 (double cut with axe), and T3, semicircle/arc (12 cm Length x 6 cm width x 4 cm deep) where applied at 1m DBH to gum tapping. He found out that semi arc method of mechanical tapping is best for all the four tree species especially for Saja (*Terminalia tomentosa* Roxb.) because comparing to chemical treatment tapping method, the mechanical method (semi arc) was found to be best for high production of gum and also found out that the minimum time is required for exudation of biopolymers in Rohina (*Soymida febrifuga* Roxb.) and Chirounji (*Buchanania lanzan* Spreng.) in all mechanical treatments as compare to chemical method.

Africans countries (Sudan) utilizes a specially designed tool, a "sunki" as modern method of tapping in *Acacia senegal*. The "sunki" has a metal head fixed to a long wooden handle. The pointed end of the head is pushed tangentially into the stem or branch so as to penetrate just below the bark, and then pulled up so as to strip a small length of bark longitudinally from the wood. Damage to the wood should be minimal. At once several branches are treated in a similar manner in order to more quantity of gum. On coming years, other branches or the reverse side of the previously treated branch are tapped. About 250 g of gum per tree per season is often cited as an average yield is obtained (FAO, 1995).

Vidyasagaran *et al*. (2016) studied different methods of resin extraction in *Canarium strictum* and found that strip cut method to be more efficient in resin extraction. As in this method, a small portion of bark was removed from Canarium tree and half blown polythene cover was fixed underneath the cut. So that the resin oozes through the strip and was flown to polythene cover directly with minimum injury to the wood. In this method of extraction, it is observed that almost 90 % of the resin was classified as first grade.

Sharma and Dutt (2016) reported that "Bore Hole Method", a new method has been experimented and standardized in Chirpine (*Pinus roxburgii*). This new method involves drilling holes into the wood to open the maximum number of resin ducts. The advantages of this technique over conventional methods include higher labour productivity, improved product quality and reduced tree stress.

An advanced improved method (mechanical assisted by chemical treatment) are being used now-days for extracting natural gum-resin to increase the production of NGRs which is adopted for commercial production. An improved tapping method and application of ethephon yielded about 466-fold increase of gum in Haldu (*Anogeissus latifolia)* (Bhatt, 1987). Use of plant regulator like ethephon, has increased exudation of gum/gum resin in certain plants such as *Mangifera indica*, *Acacia. senegal*, *Commiphora wightii,* and *Sterculia urens.* (Bhatt *et al.*, 1989; Bhatt and Ram, 1990). An improved tapping method for *Commiphora wightii* in which ethephon (2-chloroethylphosphonic acid) was applied to the tree 48 hours before tapping. It is noted that the yield of resin was higher as compared to only tapping without chemical treatment (Bhatt *et al.*, 1987).

Similar trial was done by Tewari *et al*. (2014) in *Acacia senegal* and *Acacia tortilis* which yield less amount that is 15-25gm/tree in traditional tapping techniques which when treated with "CAZRI gum inducer" resulting in production of 350-650g/tree. In addition to that they experimented with CAZRI gum inducer + irrigation + manuring which resulted in more production of gums. And reported that 30 tree/ha on such unproductive land (rocky site) can produce 5-6 kg gum/ha, which can provide an additional income of Rs. 3500-4200/- to the farmers.

Bhatt and Ram, (1990) studied the six Gum Arabic *(Acacia senegal)* trees growing on the Chambal ravines, near Barhi, Madhya Pradesh. Five trees were treated with ethephon by introducing 4 ml solution (containing 480, 720 and 960mg active ingredient) through a hole of 5 cm deep and 2.5 cm wide, slanting downwards and made using a hammer and chisel at 1.0-1.5 m above ground, in April/May. Control trees (holes bored but no Ethephon added) produced little or no gum and the most gum exudation (806-950 g/tree) obtained in the 960 mg treatment. Exudation started 4-8 days after treatment and also stated that safe technique of tapping with substantial increase in the yield of gum/gum resin is required to be developed for conservation of the fast depleting gum yielding forestry species.

Vashishth (2017) studied to standardise a tapping techniques for gum extraction in *Lannea coromendelica*. The study was conducted on tree having DBH >40 cm from natural stand where he had taken tapping methods, chemical concentrations on tree for observation. He took two methods 1) bore hole tapping method, 2) V-Shaped method and he found out that the maximum gum production was obtained in bore hole tapping method and minimum was procured from V-shaped tapping method. Ethephon has proved better extraction chemical over the sulphuric acid. Ethephon concentration of 300mg/ml showed the highest gum production of 144.2 grams/tree. However, lower concentration of sulphuric acid did not show significant results.

2.5 GUM YIELD AND DIMENSIONAL PROPERTIES OF TREES.

Sharma and Prasad (2013) studied nine trees of Gum karaya *(Sterculia urens)* in which three were used for gum tapping through semi-circular blazing and remaining six trees tapped through gum inducer technique. After one month, each blaze and hole made on the trees were again treated following same technique/method for gum collection. Treatment was done eleven times at an interval of one month during the period of experiment. They observed that higher diameter tree more than 1m yielded more gum in both the techniques of gum tapping. However, more gum production found in gum inducer technique (about 200 %) as compared to semi-circular blazing technique of gum tapping

Unanaonwi and Bada (2013) did Similar studied where they investigated the effects of height and girth on gum yield of gum arabic (*Acacia senegal)* in the natural forests. Three heights and girth classes were purposely selected and results showed that when total tree height was lower than 2.0 m, gum yield increased as tree girth goes higher from 35-54 cm (163.6-209.7 g). Tree girth significantly affected gum yield ($p<=0.05$) and trees in which total heights were lower than 2.0 m (maximum of 1.95 m) and girth higher than 54 cm (maximum of 65 cm) produced the highest mean gum yield.

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

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

Vidyasagran *et al*. (2016) studied four girth classes i.e., less than 50, 51-100,101-150 and greater than 150 in *Canarium strictum* and *Vateria indica.* And they found out a complementary relationtionship between the tree girth class and resin production, means higher the girth class higher the resin production. Sharma and his co-workers (2016) conducted an experiment to know the effect of diameter and borehole height on oleoresin yield, and found out that diameter is directly proportional to oleoresin yield that 452.81gm is the highest amount obtained from D5 (>55) which is the largest diameter among all. They also found out that oleo resin yield is indirectly proportional to borehole height as the highest amount obtained from lowest borehole height.

Patel and his co-worker in 2016 reported that chemical method is producing more gums resins in certain trees. In *Sterculia urens* (Karaya) the drilling method for application of ethephon was found better as compared to ARC method for gum exudation. In *Acacia nilotica* chemical treatment is found better than mechanical methods of gum extraction and they also stated that tree girths play very important role in gum exudation as well as temperature and relative humidity also play a significant role for the process of gummosis.

2.6 GUM YIELD AND SEASONAL INFLUENCE

Vashishth (2017) conducted experiment for gum extraction in *Lannea coromendelica* from natural stand where he studied the influence of different tapping season and found out that tapping season is also significantly affect the gum production, the highest gum production of 66.94 gram/tree was obtained in April –June tapping season that is summer season.

Kuruwanshi (2017) experimented four mechanical method of tapping (March to June) for two subsequent year (2015 and 2016) with various treatments i.e., T1 Control, T2- #blazes equally spaced with axe, T3- Semiarch method and T4 -Die method for standardising a method of tapping in *Sterculia urens, Anogesssius latifolia* and he found out that temperatures, relative humidity plays a major role in gum exudation as he observe that in the months of May exudates high from other months, same observation was found in two different year as well as two different tree species. This result was supported by Das *et al*. (2014) that in general, peak gum production is apparently stimulated by the onset of drought conditions when the rainy season ended and air temperature rise. Kramer and Kozlowski (1979) reported that the energy demanding process like bud growth/shoot development and flowering/fruiting occur during June-July and September-January respectively, the only period during which the reserve metabolities are understandly high in wood parenchyma is April-May.

2.7 GUMS YIELD AND OTHER PARAMETERS

The gum yield was positively correlated rainfall, minimum and maximum temperatures at tapping time, tapping intensity, and negatively correlated with and minimum and maximum temperatures, and tapping time at gum collection (Ballal *et al.,* 2005a). Raddad and Luukkanen (2006) found out a positive relationship between rainfall and gum yield in the season preceding tapping and also between soil water content and gum yield.

Giri *et al.* (2008) stated that the trees of Dhawada *(Anogeissus latifolia)* for tapping gums, which naturally ooze out mostly in summers. However, to increase the yield of gum sometimes people make incision in the tree bark. It is mainly harvested in March to mid-June.

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

2.8 GUMMOSIS AND TIME OF EXUDATION IN GUM YIELDING TREES

Esau (1965) reported that the production of gums in plants is not well understood, these substances often accumulated in response to injury, stress, or fungal, bacterial, or insect attack on the plant. In broad range of tree species formation of complex, variable gums occurs due to degeneration of cells. The gummosis process results in the depletion of starch in cells and in many cases appears to involve breakdown of cell walls. Gums are usually associated with xylem cells and special structures called gum ducts. The formation of ducts in the secondary xylem or wood in response to injury or induced exudation is associated with the development of traumatic gum cavities which exude gum profusely and called as 'traumatic' ducts (Purkayastha *et al.,* 1959; Ghosh and Purkayastha, 1959).

Dadswell and Hillis (1962) reported that the gum canals or cavities as well as resin pockets developed in the hard woods are generally the result of damage to the cambium by the mechanical disturbances like abrasion, insect, fire etc. cell walls are transformed in to gum may be cells of mature xylem or of cells in specialized parenchyma groups which differentiate in the cambium and later disintegrate and form the gum and duct lumen (Vander Molen *et al.,* 1977).

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

2.9 ANATOMY AND NGRS PRODUCTION

Each anatomical trait, or combination of traits, plays a role in favouring one or more xylem functions, namely water transport, mechanical stability, biological defence, and storage and mobilisation of metabolites (Beeckman, 2016). Resin is produced in two types of resin canals, which are distributed in the tree stem. The large longitudinal ducts distributed irregularly in the middle and outer portion of tree stem and the smaller horizontal canals are restricted to the outer part of the stem bark. These canals are formed by secondary division of growth cells (cambium) and are lined with a thin layered wall of secretary epithelium enclosing a central hollow portion. The canals are interconnected to form a continuous network of resiniferous canals in the tree stem. Consequently, when one of these canals is cut at the stem surface, the resin flows to the openings from the inner portions of the stem (Bhojvaid and Chaudhari, 2004).

De micco *et al*. (2016) reported that gums are also found in vessel through vessel occlusion which is natural phenomena occurring with aging and heartwood formation and in sapwood it formed in response to vessel embolism. These types of vessel occlusion play a crucial role to limit the spread of pathogens and wood decay organisms, also as part of compartmentalization after wounding. In the sapwood, they can be considered to be an effective stress response. Gerry (1914); Klein (1923); Murmanis (1975) is reported that vessel occlusion can be due to the formation of tyloses or to the deposition of gums. Although a common feature of heartwood, these organic occlusions can also occur in sapwood both normally and after wounding.

According to the "IAWA list for microscopic features for hardwood identification" deposits in vessels include "tyloses common", "tyloses sclerotic" and "gums and other deposits in heartwood" (IAWA Committee, 1989). Tyloses themselves can contain a wide variety of organic and mineral compounds, including gums, resins, starch, crystals and phenolic compound. Winckler, (1854) observed peculiar structures in vessels that she confidently described as outgrowths of neighbouring wood parenchyma cells passing through the pits, since they always originated close to a region of the vessel wall adjacent to axial or radial parenchyma cells and never in regions where two vessels were in contact. Arising mostly from ray cells and to a much lesser extent from axial paratracheal parenchyma cells, tyloses expand into the adjacent vessel through pits (Pearce, 1996; Sun *et al.*, 2008).

Braun (1967) has coined the term "contact cells", synonymous with the "vessel-associated cells" of Czaninski (1977) to indicate parenchyma cells that have the potential to form tyloses or secrete gums into vessels (Catesson &

Moreau, 1985; Morris & Jansen 2016). Tyloses are most commonly found in pitted vessels of metaxylem and secondary xylem, and more rarely in protoxylem elements with annular or spiral secondary walls (Zimmermann, 1979).

During the formation of a tyloses, the primary wall component of the pit membrane is not merely stretched and pushed into the vessel, but new wall materials, including cellulose, hemicellulose, pectins, suberin and lignin, are actively deposited (Foster, 1967; Pearce & Holloway, 1984; Barnett *et al.*, 1993).

2.10 GUMS IN VESSEL WITH OR WITHOUT TYLOSES

"Gum" and "Gel" have been used to indicate materials occluding vessels, mainly composed of pectins and polysaccharides (Koran and Yang, 1972; Rioux *et al.*, 1998). Gums have been reported to form where gels were firstly formed after pathogen-released pectinolytic and cellulolytic enzymes have attacked walls of cells surrounding vessels (Agrios, 1969). There is a dichotomy between the anatomical and physiological literature: since gels easily dissolve, they are not normally recorded in anatomical descriptions. Solidified gum deposits (responsible for heartwood colours, and discoloration of wounded wood) may well have had unreported gels as their precursors.

Gums have been described as amorphous material occluding vascular tissues or intercellular spaces (Catesson and Moreau, 1985). Hillis (1987) reported that many secondary metabolites stored in vessel are referred as gum although they are not water-soluble compounds as gums are by definition.

Bonsen and Kučera (1990) reported like tyloses, gums occluding vessels derive from contact parenchyma cells. Chattaway (1949) said that gums in vessels can be either produced by the secretory activity of surrounding living cells (mainly ray cells) and deposited directly into the adjacent vessel lumen or, more rarely, can be secreted by a previously formed tylosis. Individual tyloses may also be filled with gums.

The occlusion of vessels by gums is different from the secretion of gums in ducts. The gums causing vessel occlusion have a different chemical composition from those produced in ducts, which may also contain components originating from the lysis of cells located near the gum canal lumen or from cell-wall decomposition (Groom, 1926; Rioux *et al.,* 1995; Evert, 2006).

Based on these considerations, distinguishing between the true gums, mainly made of pectic material occluding vessels, and gums secreted in gum ducts, Rioux *et al.* (1998) proposed using only the term 'gel' to indicate the pectin occlusions secreted by parenchyma cells into conduits. Like tyloses, gums have been reported by many authors as occurring in both heartwood and sapwood, either due to natural aging or to factors triggering embolism.

MATERIAL AND METHODS

MATERIAL AND METHODS

The present study entitled "Standardisation of gum-oleoresin extraction technique in matti (*Ailanthus triphysa* (Dennst.) Alston)" was carried out at Instructional Farm, College of Forestry, Vellanikkara during the year 2017-2018. The main objective of the study was to asses the influence of different girth classes and different tapping methods in gum-oleoresin production from *Ailanthus triphysa* tree. The study also explored the anatomical studies of sapwood, meristem and bark of Ailanthus tree for proper understanding the process of gummosis. The study also explored the effect of different climatic parameters in gum-oleoresin production.

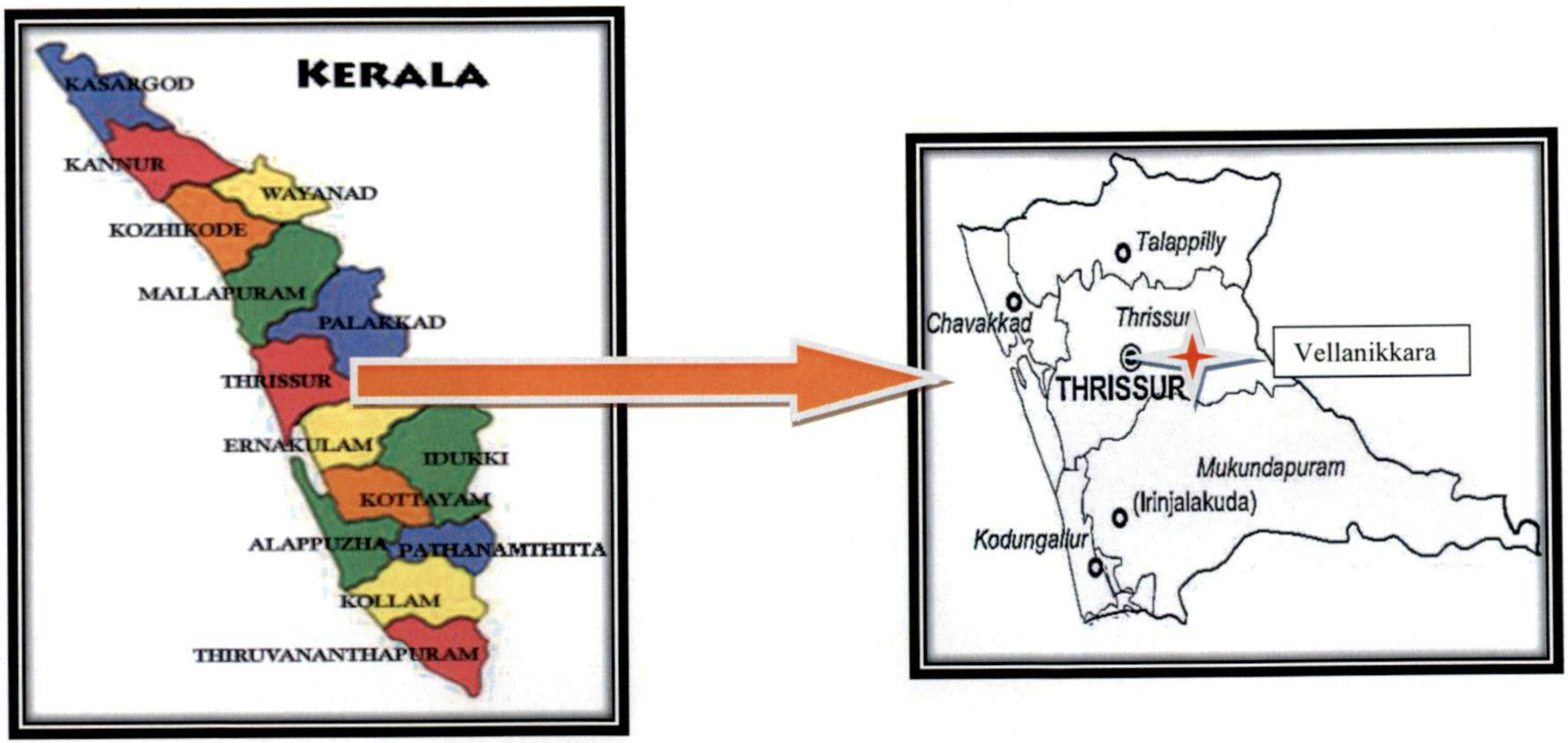
3.1 LOCATION

The present study was conducted in a 25-years-old *Ailanthus triphysa* (Dennst.) Alston. *s*tand in experimental site located at Instructional Farm, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala at 10° 32' N latitude and 76° 10' E longitude, and 22.5 m above mean sea level. The study was conducted for a period of one year (May 2017 to April 2018).

3.2 CLIMATE AND SOIL

Vellanikkara experiences a warm humid climate, the area is benefited by both i.e. South-West and North-East monsoons, with a greater share from South-West monsoon (June to August). The annual rainfall of 2387.7 mm whereas the mean minimum temperature ranged from 21.1°C to 24.9 °C. The mean maximum temperature varied from 30.1 °C to 36.7 °C. The soil of experimental site was deep well drained sandy clay loam of ultisol (Typic-Plinthustult-Vellanikkara series midland laterite-ustic moisture regimes (dry period February to May) and iso-hyperthermic temperature regimes) having pH of 5.5.

Plate. 1 Map showing the location of study area.



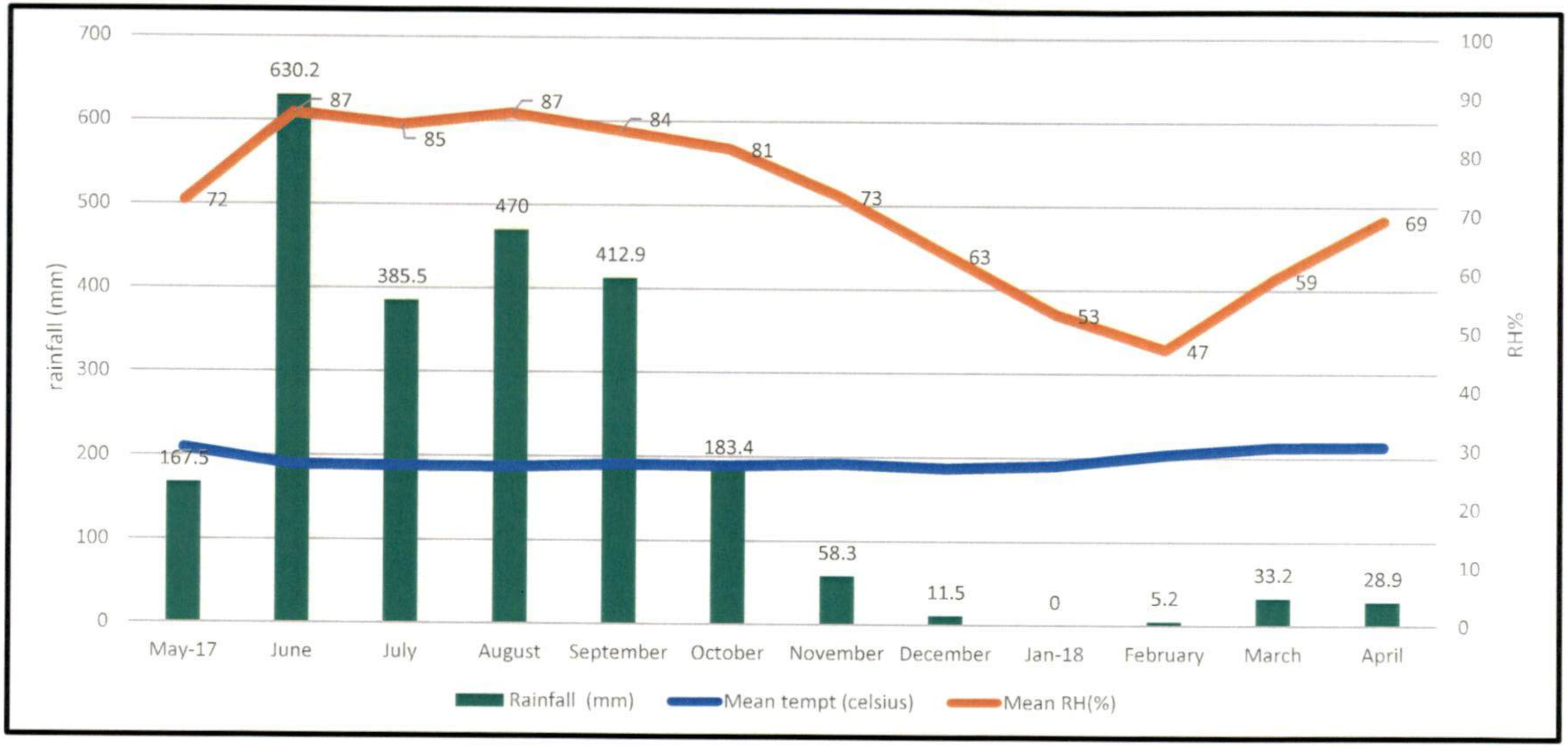


Fig 1. Meteorological data (May 2017 -June 2018) collected from Department of Meteorology, College of Horticulture, Kerala Agricultural University, Vellanikkara.

42

Plate 2. 25 years old *Ailanthus triphysa* plantation located in Instructional Farm, College of Forestry.

3.3 MATERIALS

3.3.1. *Ailanthus triphysa*

Ailanthus triphysa is also popularly known as Matti is a multipurpose tree species. It is a deciduous tree with cylindrical trunk with moderate root spread and deep rooting tendency. It is fast growing tree species with compact crown which make its suitable for intercropping in different agroforestry model. Its wood is used for making match splint, bark is used as for medicinal purposes, it produces a viscous aromatic resin which used to make high value incense stick of export quality.

3.3.2 Accessories for tapping

3.3.2.1 Cup

Cup is made up of plastic having 1000 ml capacity for holding the gum-oleoresin. Black colour cups were used for collection.

3.3.2.2 Cup holder

Cup holder are made up of aluminium metal in a specified arrangement, readily available in market. Its plays a major role in extraction of quality gum-oleoresin.

3.3.2.3 Tin-lip

It is a metal strip having length of 10 cm and width of 4 cm with triangle shape through which the gum-oleoresin flows down from the tree trunk to collection cup. It was attached to the end of the tapping cut. It avoids spreading of gum-oleoresin on tree trunk thereby provides resins without much impurities.

3.3.2.4 Rope

Rope that was used during the study period was plastic rope which support the cup holder in proper place for long time in same position.

3.3.2.5 Tapping knife

It is made of iron with a wooden handle of 35" length in which the wooden handle is with 15cm and the iron part is having 20 cm. It is designed in such a way to make a proper cut on the trunk for extracting resins.

3.3.2.6 Haglof bark gauge

It is an instrument for measuring bark thickness made in Sweden. Gauge is aluminium with steel recessed tip with a durable plastic end knob and has a graduation in millimetre or inch. The bark gauge having a shaft with a sharp point which is pushed through the bark until the underlying wood is felt. The sleeve around the shaft is shifted to surface and thickness of bark sample can be read from the calibrated shaft.

3.3.2.7 Sliding Microtome

It is an instrument to take anatomical section of wood. In this instrument the specimen being sectioned is made to slide on a track.

3.3.2.8 Rotary microtome

This instrument is also used foe making anatomical section, mostly used for soft tissue. In this instrument wheel action is translated into a back and froth movement of specimen being sectioned.

3.4 METHODS

A preliminary survey was done in Ernakulum district of Kerala for knowing the traditional tapping technique adopted by farmers for the extraction of gum-oleoresin from Ailanthus trees. The field experiment was conducted on 25 years old *Ailanthus triphysa* sample trees based on different girth classes viz., less than 75 cm, 75-150 cm and greater than 150 cm for studying the yield based on three different tapping methods viz., V-Shaped method, Cup and Lip method and Straight-Cut method and three replications was done for each girth class and tapping methods. So, a total of twenty-seven trees were selected for conducting the field experiment.

3.4.1 Design and Layout of the experiment

Design : Factorial Randomised block design (FRBD).

Treatments : 9

Replication : 3

3.4.2 Treatment details (Gum-oleoresin tapping)

Trees with different dimension were divided into three girth classes i.e., < 75 cm, 75-150 cm and > 150 cm. For standardising extraction technique, three tapping methods were selected and for each tapping method, three replication were taken from three different girth classes. In total twenty seven trees were selected for field level observations. Tapping was done on every alternate day. The various tapping techniques followed are listed below

3.4.2.1 V- Shaped cut method

A V- shaped diagonal cut was made on both the side of the bark with each side cutting length of 15 to 25 cm depending on the girth class and a chill or metal strip was fitted to the end of the cut and with a help of a rope and cup holder, the collecting vessel or cup was placed above the holder right below the chill for easy collection. The width of cut is also expanded after each cut (Plate 4 (a)).

3.4.2.2 Cup and Lip method

In this method, a slanting cut of 40-50 cm was made on the bark depending upon the girth class which includes the removal of bark nearly on horizontal plane and injuring the sapwood. Then a chill is fitted to the end of the cut and collecting vessel was placed right below the chill for easy collection with a help of cup holder and a rope (Plate 4 (b)).

3.4.2.3 Straight-Cut method

In straight cut method, a vertical cut is made on the bark of the tree at a length of 40-50 cm in height which includes removing of bark and injuring the sapwood with a help of a specialized knife and a small collecting vessel is fitted at the bottom of the cut. The width of the cut was nearly one cm initially, but it is widened after every cutting because next cut is followed by removing a layer of bark and injuring the sapwood adjacent to the previous cut (Plate 4 (c)).

Fig 2. Flow chart of extraction of gum-oleoresin from *Ailanthus triphysa.*

Survey for trees of all girth class

↓

Measurement

↓

Marking of tree

↓

Tapping or cutting methods applied

↓

Fixing of cups and chilled

↓

Tapping every alternate Day

↓

Monthly collection of gum-oleoresin for statistical analysis collection done for 12 months.

48

Plate 3 (a)

Plate 3 (b)

Plate 3(c)

Plate 3 (d)

Plate 3. Acessories material require for the experiment. (a) cup + cup holder + rope. (b) Designed knife for extraction gum-oleoresin. (c) Sliding microtome (d) Haglof bark gauge.

49

Plate 4 (a)

Plate 4 (b)

Plate 4 (c)

Plate 4. Initial cut of different extraction techniques (a) V-Shaped (b) Cup and Lip Method (c) Straight- Cut.

Plate 5. Systematic representation of Field work

3.5. ANATOMY

3.5.1 Wood anatomical properties

Wood anatomical properties were studied with the help of a sliding wood microtome (Leica SM 2000R). Anatomical features were studied mainly to know the effect of cellular structure on gum-oleoresin production on three different tapping methods.

3.5.1.1 Sapwood anatomy

Sapwood core samples of size 2 cm^3 was taken out from each tree by using a Haglöf Increment Borer. The specimens were then softened by keeping in water bath (Rotex water bath) at 100 ^{0}C for 2 hrs. Transverse sections (TS) and longitudinal sections (TLS) and radial sections of size 10-15 μm thickness were prepared using the wood microtome The sections were stained using safranin and later washed through a series of alcohol solutions at different concentrations (70 %, 90 % and 95 %) to ensure complete dehydration. They were subsequently dipped in acetone followed by xylene and finally mounted in DPX mountant to prepare permanent slides (Johansen, 1940).

3.5.1.2 Bark anatomy

Bark and meristem samples of size of 2×2 cm were taken out from trees of different girth class with the help of a chisel and hammer for studying the anatomical properties. The specimens were then kept in FAA (Formal Acetic Acid Alcohol) solution for 24 hour for killing and fixing. Then the samples were aspirated in an aspirator (samples kept in small beaker with FAA and suction given, bubbles are seen coming and when they stop coming it marks the end of aspiration) and kept in FAA solution for 24 hours. Then the samples were dehydrated for 1 hour in each alcohol series (30%,50%, 70%, 90%,100%) of ethyl alcohol. Then infiltration of paraffin was done manually (3 hours) for each series at 60° C in different ratios as given below

a. TBA (Tertiary butyl alcohol)
b. TBA : Wax (3:1)
c. TBA : Wax (1:1)
d. TBA : Wax (1:3)
e. Pure paraffin wax (400 ml)

After cooling, the specimen wax embedded with the help of a wax embedding machine. Then sectioning was done with the help of a rotary microtome (Leica SM 2125 RT). Subsequently, the sections were kept in xylene for removing extra wax then passed through into safranin for 2-3 min. Later passed through alcohol series, followed by drying for 2-3 hours and then put in xylene and finally mounted in DPX for making permanent slide.

3.5.1.3. Image Analysis

Microscopic examination and quantification of sections was undertaken using an Image Analyzer (Labomed Digi Pro). It consists of a microscope (Leica DM 750), Personal computer, Software (Lasez). The image analyzer provides quick and accurate data replacing the more laborious traditional methods.

Fig 3. Flow chart for preparing sapwood anatomy section

Collection of core sapwood sample by help of increment borer

↓

Section taken from sliding microtome

↓

Section was put in Saffranin (2drops+water)

↓

70% alcohol (2-4 min)

90% alcohol (2 min)

95%alcohol (2min)

Acetone (20 min)

↓

Drying (1.5-2.5 hour) in room temperature

↓

Xylene (2 hour)

↓

Section was DPX mounted

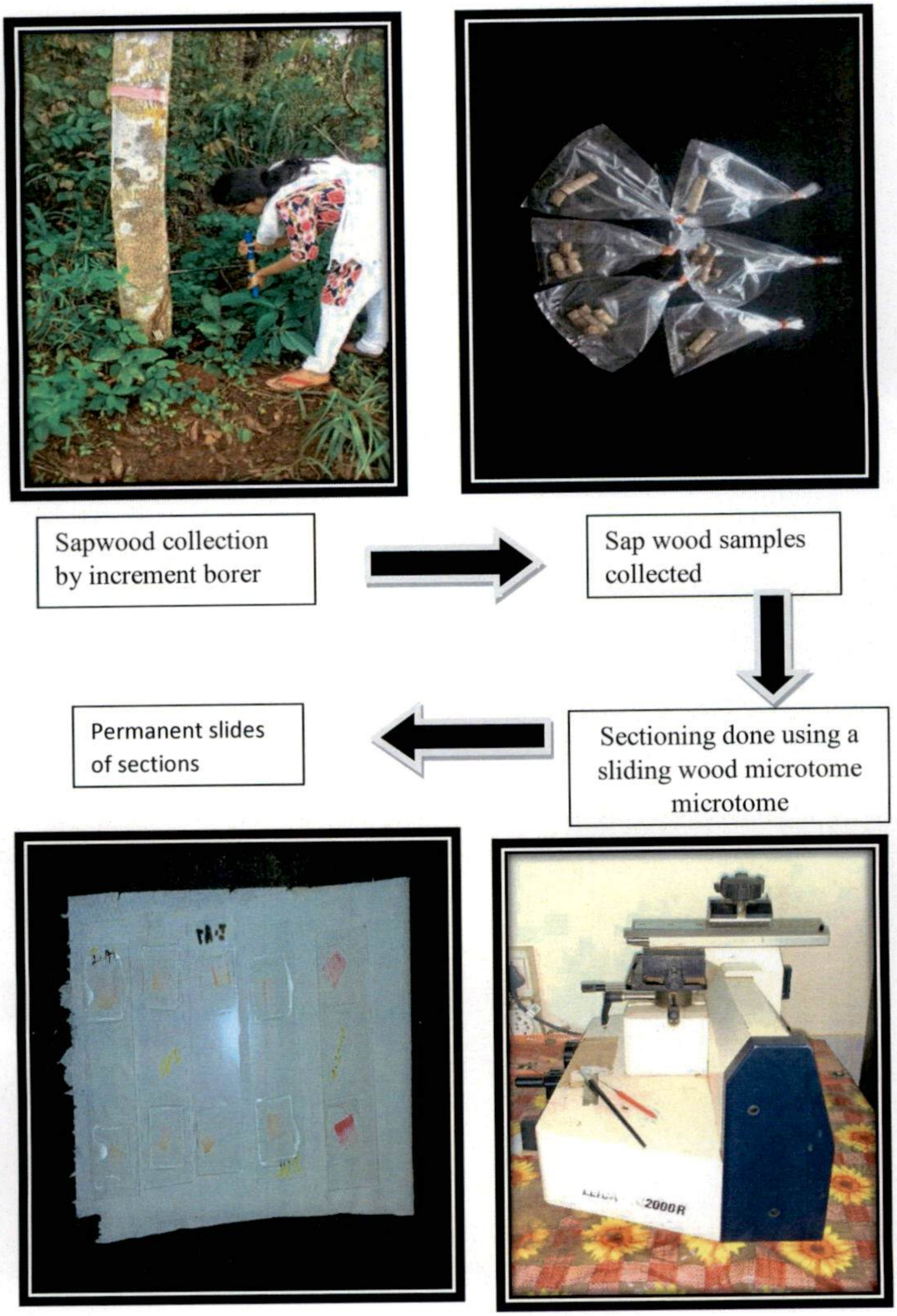


Plate 6. Procedure for preparing anatomical sections of sapwood.

Fig 4. Flow chart for preparing bark anatomy

Sample collection

↓

Kept in FAA solution for (24 hours)

↓

Kept in each alcohol series (50%, 70%, 90%, 95%, 100%) for 1 hour

↓

Wax infiltration in 60 ^{0}C

↓

Wax embedding

↓

Cooling and Sectioning in rotary microtome

↓

Section are put in xylene to remove extra wax

↓

Section was put in Safranin (2drops+water)

↓

Alcohol series and acetone (20min)

↓

Drying (1.5-2.5 hour) in room temperature

↓

Xylene (2 hour) after drying, Section was DPX mounted

↓

Kept for drying (Permanent slides are ready for analysing

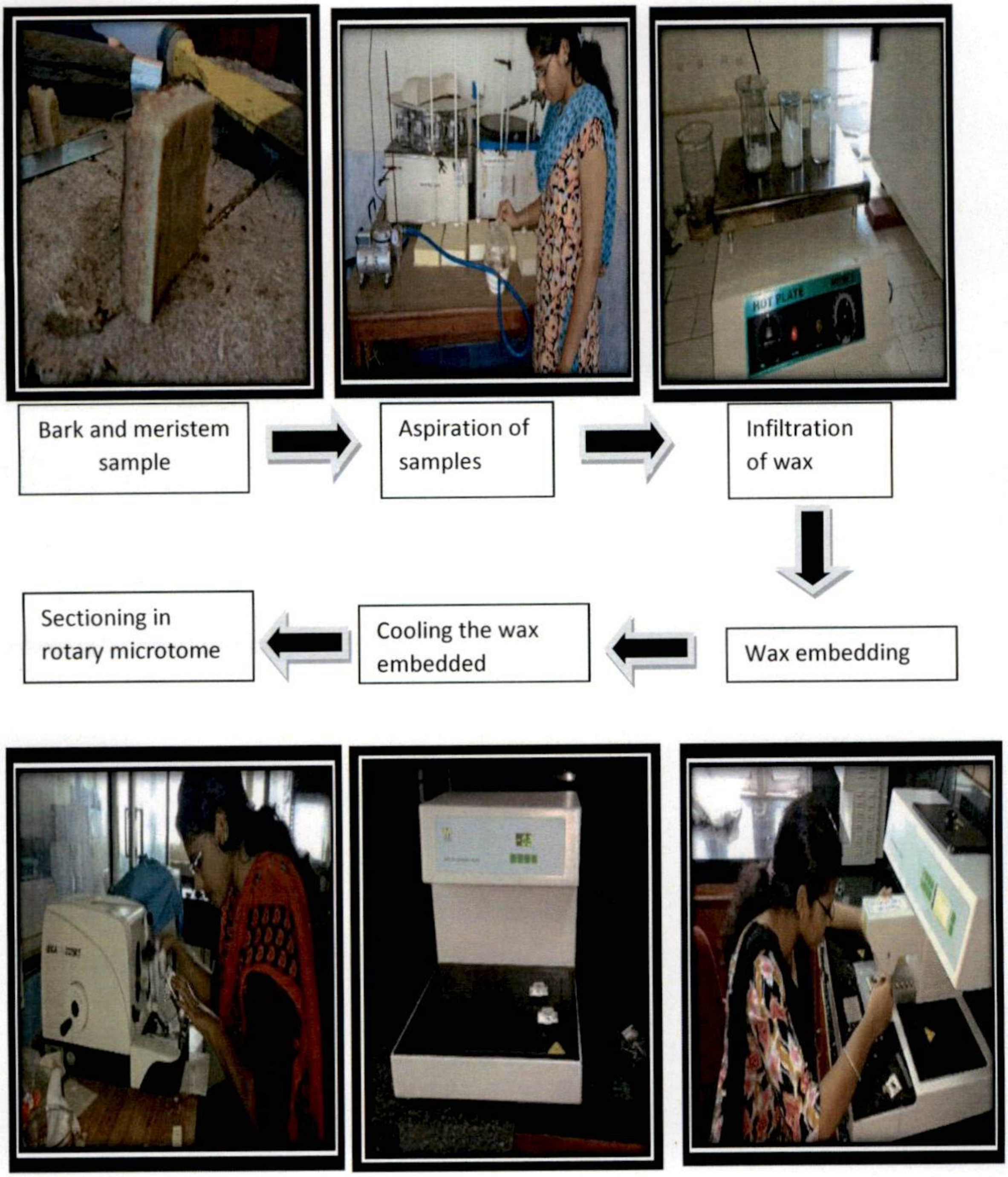


Plate 7. Procedure for taking bark and meristem anatomy

3.6 OBSERVATION

3.6.1 Quantification of gum-oleoresin yield due girth classes.

Quantification of gum-oleoresin yield by all the sample trees of different girth classes was done at monthly interval for 1 year duration (May 2017 to April 2018) with a help of weighing machine and expressed in grams.

3.6.2 Quantification of gum-oleoresin yield due tapping methods

Quantification of gum-oleoresin yield by all the experimented trees of different tapping methods at different was done for 1 year duration (May 2017 to April 2018) with a help of weighing machine and expressed in grams.

3.6.3 Anatomical properties

In sapwood, meristem and bark anatomical properties were studied to observe the relative position of gum-oleo resin canal/cellular distribution, the orientation of gum-oleoresin canals/cells and also to know the mechanism of gum-oleoresin formation, their movement and deposition inside the cells.

3.6.4 Measurement of bark thickness

The bark thickness was measured by using Haglof bark gauge. The bark gauge having a shaft with a sharp point which pushed through the bark until the underlying wood is felt. The sleeve around the shaft is shifted to the surface and thickness of the bark sample can be read from the calibrated shaft and was recorded in field data book in centimetre (cm).

3.7 STATISTICAL ANALYSIS

The data were subjected to statistical analysed using ANOVA in SPSS Version 21.0 to ascertain the significance of various parameters. The Duncan's Multiple Test was conducted to know the differences among treatments at 5% significance level. Correlation study was done for the parameters like bark thickness, girth classes and climatic variable in SPSS Version 21.0 to ascertain the significance.

RESULTS

RESULTS

The study on standardisation of extraction technique of gum-oleoresin in Matti (*Ailanthus triphysa* (Dennst.) Alston.) was carried out at Vellanikkara revealed significant information on gum-oleoresin yield based on the influence of girth classes and tapping methods in 25 years old *Ailanthus triphysa* plantation. The study also explored the anatomical features with gum-oleoresin production. The salient results are presented hereunder with the following headings:

- Effect of girth classes and tapping method on gum-oleoresin yield at monthly intervals (May 2017 to April 2018).
- Effect of girth classes and extraction techniques in gum-oleoresin yield in different season i.e., (Monsoon, Post Monsoon and Summer season).
- Effect of seasons and treatment on gum-oleoresin yield.
- Effect of girth classes and tapping method on gum-oleoresin yield.
- General features of *Ailanthus triphysa* wood anatomy.
- Effect of bark thickness and girth on gum-oleoresin yield.
- Effect of climatic parameter on gum-oleoresin yield

4.1 EFFECT OF GIRTH CLASSES AND EXTRACTION TECHNIQUES ON GUM-OLEORESIN YIELD AT MONTHLY BASIS (MAY 2017- APRIL 2018)

4.1.1 Effect of extraction techniques and girth classes on gum-oleoresin yield in the May 2017.

The present study revealed that the gum-oleoresin yield due to extraction techniques ranged from 11.66 g to 34 .00 g in V-Shaped method, 20.00 g to 55.00 g in cup and lip method and 3.00 g to 27.66 g in Straight cut method and also it was found to be significantly different in gum-oleoresin yield due to different extraction techniques followed during the month of May (Table 1.) The study reveals that the highest amount of gum-oleoresin was found in cup and lip method and lowest in straight-cut method.

Similarly, present study revealed that that the gum-oleoresin yield from *Ailanthus triphysa* tree during the month of May ranged from 3.00 g to 20.00 g for < 75 girth class, 27.66 g to 44.00 g for 75-150 girth class and 26.33 g to 55.00 g for girth class >150. It was found that there was a significant difference in gum-oleoresin yield due to girth class variation (Table.1). The study revealed that the girth class <75 is significantly different from >75 girth classes on gum-oleoresin yield.

Table 1. Gum-oleoresin yield from *Ailanthus triphysa* during the month of May 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	Extraction techniques				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight-cut method	Mean yield (Girth)	P-value For girth
<75	11.66	20.00	3.00	**11.55**^{a}	0.001** C.D (14.52)
75-150	31.33	44.00	27.66	**34.33**^{b}	
>150	34.00	55.00	26.33	**38.44**^{b}	
Mean yield (Tapping)	**25.66**^{ab}	**39.66**^{b}	**19.00**^{a}		
P-value for tapping	0.022* C.D (14.52)				

*- significant difference at 5 %, ** significant difference in 1%.

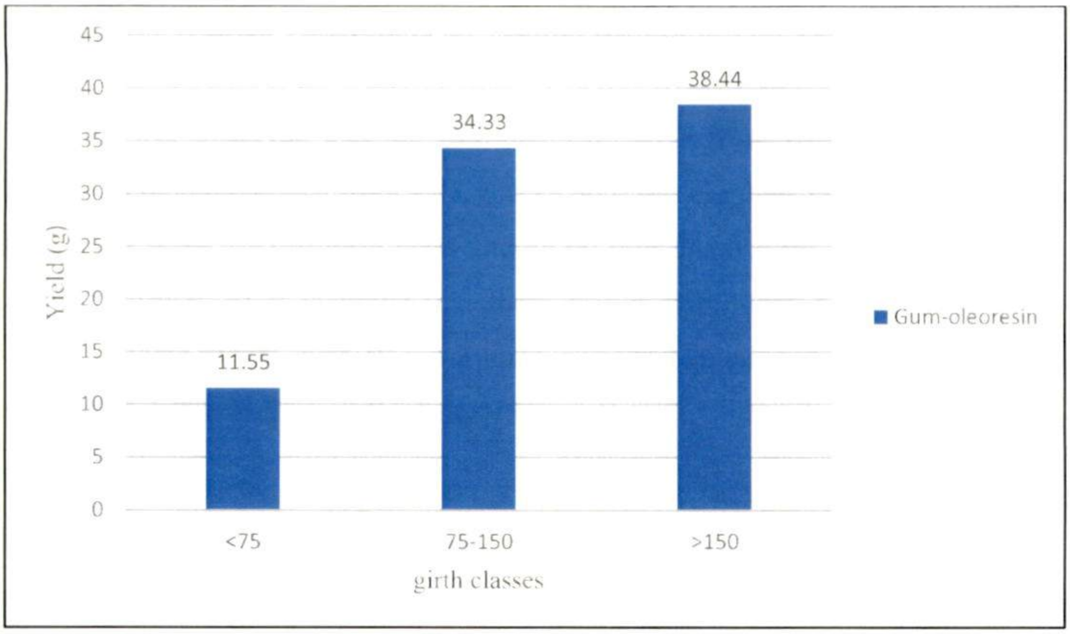


Fig 5. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during May 2017.

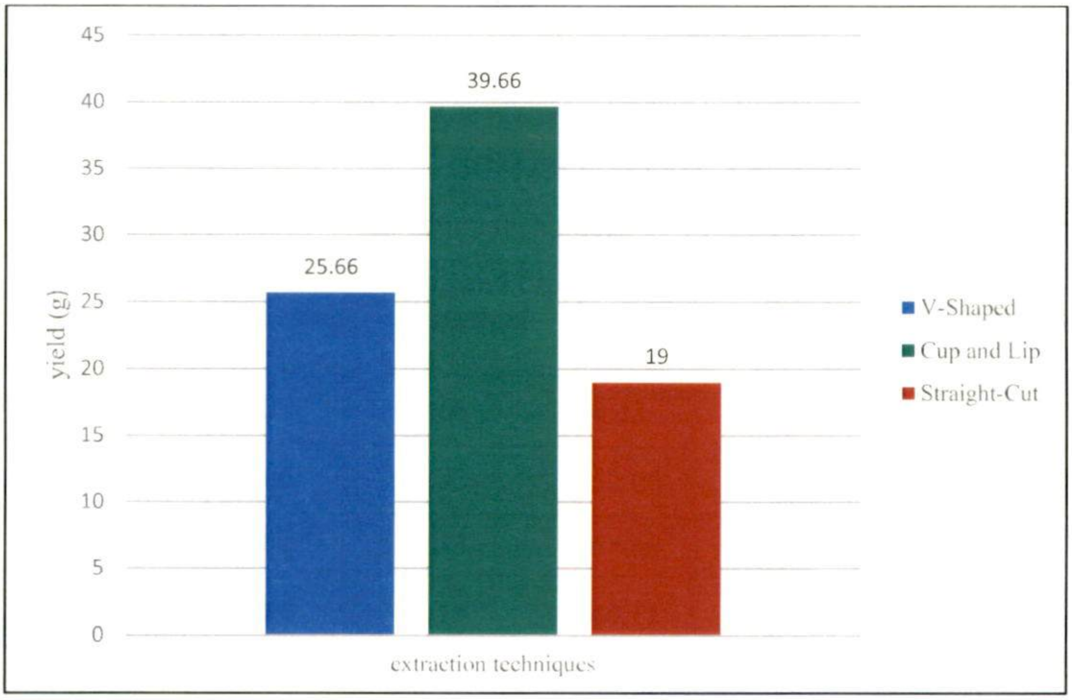


Fig 6. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.2 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of June 2017.

It was observed that the gum-oleoresin yield from Ailanthus tree during the month of June ranged from 4.33 g to 19.66 g for less than 75 girth class, 44.66 g to 58.33 g for 75-150 girth class and 36.00 g to 64.00 g for girth class greater than 150(Table. 2) It is found that there was a significant difference in gum-oleoresin yield due to girth class variation with 75-150 cm and >150 cm showing significant different from girth class <75 cm.

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 14.33 g to 36 .00 g in V-Shaped method, 19.66 g to 58.33 g in Cup and Lip method and 4.33 g to 64.00 g in Straight-Cut method. Gum-oleoresin yield due to different extraction techniques was not significantly different during the month of June.

Table 2. Gum-oleoresin yield from *Ailanthus triphysa* during the month of June 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	Extraction techniques				
Girth classes (cm)	V-shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth)	P-value For girth
<75	14.33	19.66	4.33	**12.77^{a}**	0.020* C.D(29.61)
75-150	44.66	58.33	52.00	**51.66^{b}**	
>150	36.00	51.33	64.00	**50.44^{b}**	
Mean yield(Tapping)	**31.66**	**43.11**	**40.11**		
P-value for tapping	0.702^{ns}				

- *significant different, ns –non-significant different at 5% level

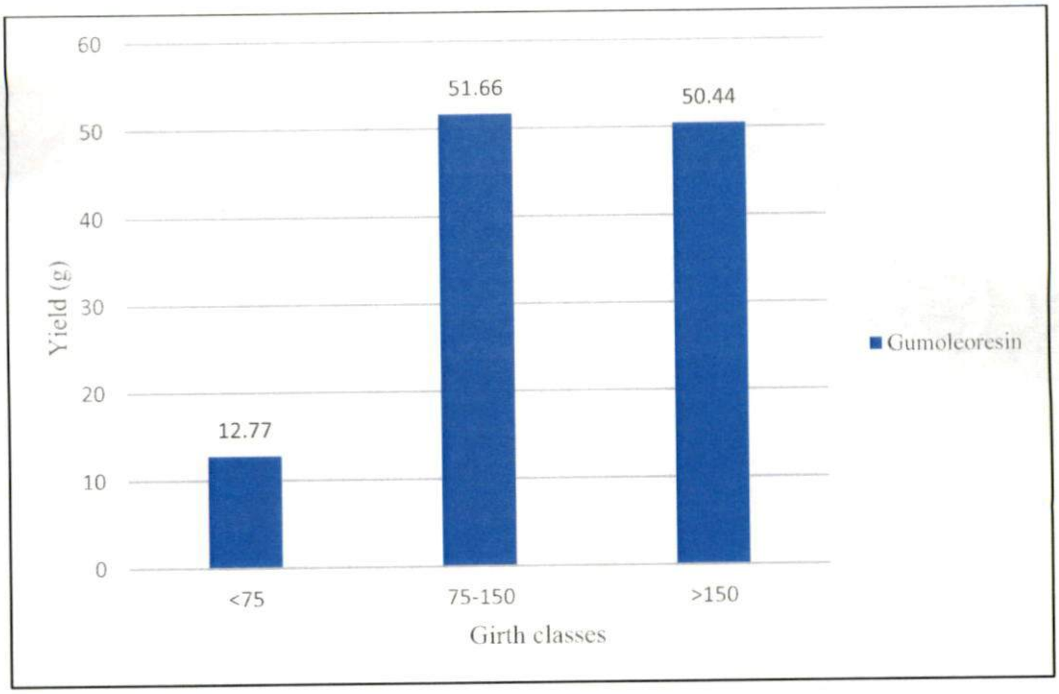


Fig 7. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during June 2017.

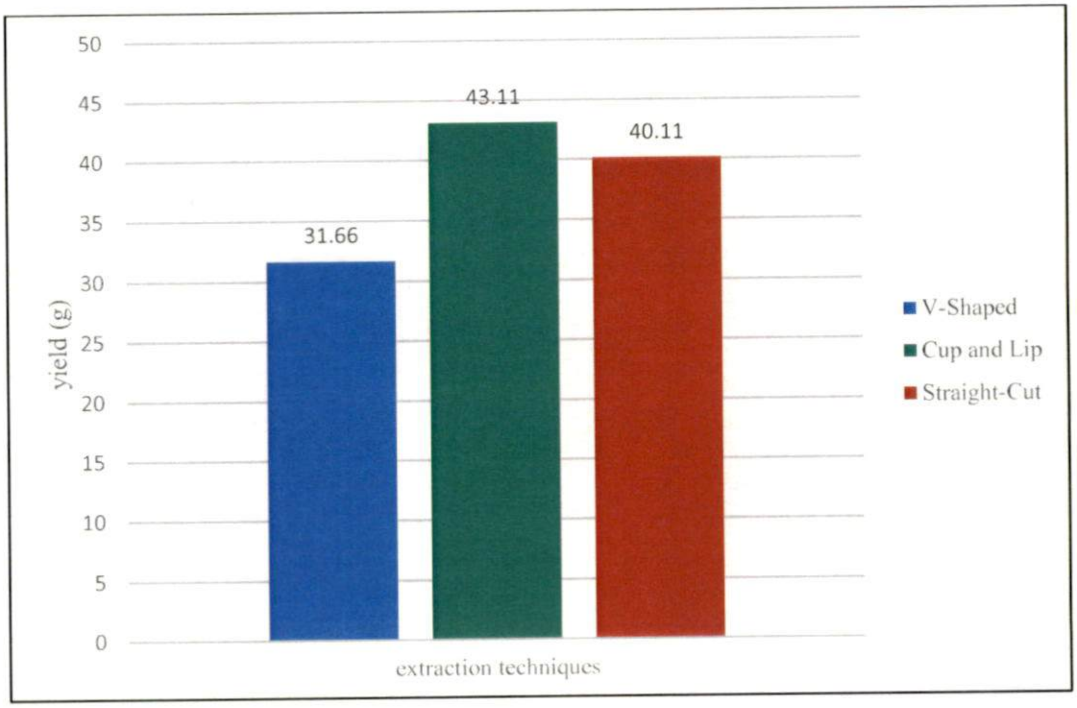


Fig 8. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.3 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of July 2017

It is noticed from the present study that the gum-oleoresin yield from Ailanthus tree during the month of July ranged from 1.33 g to 26.66 g for less than 75 girth class, 38.66 g to 80.33 g for 75-150 girth class and 54.66 g to 66.66 g for girth class greater than 150. It was found to be non-significant difference in gum-oleoresin yield due to girth class variation.

The gum-oleoresin yield due to extraction techniques ranged from 15.00 g to 54.66 g in V-Shaped method, 26.66 gm to 80.33 gm in cup and lip method and 1.33 g to 55.33 g in Straight-Cut method. Difference in gum-oleoresin yield due to different extraction technique practices was found to be non-significant.

Table 3. Gum-oleoresin yield from *Ailanthus triphysa* during the month of July 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction technique**				
Girth classes (cm)	V-shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth)	P-value For girth
<75	15.00	26.66	1.33	**14.33^{a}**	0.067^{ns}
75-150	45.33	80.33	38.66	**54.77^{b}**	
>150	54.66	66.66	55.33	**58.88^{b}**	
Mean yield (Tapping)	**38.33**	**57.88**	**31.77**		
P-value for tapping	0.430^{ns}				

ns- non-significant different at 5% level

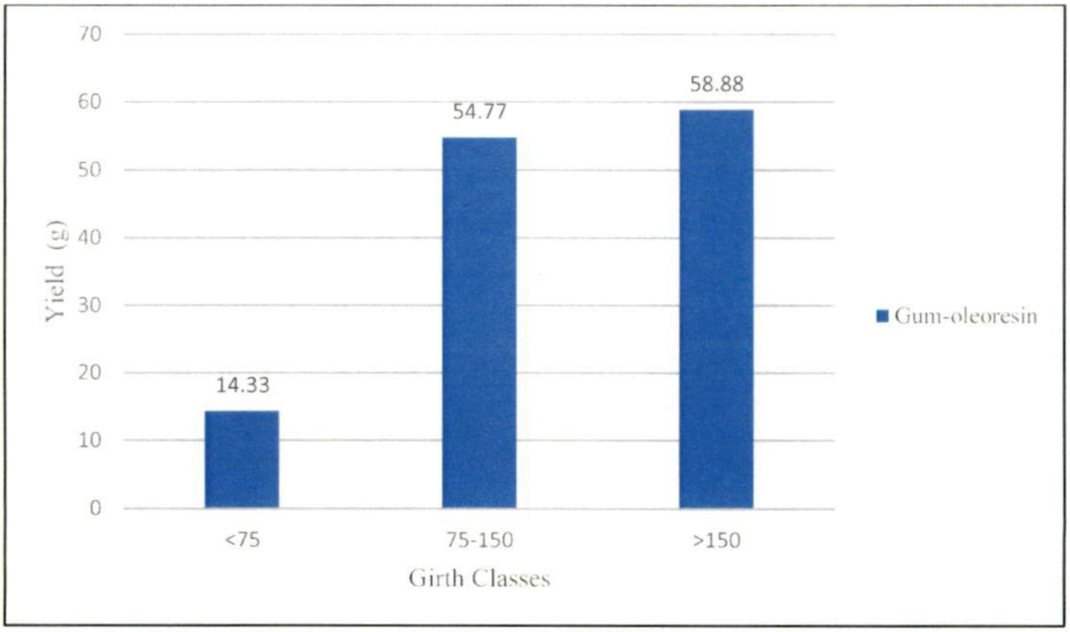


Fig 9. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during July 2017.

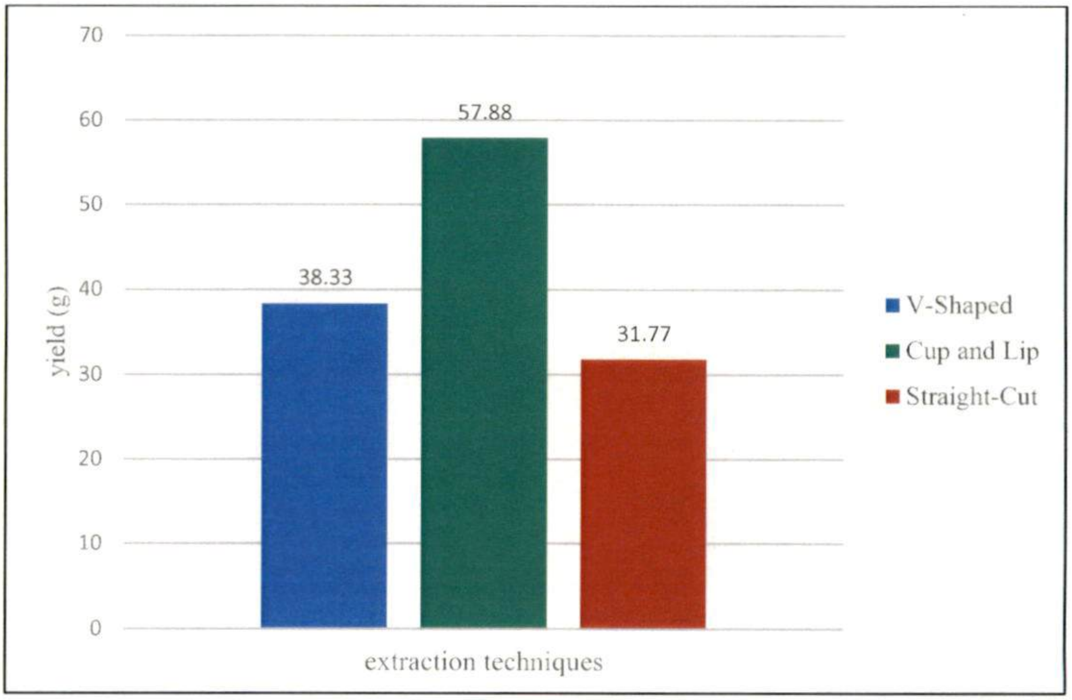


Fig 10. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.4 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of August 2017.

It was observed that the gum-oleoresin yield from Ailanthus tree during the month of August ranged from 0.66 g to 7.33 g for < 75 girth class, 16.00 g to 46.33 g for 75-150 girth class and 25.66 g to 38.66 g for girth class > 150. It is statistically found non-significant difference in gum-oleoresin yield due to girth class variation (Table. 4).

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 4.66 g to 38.66 g in V-Shaped method, 7.33 g to 46.33 g in cup and lip method and 0.66 g to 25.66 g in Straight-Cut method. It indicates that the gum-oleoresin yield due to different extraction techniques practices was not significantly different during the month of August.

Table 4. Gum-oleoresin yield from *Ailanthus triphysa* during the month of August 2017.

	GUM-OLEORESIN YIELD IN GRAMS (g)				
Factors	**Extraction technique**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight-cut method	Mean yield (Girth)	P-value For girth
<75	4.66	7.33	0.66	**4.22**	0.124^{ns}
75-150	29.66	46.33	16.00	**30.66**	
>150	38.66	36.66	25.66	**33.66**	
Mean yield (Tapping)	**24.33**	**30.11**	**14.11**		
P-value for tapping	0.563^{ns}				

ns –non-significant different at 5% level

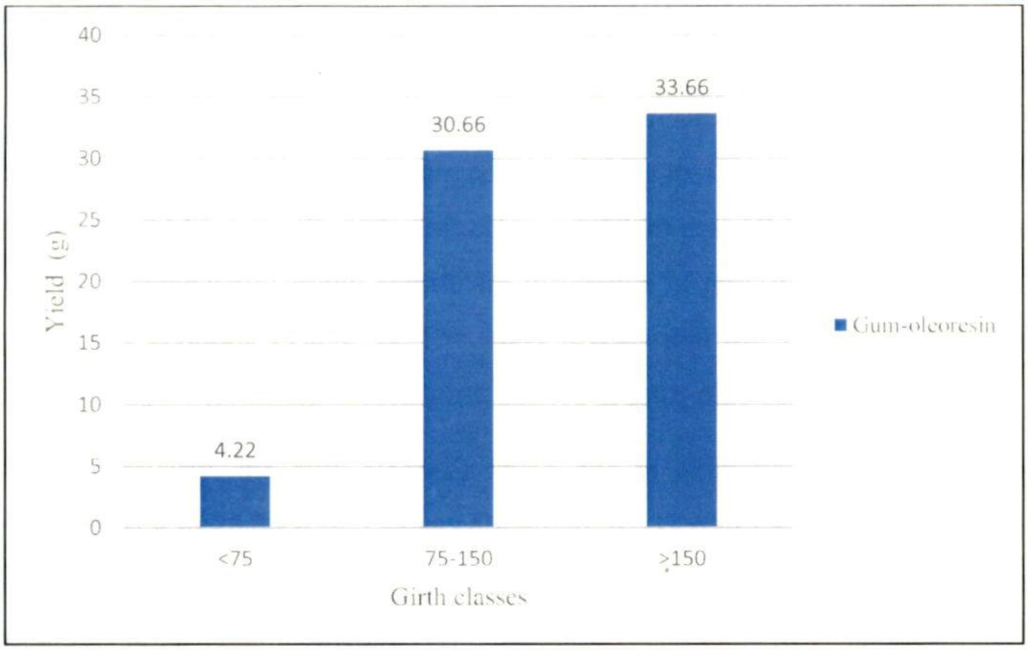


Fig 11. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during August 2017.

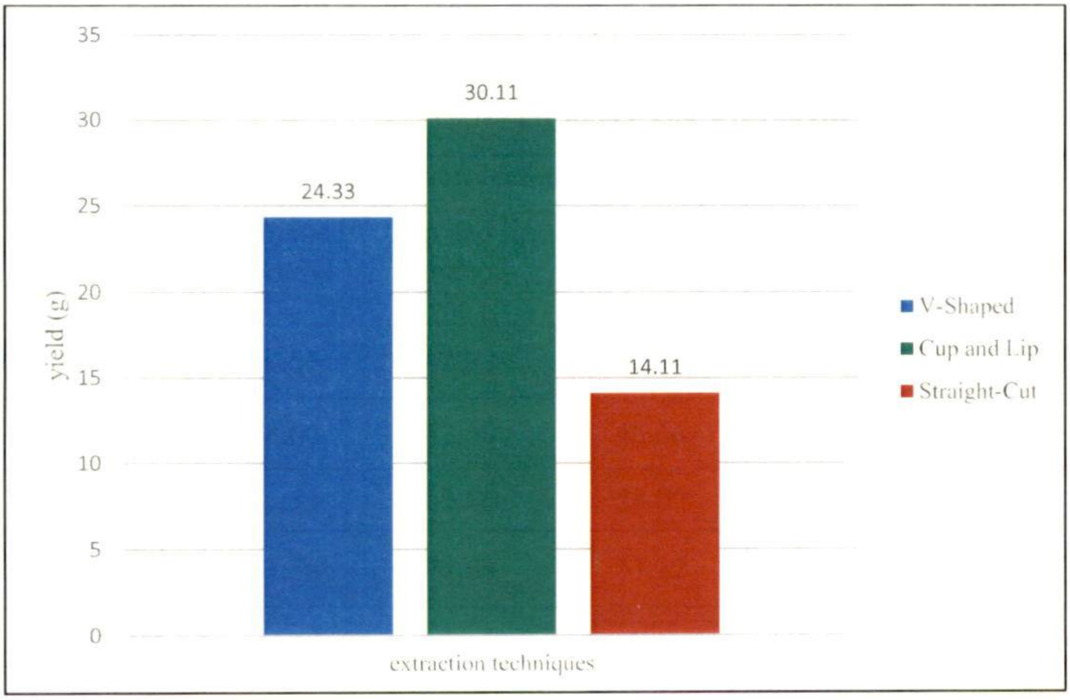


Fig 12. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.5 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of September 2017.

Present study revealed that the gum-oleoresin yield from Ailanthus tree during the month of September ranged from 8.00 g to 42.33 g for < 75 girth class, 45.66 g to 82.66 g for 75-150 girth class and 58.00 g to 89.66 g for girth class > 150. It is statistically found significant difference in gum-oleoresin yield due to girth class variation (Table 5). The study reveals that the <75 cm girth class is significantly different from other girth classes in gum-oleoresin production

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 20.66 g to 75.33 g in V-Shaped method, 42.33 g to 89.66 g in Cup and Lip method and 8.00 g to 58.00 g in Straight-Cut method. Difference in gum-oleoresin yield due to different extraction techniques was found to be non-significant during the month of September.

Table 5. Gum-oleoresin yield from *Ailanthus triphysa* during the month of September 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight-cut method	Mean yield (Girth)	P-value For girth
<75	20.66	42.33	8.00	**23.66^{a}**	
75-150	58.66	82.66	45.66	**62.33^{b}**	0.025^{*} C.D (36.76)
>150	75.33	89.66	58.00	**74.33^{b}**	
Mean yield (Tapping)	**51.55**	**71.55**	**37.22**		
P-value for tapping	0.173^{ns}				

**- significant different, ns –non-significant different at 5% level*

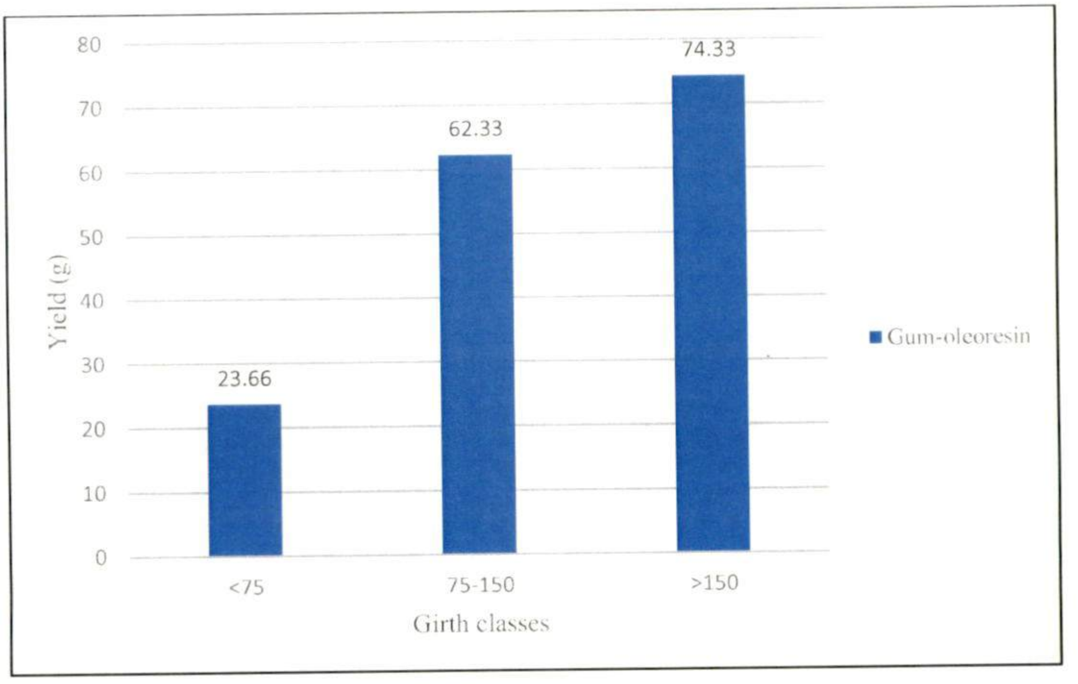


Fig 13. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during September 2017.

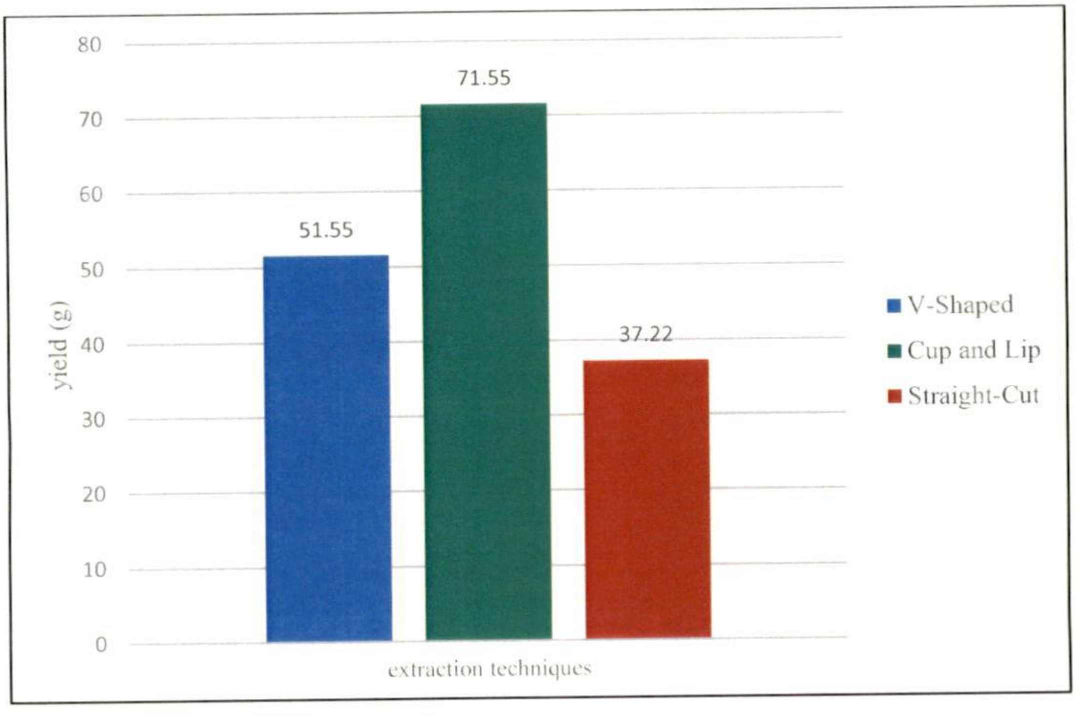


Fig 14. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.6 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of October 2017.

It was observed that the gum-oleoresin yield from Ailanthus tree during the month of October ranged from 10.66 gm to 71.00 g for < 75 girth class, 88.00 g to 188.66 g for 75-150 girth class and 122.66 g to 133.3 g for girth class > 150. It is statistically found significant difference in gum-oleoresin yield due to girth class variation (Table.6). The study reveals that the greater girth classes like 75-150 cm and >150 cm is par from <75 cm girth class in the gum-oleoresin yield.

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 30.33 g to 122.66 g in V-Shaped method, 71.00 g to 188.66 g in Cup and Lip method and 10.6 g to 123.66 g in Straight-Cut method. Difference in gum-oleoresin yield due to different extraction techniques was found to be non-significant during in month of October. (Table 6). The mean value registered the highest amount of gum-oleoresin found in Cup and Lip method (130.99 g) and lowest in Straight-cut method (74.11 g).

Table 6. Gum-oleoresin yield from *Ailanthus triphysa* during the month of October.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight-Cut method	Mean yield (Girth)	P-value For girth
<75	30.33	71.00	10.66	**37.33^{a}**	0.015^{**} C.D (64.21)
75-150	92.66	188.66	88.00	**123.11^{b}**	
>150	122.66	133.3	123.66	**126.55^{b}**	
Mean yield (Tapping)	**81.88**	**130.99**	**74.11**		
P-value for tapping	0.160^{ns}				

**- significant different, ns –non-significant different at 5% level*

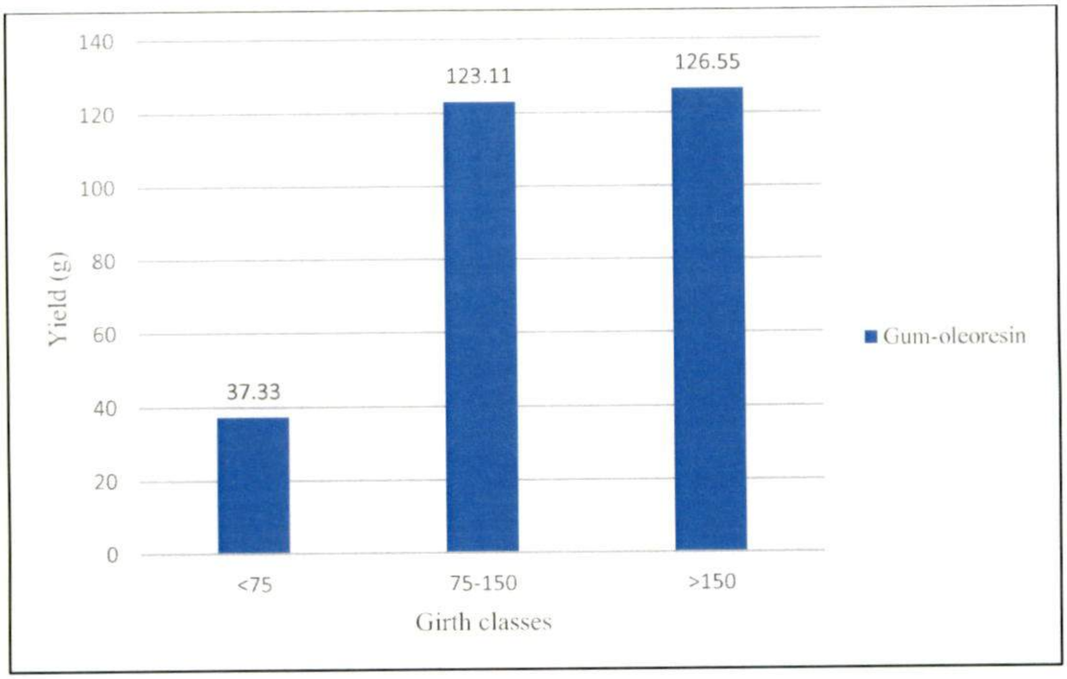


Fig 15. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during October 2017.

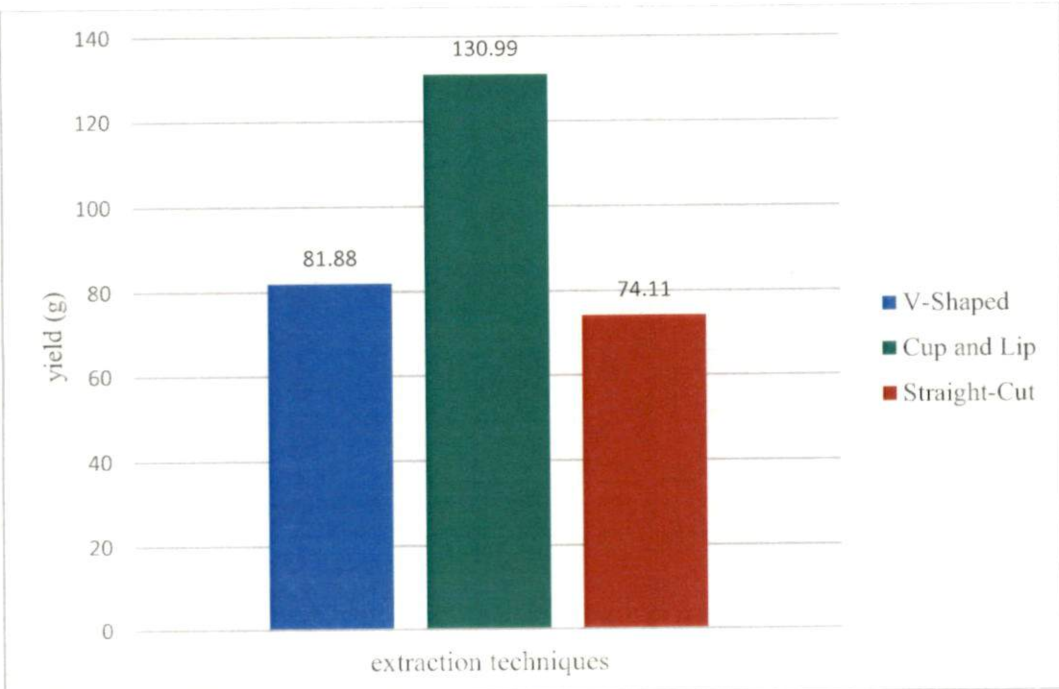


Fig 16. Gum-oleoresin yield obtained from different extraction technique in *Ailanthus triphysa*.

4.1.7 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of November 2017

The present study revealed that the gum-oleoresin yield from Ailanthus tree during the month of November ranged from 12.00 g to 49.33 g for < 75 girth class, 74.33 g to 146.33 g for 75-150 girth class and 111.6 g to 127.66 g for girth class > 150. There was significant difference in gum-oleoresin yield due to girth class variation (Table. 7). The study reveals that the greater girth classes like 75-150 cm and >150 cm is par from <75 cm girth class in the gum-oleoresin yield.

Similarly, the gum-oleoresin yield due the extraction techniques ranged from 19.66 g to 111.66 g in V-Shaped method, 49.33 g to 146.33 g in Cup and Lip method and 12.00 g to 124.33 g in Straight cut method. Difference in gum-oleoresin yield due to different extraction practices was found to be non-significant for the month of November. The mean value registered the highest amount of gum-oleoresin in cup and lip method (107.77 g) and lowest in V-Shaped method (68.55 g).

Table 7. Gum-oleoresin yield from *Ailanthus triphysa* during the month of November 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight cut method	Mean yield (Girth)	P-value For girth
<75	19.66	49.33	12	**26.99^{a}**	0.018^{*} **C.D(65.74)**
75-150	74.33	146.33	91.33	**103.99^{b}**	
>150	111.66	127.66	124.33	**121.22^{b}**	
Mean yield (Tapping)	**68.55**	**107.77**	**75.89**		
P-value for tapping	0.423^{ns}				

s- significant different, ns –non-significant different at 5% level

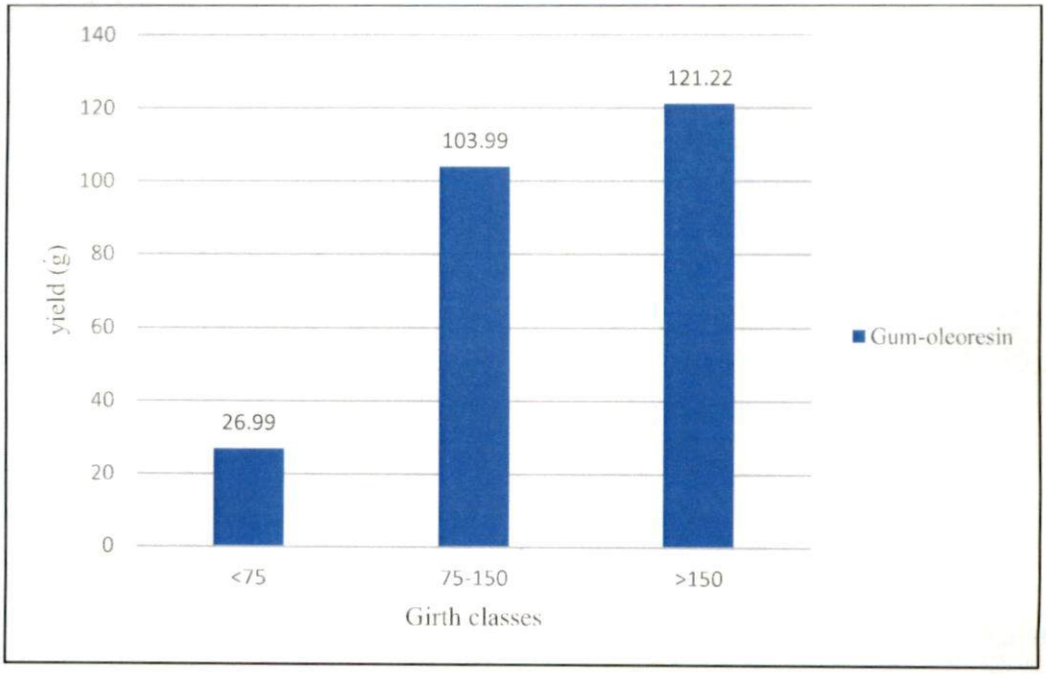


Fig 17. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during November 2017.

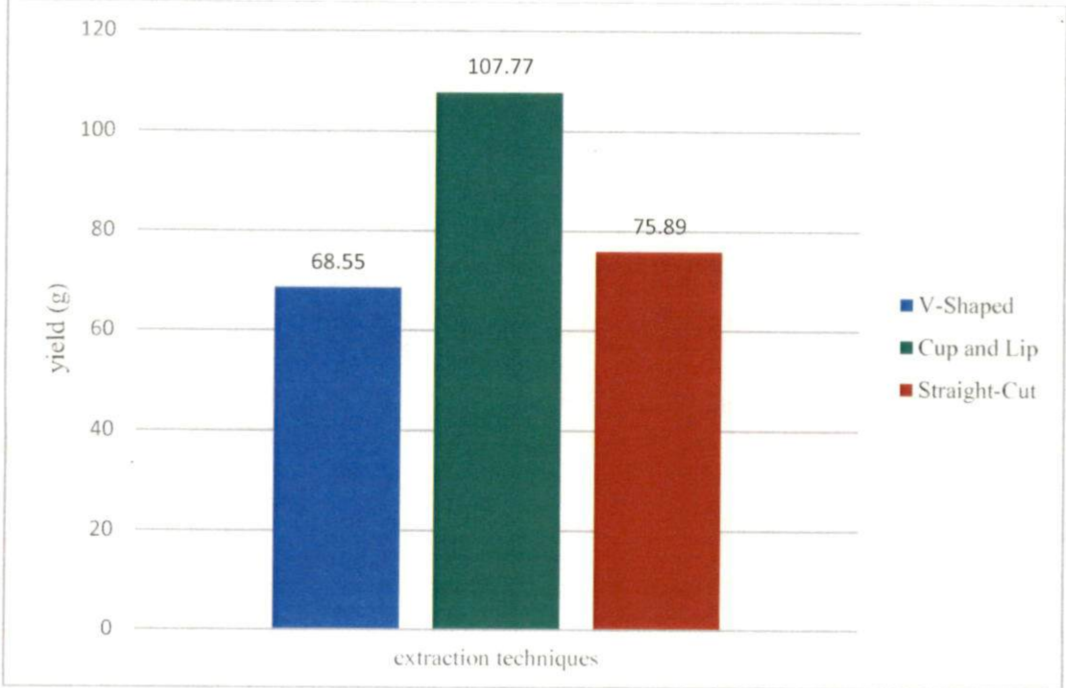


Fig 18. Gum-oleoresin yield obtained from extraction techniques in *Ailanthus triphysa*.

4.1.8 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of December 2017.

The gum-oleoresin yield from Ailanthus tree during the month of December was studied one of the mean values ranged from 0.66 g to 14.66 g for < 75 girth class, 45.00 g to 52.66 g for 75-150 girth class and 54.66 g to 102.00 g for girth class >150. The data showed significant difference in gum-oleoresin yield due to girth class variation (Table 8) with girth class <75 cm significantly different from girth class 75-150 cm and >150 cm.

The gum-oleoresin yield due to extraction techniques ranged from 6.33 g to 65.66 g in V-Shaped method, 14.66 g to 54.66 g in cup and lip method and 0.66 gm to 102.00 g in Straight-Cut method. (Table. 8). Difference in gum-oleoresin yield due to different extraction techniques was found to be non-significant for the month of December. The mean value registered the highest amount of gum-oleoresin in Cup and Lip method (74.44 g) and lowest in Straight-Cut method (50.66 g).

Table 8. Gum-oleoresin yield from *Ailanthus triphysa* during the month of December 2017.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth)	P-value For girth
<75	6.33	14.66	0.66	**7.21^{a}**	
75-150	45.00	52.66	49.33	**48.99^{b}**	0.006^{**}
>150	65.66	54.66	102.00	**73.88^{b}**	C.D (37.48)
Mean yield (Tapping)	**38.99**	**74.44**	**50.66**		
P-value for tapping	0.770^{ns}				

**- significant different at 5% level, ** - significant different at 1 % level,*

ns –non-significant different

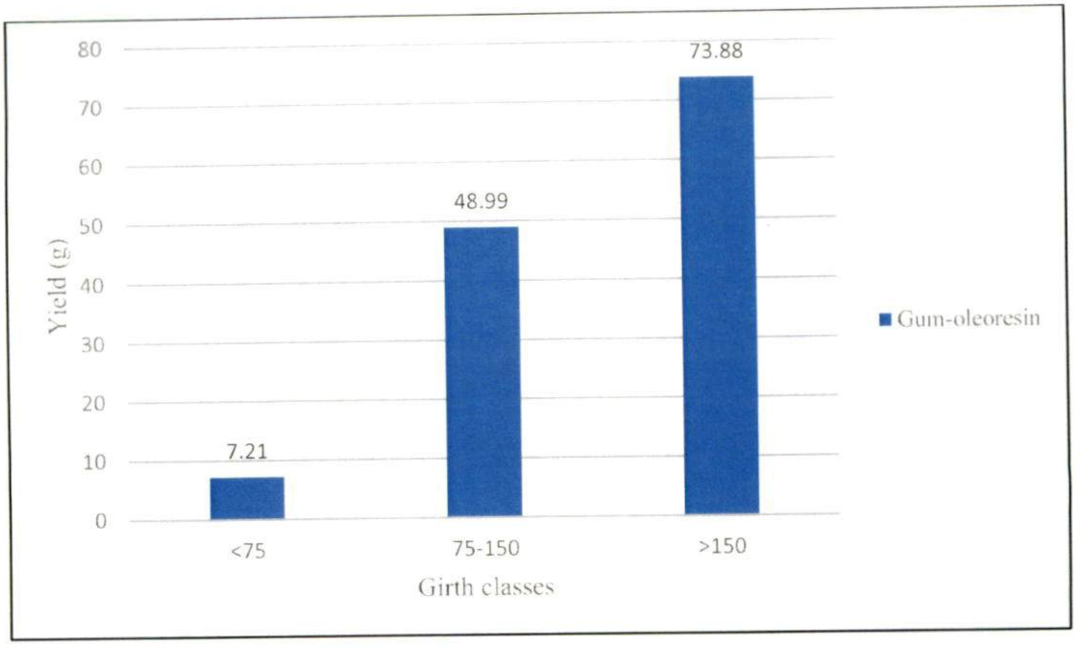


Fig 19. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during December 2017.

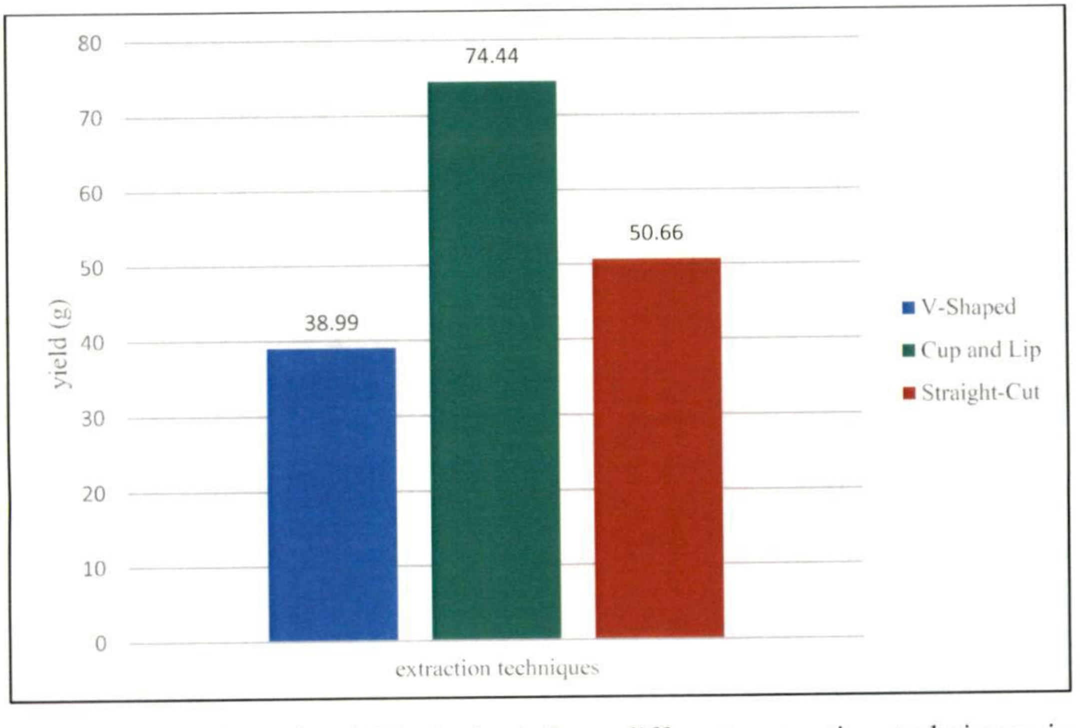


Fig 20. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.9 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of January 2018.

Present study observed that the gum-oleoresin yield from Ailanthus tree during the month of January ranged from 2.33 g to 15.33 g for < 75 girth class, 28.33 g to 53.66 g for 75-150 girth class and 47.67 g to 61.33 g for girth class >150. It is observed that there was significant difference in gum-oleoresin yield due to girth class variation (Table 9).

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 6.66 g to 61.33 g in V-Shaped method, 15.33 g to 53.66 g in cup and lip method and 2.33 g to 57.67 g in Straight-Cut method (Table 9). Difference in gum-oleoresin yield due to different extraction technique practices was found to be non-significant for the month of January. The mean value registered the highest amount of gum-oleoresin in Cup and Lip method (38.89 g) and lowest in V-Shaped method (32.11 g).

Table 9. Gum-oleoresin yield from *Ailanthus triphysa* during the month of January 2018.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes(cm)	V-shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth)	P-value for girth
<75	6.66	15.33	2.33	**8.11^{a}**	
75-150	28.33	53.66	46.66	**42.84^{b}**	
>150	61.33	47.67	57.67	**55.56^{b}**	0.003**
Mean yield (Tapping)	**32.11**	**38.89**	**35.56**		C.D (25.52)
P-value for tapping	0.855^{ns}				

**- significant different at 5 % level, ** -significant different at 1 %,*

ns –non-significant different at 5% level

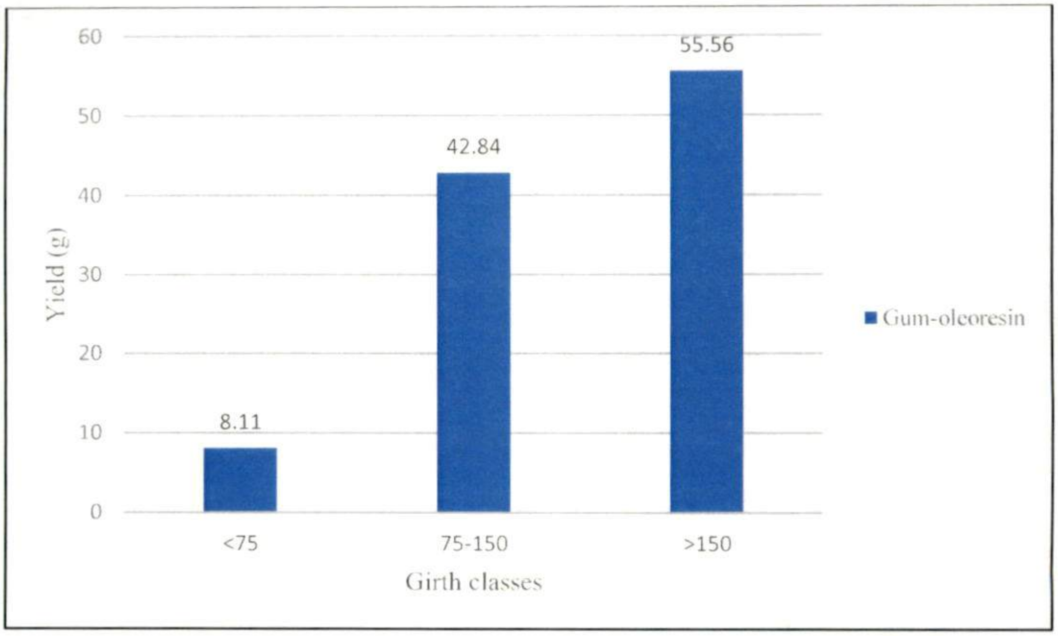


Fig 21. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during January 2018.

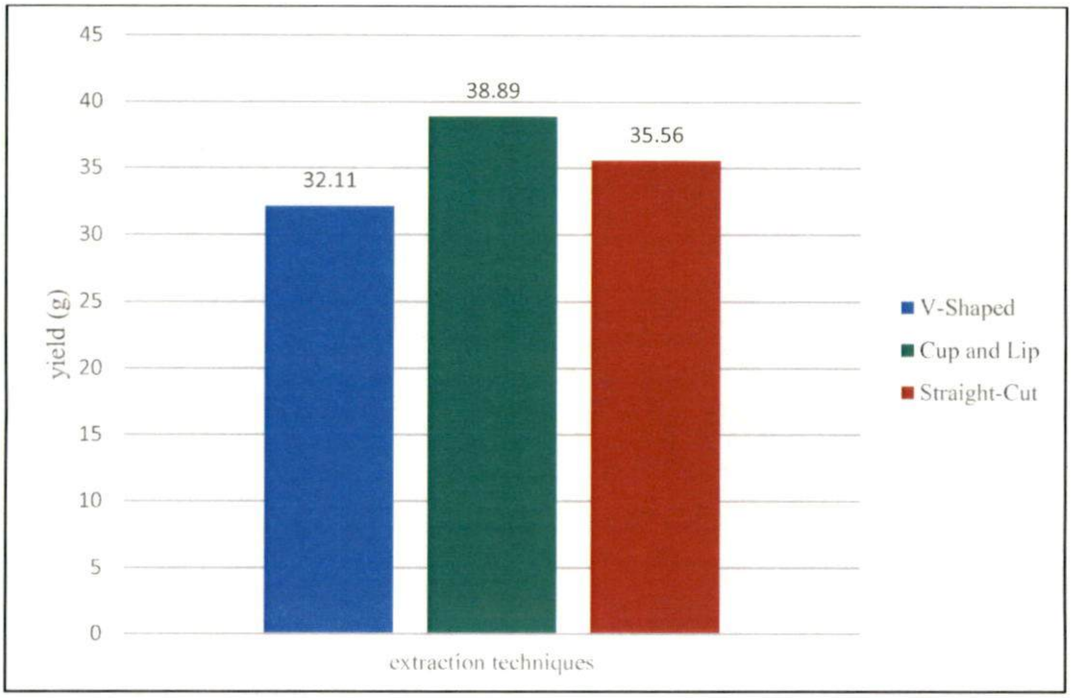


Fig 22. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.10 Effect of girth classes and extraction techniques on gum-oleoresin yield in the month of February 2018.

Present study revealed that the gum-oleoresin yield from Ailanthus tree during the month of February ranged from 0.00 g to 4.67 g for < 75 girth class, 17.00 g to 22.00 g for 75-150 girth class and 20.67 g to 59.67 g for girth class > 150. It is statistically found significant difference in gum-oleoresin yield due to girth class variation (Table 10).

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 2.33 g to 38.00 g in V-Shaped method, 4.67 g to 20.67 g in Cup and Lip method and 0.00 g to 59.67 g in Straight-Cut method (Table. 10). Difference in gum-oleoresin yield due to different extraction technique was found to be non-significant for the month of February. The mean value registered the highest amount of gum-oleoresin in Straight-cut method (27.22 g) and lowest in Cup and Lip method (14.11 g).

Table 10. Gum-oleoresin yield from *Ailanthus triphysa* during the month of February 2018.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight cut method	Mean yield (Girth)	P-value for girth
<75	2.33	4.67	0.00	**2.33^{a}**	
75-150	21.00	17.00	22.00	**20.00^{ab}**	0.035^{*}
>150	38.00	20.67	59.67	**39.44^{b}**	C.D (27.31)
Mean yield (Tapping)	**20.44**	**14.11**	**27.22**		
P-value for tapping	0.605^{ns}				

**- significant different, ns –non-significant different at 5% level*

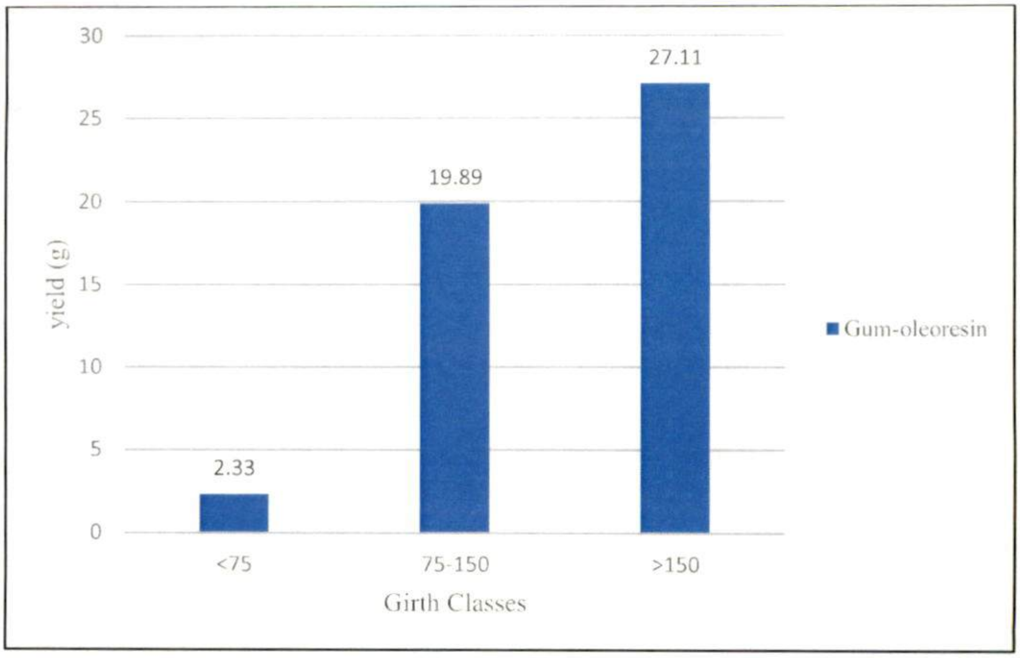


Fig. 23. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during February 2018.

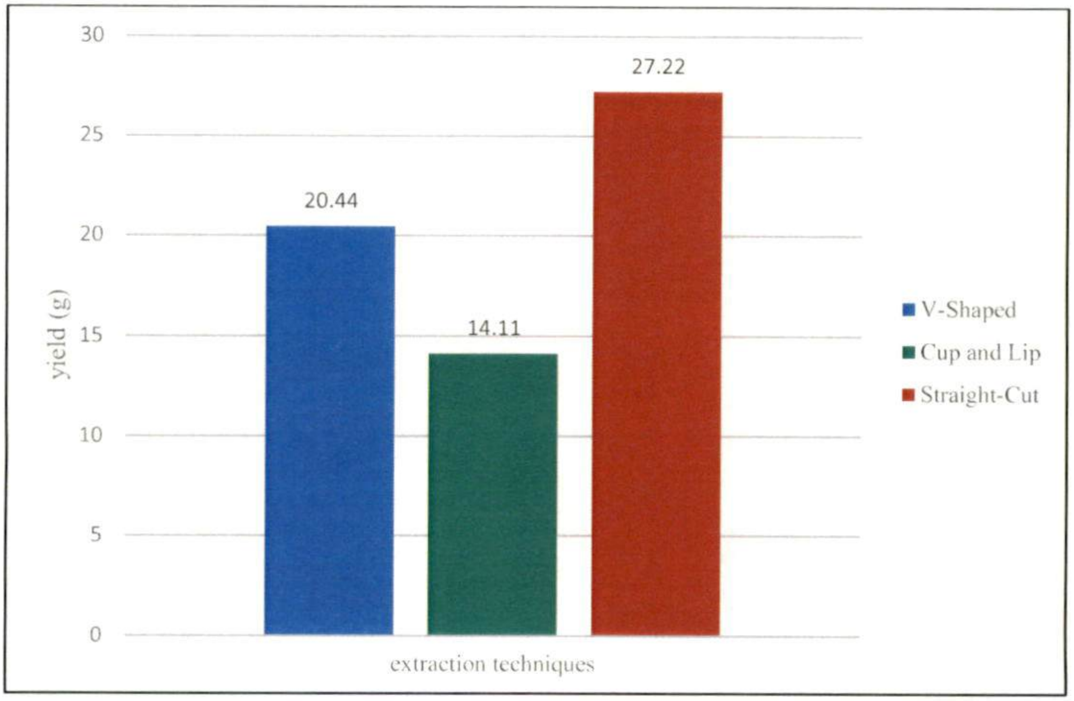


Fig 24. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.11 Effect of girth classes and tapping method on gum-oleoresin yield in the month of March 2018.

The present studies revealed that the gum-oleoresin yield from Ailanthus tree during the month of March ranged from 0.00 g to 0.00 g for < 75 girth class, 18.67 g to 21.30 g for 75-150 girth class and 23.67 g to 32.67 g for girth class >150. It is statistically found significant difference in gum-oleoresin yield due to girth class variation (Table 11).

Similarly, the gum-oleoresin yield due to extraction techniques ranged from 0.00 g to 23.67 g in V-Shaped method, 0.00 g to 25.00 g in cup and lip method and 0.00 g to 32.67 g in Straight cut method. Difference in gum-oleoresin yield due to different extraction technique was found to be non-significant for the month of March. The mean value registered the highest amount of gum-oleoresin found in Straight-Cut method (17.44 g) and lowest in V-shaped method (14.11 g).

Table 11. Gum-oleoresin yield from *Ailanthus triphysa* during the month of March 2018.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-Shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth)	P-value for girth
<75	0.00	0.00	0.00	**0.00**[a]	
75-150	18.67	21.30	19.67	**19.89**[b]	0.007^{**}
>150	23.67	25.00	32.67	**27.11**[b]	C.D (15.92)
Mean yield (Tapping)	**14.11**	**15.44**	**17.44**		
P-value for tapping	0.904^{ns}				

*** significant different at 5% and 1% level, ns- non-significant different.*

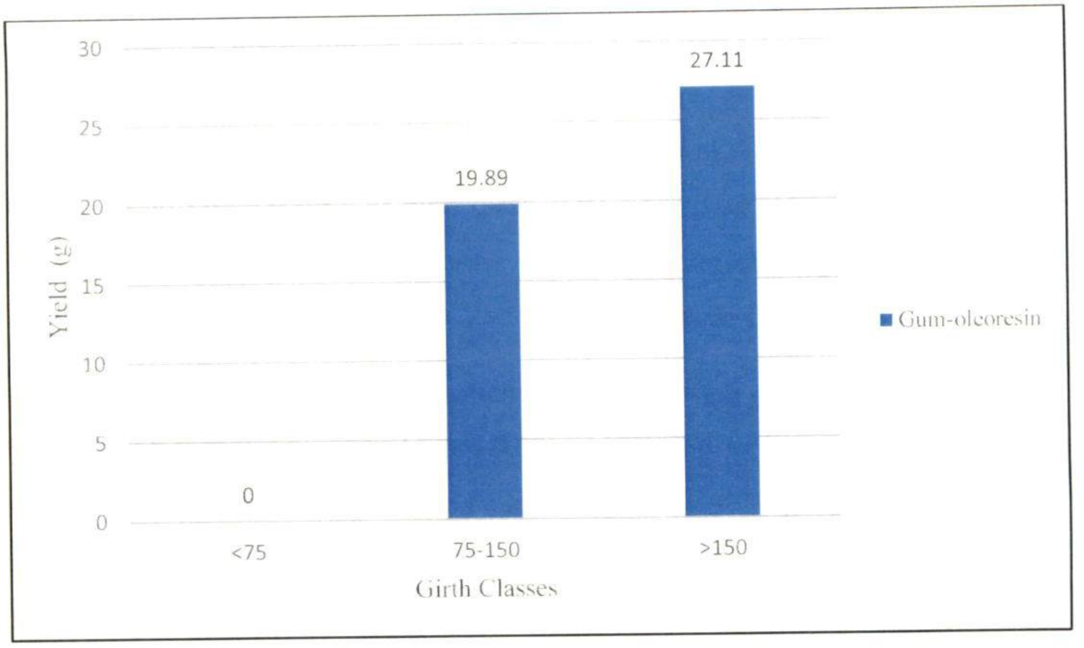


Fig 25. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during March.

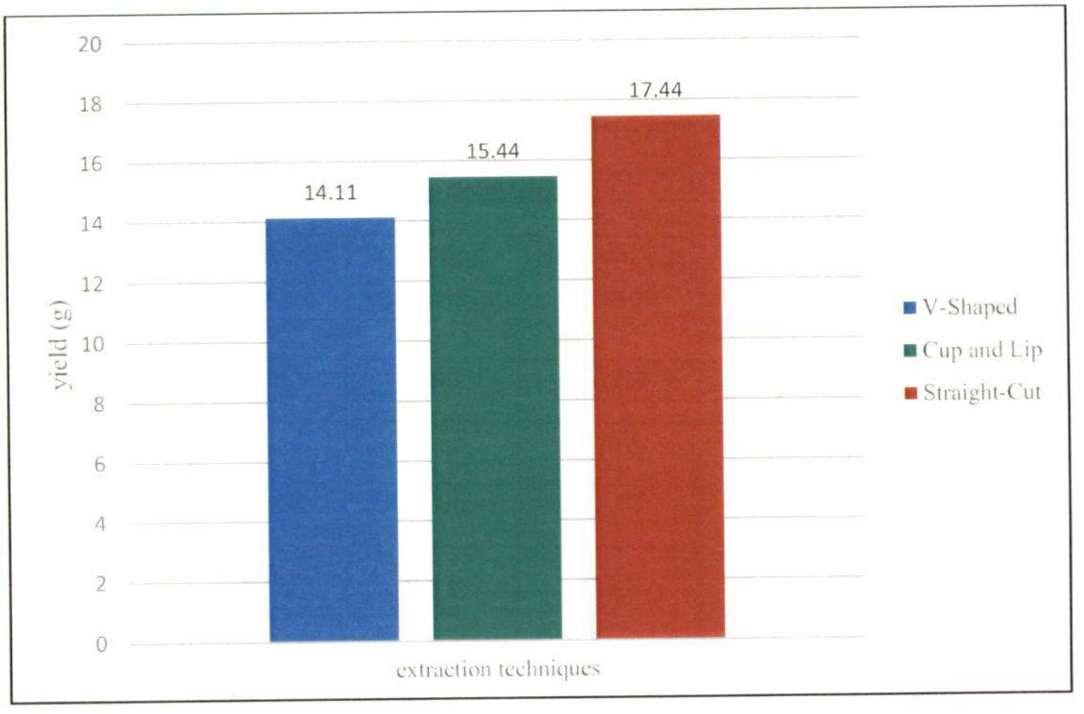


Fig 26. Gum-oleoresin yield obtained from different extraction techniques in *Ailanthus triphysa*.

4.1.12 Effect of girth classes and tapping method on gum-oleoresin yield in the month of April 2018.

In the month of April gum-oleoresin yield from Ailanthus tree was ranged from 0.00 g to 0.00 g for <75 girth class, 9.67 g to 13.33 g for 75-150 girth class and 11.67 g to 13.00 g for girth class > 150. This indicates a significant difference in gum-oleoresin yield due to girth class variation (Table 12)

It is also observed from the present study that the gum-oleoresin yield due to extraction techniques ranged from 0.00 g to 13.00 g in V-Shaped method, 0.00 g to 13.00 g in Cup and Lip method and 0.00 g to 11.67 g in Straight cut method (Table 12). Difference in gum-oleoresin yield due to different extraction technique was found to be non-significant for the month of April. The mean value registered the highest amount of gum-oleoresin in mean of V-shaped method (8.78 g) and lowest in Straight-Cut method (7.11 g).

Table 12. Gum-oleoresin yield from *Ailanthus triphysa* during the month of April 2018.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight cut method	Mean yield (Girth)	P-value For girth
<75	0.00	0.00	00.00	**0.00**^{a}	
75-150	13.33	11.33	9.67	**11.44**^{b}	0.012*
>150	13.00	13.00	11.67	**12.56**^{b}	C.D(20.63)
Mean yield (Tapping)	**8.78**	**8.11**	**7.11**		
P-value for tapping	0.913^{ns}				

**- significant different, ns –non-significant different at 5% level*

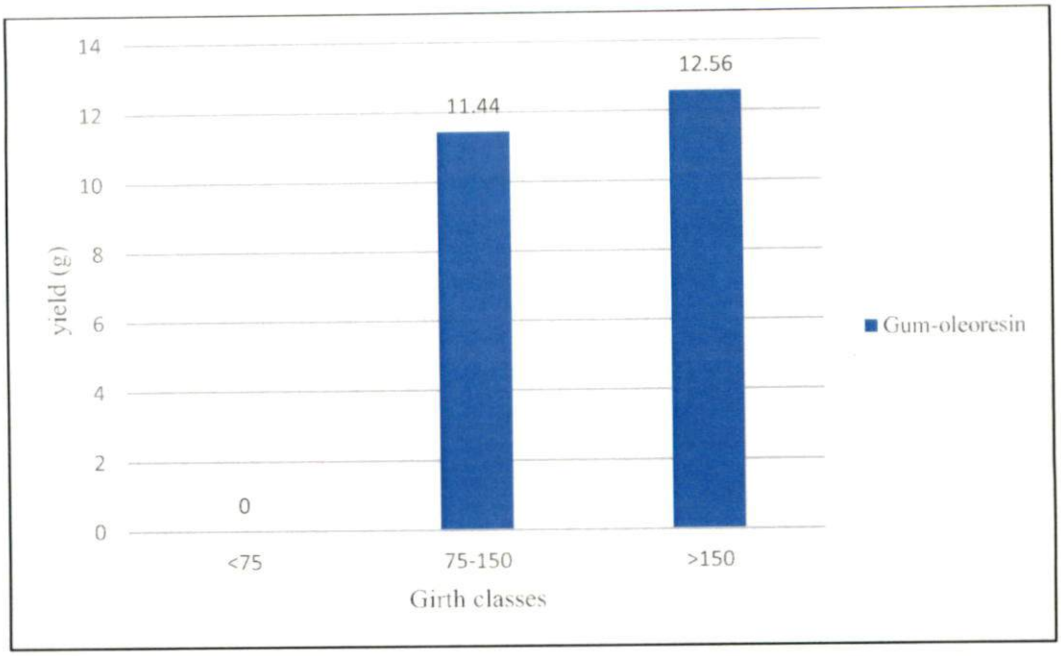


Fig 27. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during April.

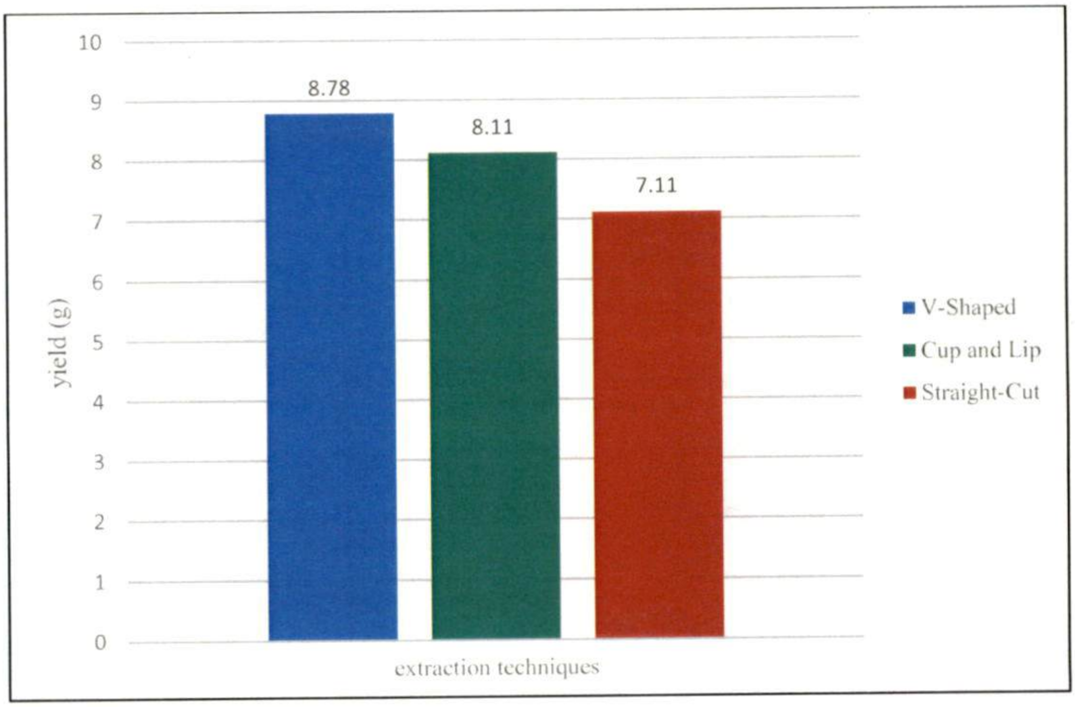


Fig 28. Gum-oleoresin yield obtained from extraction techniques in *Ailanthus triphysa*.

4.2. EFFECT OF DIFFERENT SEASON ON GUM-OLEORESIN YIELD. i.e., (MONSOON, POST MONSOON AND SUMMER SEASON).

4.2.1 Effect of monsoon season on gum-oleoresin yield.

Present study revealed that the gum-oleoresin yield from Ailanthus tree during the Monsoon or rainy season (June, July, August, and September) ranged from 3.60 g to 24.13 g for < 75 girth class, 38.10 g to 66.76 g for 75-150 girth class and 5.08 g to 61.03 g for girth class > 150. This reveals a significant difference in gum-oleoresin yield due to girth class variation (Table 13) with <75 girth class is par from 75-150 cm and >150 cm.

Similarly, the gum-oleoresin yield due to tapping method ranged from 13.76 gm to 51.20 gm in V-Shaped method, 24.13 g to 66.76 g in Cup and Lip method and 3.60 g to 50.8 g in Straight-Cut method (Table. 13). Difference in gum-oleoresin yield due to different extraction technique was found to be non-significantly different during the monsoon season. The mean value registered the highest amount of gum-oleoresin in the Cup and Lip method (50.64 g) and lowest in Straight-Cut method (30.83 g).

Table 13. Gum-oleoresin yield from *Ailanthus triphysa* during the monsoon.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-Shaped method	Cup and Lip method	Straight-Cut method	Mean yield (Girth/tree)	P-value for girth
<75	13.76	24.13	3.6	**13.83**^{a}	
75-150	44.43	66.76	38.1	**49.76**^{b}	
>150	51.2	61.03	50.8	**54.34**^{b}	0.039*
Mean yield (Tapping/tree)	**36.46**	**50.64**	**30.83**		C.D (33.22)
P-value for tapping	0.476^{ns}				

**- significant different, ns –non-significant different at 5% level*

4.2.2 Effect of gum-oleoresin yield in post-monsoon season.

Present study observed that the gum-oleoresin yield from Ailanthus tree during the Post-Monsoon season which consist of (October November, December and January) ranged from 6.93 g to 38.16 g for < 75 girth class, 60.53 g to 110.88 g for 75-150 girth class and 90.87 g to 102.43 g for girth class >150. This indicates a significant difference in gum-oleoresin yield due to girth class variation (Table. 14). The study reveals that greater girth classes ie.,75-150 cm and >150 cm was significantly different from <75 cm girth class in gum-oleoresin production.

It is also observed that the gum-oleoresin yield due to extraction techniques ranged from 16.2 g to 90.87 g in V-Shaped method, 38.16 g to 110.88 g in Cup and Lip method and 6.93 g to 102.43 g in Straight Cut method. Difference in gum-oleoresin yield due to different extraction technique was found to be non-significantly different during the Post-Monsoon season.

Table 14. Gum-oleoresin yield from *Ailanthus triphysa* during the post-monsoon season.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight-Cut method	Mean yield (Girth/tree)	P-value for girth
<75	16.2	38.16	6.93	**20.43[a]**	0.008** C.D (46.26)
75-150	60.53	110.88	69.37	**80.26[b]**	
>150	90.87	91	102.43	**94.76[b]**	
Mean yield (Tapping/tree)	**55.87**	**80.01**	**59.57**		
P-value for tapping	0.549[ns]				

***- significant different at 5% and 1% level, ns –non-significant different at 5% level.*

4.2.3 Effect of gum-oleoresin yield in summer season.

The gum-oleoresin yield from *Ailanthus triphysa* tree during the summer season which consist of (February, march April and May) was ranged from 0.67 g to 6.17 g for < 75 girth class, 19.67 g to 23.50 g for 75-150 girth class and 27.17 g to 53.17 g for girth class > 150. It indicates a significant difference in gum-oleoresin yield due to girth class variation (Table. 15).

Similarly, the gum-oleoresin yield due to tapping method ranged from 3.50 g to 27.17 g in V-Shaped method, 6.17 g to 53.17 g in Cup and Lip method and 0.67 g to 32.58 g in Straight cut method. Difference in gum-oleoresin yield due to different extraction techniques was found to be non-significantly different during the Post-Monsoon season. The mean value registered the highest amount of gum-oleoresin in Cup and Lip method (27.17 g) and lowest in V-Shaped method (17.22 g).

Table 15. Gum-oleoresin yield from *Ailanthus triphysa* during the Summer season.

	GUM-OLEORESIN YIELD (g)				
Factors	**Extraction techniques**				
Girth classes (cm)	V-shaped method	Cup and lip method	Straight cut method	Mean yield (Girth /tree)	P-value For girth
<75	3.5	6.17	0.67	**3.47^{a}**	
75-150	21	23.5	19.67	**21.39^{b}**	
>150	27.17	53.17	32.58	**37.64^{b}**	0.005^{**} C.D (14.48)
Mean yield (Tapping/ tree)	**17.22**	**27.61**	**17.64**		
P-value for tapping	0.944^{ns}				

***- significant different at 5% and 1% level, ns –non-significant different at 5% level*

4.3 EFFECT OF DIFFERENT SEASON, GIRTH AND EXTRACTION TECHNIQUE ON GUM-OLEORESIN YIELD

Present study revealed that the gum-oleoresin yield from *Ailanthus triphysa* tree during the different season (monsoon or rainy, Post-Monsoon and Summer) found to be significant different from each other. The highest gum-oleoresin yield is higher in Post-Monsoon season (65.15 g) followed by Monsoon season (39.23 g) and then in Summer season (18.08 g) (Table 16). When comparing the different girth classes and tapping method (treatment) and their effect in gum-oleoresin production it was observed that treatment (G1S1, G2C2 and G3S3) was found to significantly different from other treatment (Table.16) The highest quantity of gum-oleoresin was recorded by treatment G2C2 and G3S3 whereas lowest quantity of gum-oleoresin recorded by G1S1.

The treatment abbreviation are expanded as follows (Table 16)

G1- girth class 1 (<75 cm)

G2- girth class 2 (75-150 cm)

G3- girth class 3 (>150 cm)

V- V- Shaped extraction technique

C- Cup and Lip extraction technique

S- Straight-Cut extraction method.

Table 16. Effect of different season, girth and extraction technique on gum-oleoresin yield (g).

Treatment *season mean table					
Treatment	Monsoon	Post-monsoon	Summer	Total mean	P-value of treatment
G1V1	13.77	16.2	3.5	11.16^{ab}	
G1C1	24.13	38.17	6.17	22.82^{abc}	
G1S1	3.6	6.93	0.67	**3.73^{a}**	0.001** C.D (33.96)
G2V2	44.43	60.53	21	41.98^{bcd}	
G2C2	66.76	110.87	23.5	**67.04^{d}**	
G2S2	38.1	69.37	19.67	42.38^{bcd}	
G3V3	51.2	90.87	27.17	56.41^{cd}	
G3C3	61.03	91	28.47	60.16^{cd}	
G3S3	50.8	102.43	32.58	**61.93^{d}**	
Total mean	39.23^{b}	65.15^{c}	18.08^{a}		
P-Value	0.000** C.D (19.61)				

***- significant different at 5% and 1% level.*

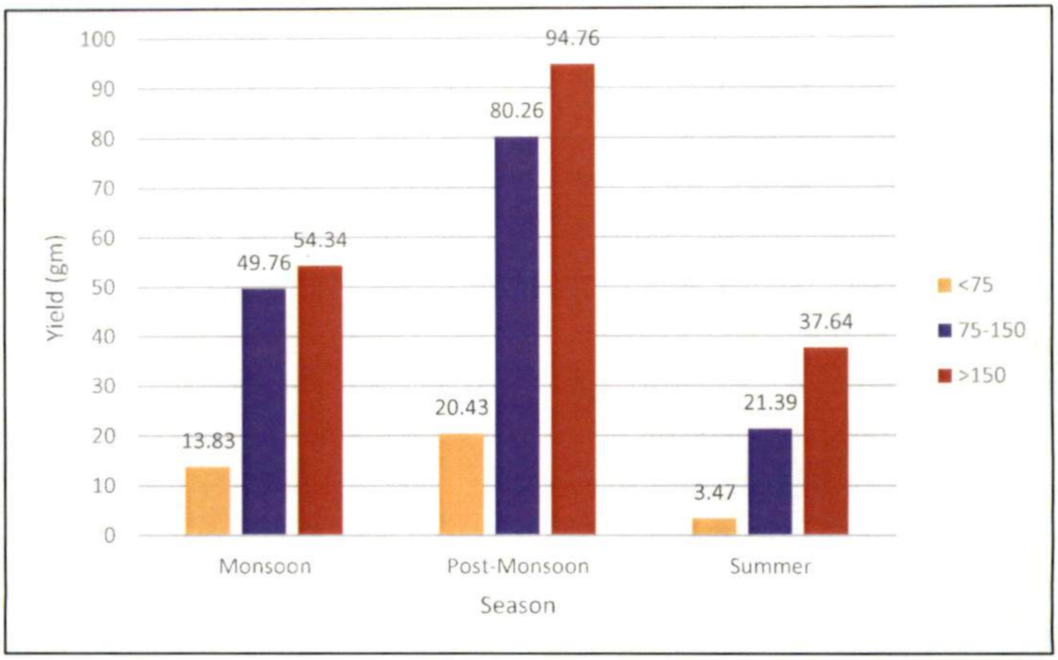


Fig 29. Gum-oleoresin yield of *Ailanthus triphysa* from its different girth classes during different seasons.

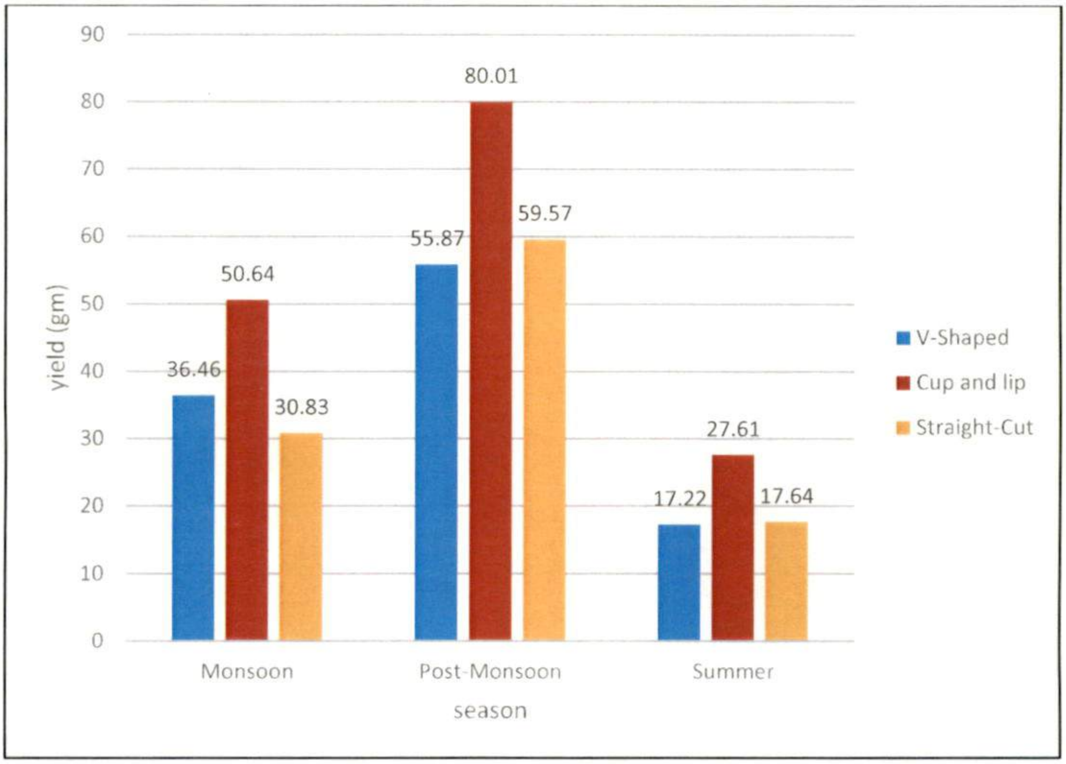


Fig 30. Gum-oleoresin yield obtained from different extraction techniques applied in different girth classes of *Ailanthus triphysa* during different seasons.

4.4 EFFECT OF GIRTH CLASSES AND TAPPING METHOD ON GUM-OLEORESIN YIELD OF ONE YEAR (MAY 2017-APRIL 2018).

Present study revealed that the gum-oleoresin yield from Ailanthus tree during the whole study period (May 2017 to April 2018) was ranged from 0.00 g to 126.55 g in an average. Among the girth classes its varied from 0.00 g to 37.33 g for less than 75 girth class, 11.44 g to 123.11 g for 75-150 girth class and 12.56 g to 126.55 g for girth class greater than 150. Data presented above shows the similar trend as it was noticed at monthly intervals. Girth classes was found to be significant different with <75 cm girth class is par from girth class 75-150 cm and >150 cm girth class.

Similarly, the gum-oleoresin yield due to different extraction technique during the twelve months starting from May 2017 to April 2018 ranged from 7.11 g to 130.99 g in an average. In the different tapping methods, it ranged from 8.78 g to 81.88 g in V-Shaped method, 8.11 g to 130.99 g in Cup and Lip method and 7.11 gm to 75.89 gm in Straight-Cut method. (Table 17, Fig 27) Statistically it was found to be non-significant difference in gum-oleoresin yield due to different tapping method followed during the study period. However, in mean of tapping method practiced, the highest amount of gum-oleoresin found in mean of Cup and Lip method (597.96 g) and the V-Shaped method and Straight-cut method yield is nearly same that is 435.84 g and 430.20 g respectively (Table 18). The October month was found be best as it produces highest amount of resin i.e., 289.98 g.

The interaction between girth classes and tapping technique found to be non-significant for all the monthly intervals analysis as well as for whole study period, that means there is no relationship between girth class and extraction techniques.

Table 17. Effect of girth classes (cm) and tapping method on gum-oleoresin yield (gm) (May 2017-April 2018)

Girth classes effect													
	May-17	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.18	Feb.	Mar.	Apr.	Total
<75 cm	11.55	12.77	14.33	4.22	23.68	37.33	26.11	7.21	8.11	2.33	0.00	0.00	147.64^{a}
75-150 cm	34.33	51.66	54.77	30.66	62.33	123.11	103.99	48.99	42.89	20.00	19.89	11.44	604.06^{b}
>150 cm	38.44	50.44	58.88	33.66	74.33	126.55	121.22	73.88	55.56	39.44	27.11	12.56	712.07^{c}
Mean	84.32	114.87	127.98	68.54	160.5	289.98	251.31	130.08	106.56	61.77	46.98	24	
P-Value	0.011^{**}												
Tapping methods effect													
V- Shaped	25.66	31.66	38.33	24.33	51.55	81.88	68.55	38.78	32.11	20.44	14.11	8.78	435.84^{ns}
Cup and lip	39.66	43.11	57.88	30.11	71.55	130.99	107.77	40.44	38.89	14.11	15.44	8.11	597.96^{ns}
Straight-cut	19.00	40.11	31.77	14.11	37.22	74.11	75.89	50.67	35.56	27.22	17.44	7.11	430.20^{ns}
Mean	84.32	114.87	127.98	68.54	160.5	289.98	251.31	130.08	106.56	61.77	46.98	24	
P-Value	0.549^{ns}												
P-Value **Interaction**	0.938^{ns}												

***- significant different at 5% and 1% level, ns -non-significant difference at 5 %*

92

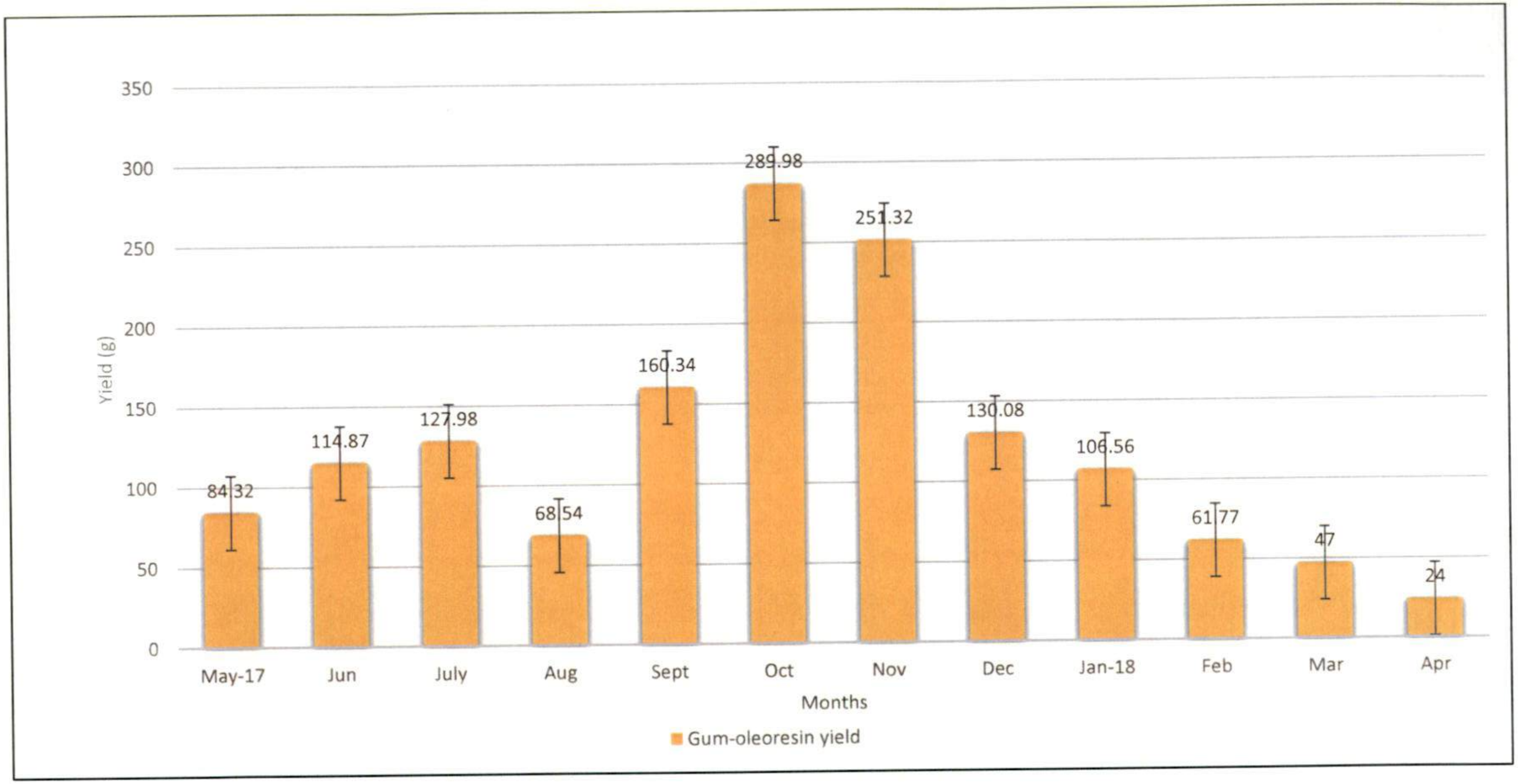


Fig. 31. Gum-oleoresin yield obtained from different month during the whole study period (May 2017 to April 2018)

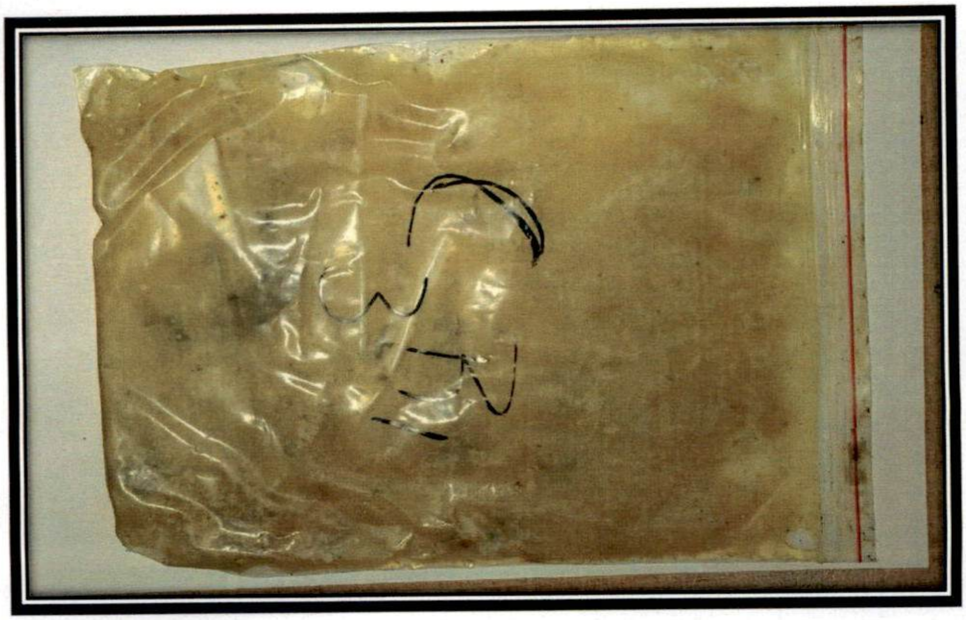


Plate 8 (a) Fresh gum-oleoresin

Plate 8 (b) Dry gum-oleoresin

Plate 8. Gum-oleoresin (a) Fresh gum-oleoresin, (b) Dry gum-oleoresin

4.5 WOOD ANATOMICAL FEATURES OF *AILANTHUS TRIPHYSA*.

4.5.1 Anatomical description of *Ailanthus triphysa* wood.

Anatomically, sapwood was not found to be distinct from heartwood as the heartwood was of same colour as sapwood. The wood is diffuse porous, growth rings are indistinct, vessels are large, their number ranges from very few to few, vessels are solitary or in radial multiples of 2, 3 or more. Parenchyma is Paratracheal in nature, vasicentric, aliform form. Fibres were non-septate; thick to thin walled.

4.5.2 Cellular description of resin production.

Sapwood anatomy shows both types of ray cells *i.e.,* uniserated and multiseriated, having procumbent body ray cells with upright cells (Plate 8. (a)) which were located adjacent to the vessels walls (Plate 8. (c)). and also it was observed that some of rays cells contained same colour substance as seen inside the vessel, seen clearly on the vessel walls in a clear note pits are observed on vessel wall (Plate 8. (b)). It was also observed that not all the vessels were filled with coloured deposit, some are filled and some are empty and some are half-filled which was clearly visible (Plate 8. (d)).

Cellular distribution of sapwood clearly shows the involvement of vessels in the deposition of gum oleoresin in the form of coloured deposits and it was also observed that there is no distinct "gum canal" and "traumatic ducts" formation, which indicates gums in vessel is produced by secretory activity of surrounding living cells, mainly ray cells (which function mainly for lateral conduction) and deposited directly into the adjacent vessel lumen through simple perforation pits as the pits are clearly seen in the vessel wall as given in the Plate 8(b).

It could also be noticed that gum-oleoresin canals were not found in the bark portion because the bark of *Ailanthus triphysa* were dry and consist of coarse yellow coloured granular structure which were visible on the sample as well as through microscope i.e., sectioning in anatomical sections (Plate 9. (b)). Even this coarser granular material often obstruct obtaining a proper anatomical section as it has tendency to break on the rotary microtome blade which is shown (Plate 9. (b)).

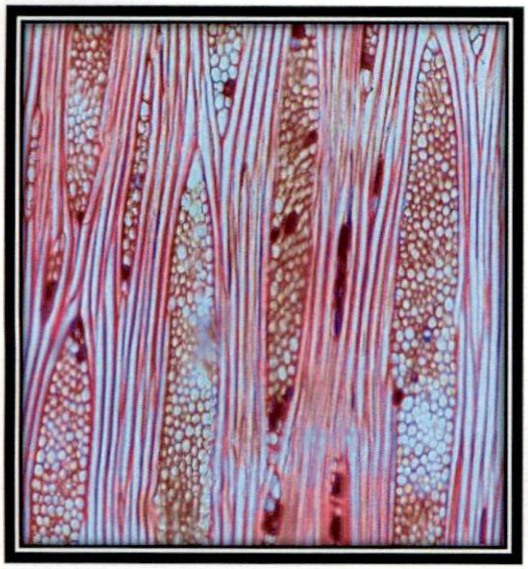


Plate 9. (a)

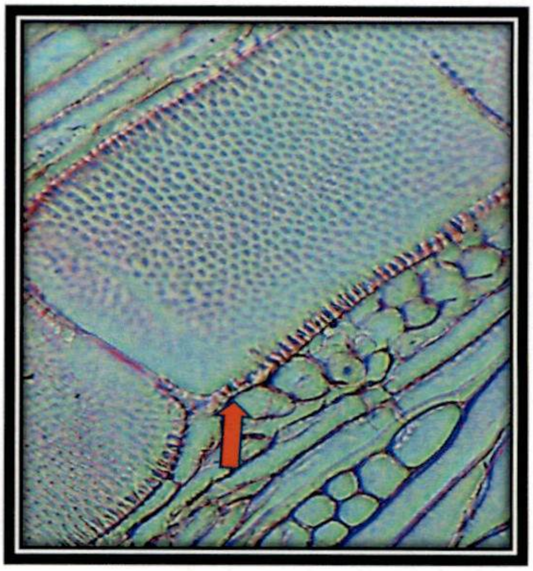


Plate 9. (b)

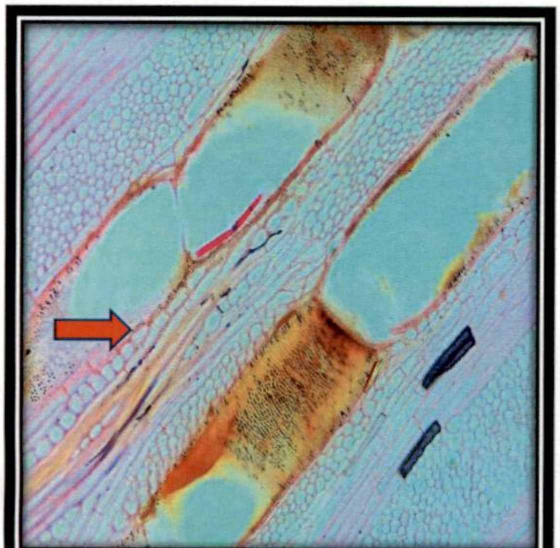


Plate 9. (c)

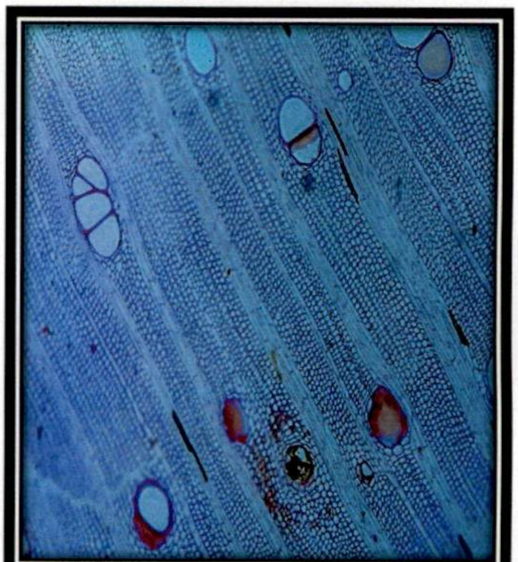


Plate 9. (d)

Plate 9. – Anatomy 8(a) End of ray parenchyma were filled with gum-oleoresin, 9(b) Pits are clearly seen in vessels. 9(c) L.S section of solidified colour deposit in Vessel. 9(d) C.S with partially filled vessels.

Plate 10. (a)

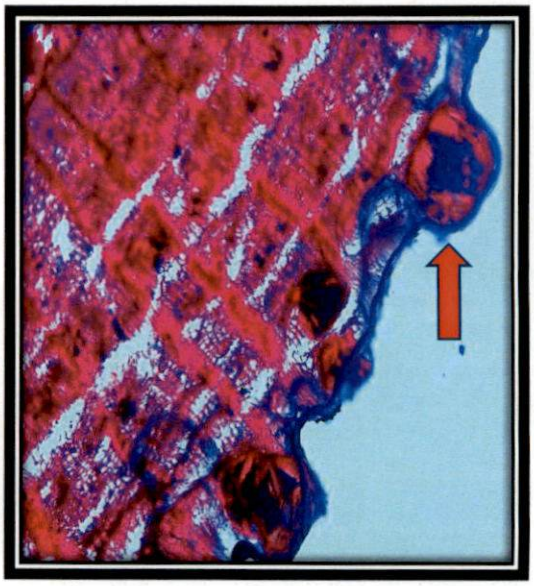


Plate 10. (b)

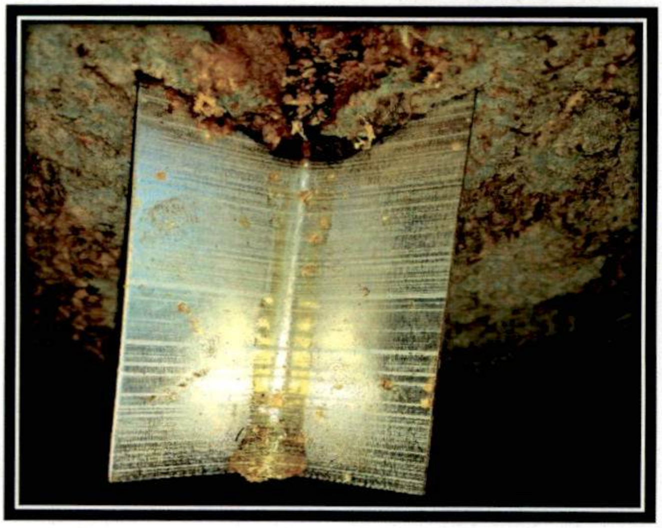


Plate 10. (c)

Plate 10.- 10 (a) bark sample with presence of coarse grain, 10 (b) anatomical section of meristem and bark with stony granules. 10 (c) yellow colour gum-oleoresin exudation from *Ailanthus triphysa.*

4.6 EFFECT OF BARK THICKNESS ON GUM-OLEORESIN YIELD.

The present study revealed that the gum-oleoresin yield from the *Ailanthus triphysa* due to different bark thickness found to be significantly different as the P value is found to be 0.00 which is significant. It was observed from the correlation studies that the girth class increases the bark thickness also increases and consequently increases the gum-oleoresin production (Table.18).

The correlation coefficient range lie between -1 to +1. In the present study correlation coefficient between girth class and bark thickness was found to be 0.82, correlation between gum-oleoresin yield and girth class was found to be 0.69 and correlation between gum-oleoresin yield and bark thickness was found to be 0.65 which is nearer to 1. It indicates that positively correlated with the gum-oleoresin production that means greater the girth class greater the bark thickness, consequently greater the gum-oleoresin production.

Table 18. Effect of girth classes, bark thickness on gum-oleoresin production

		Bark thickness (cm)	Girth class (cm)	resin yield (g)
Bark thickness (cm)	Pearson correlation	1		
	Sig. (2-tailed)			
	N	27		
Girth class (cm)	Pearson correlation	0.82**	1	
	Sig. (2-tailed)	0.00		
	N	27	27	
Gum-oleoresin yield (g)	Pearson correlation	0.65**	0.69**	1
	Sig. (2-tailed)	0.00	0.00	
	N	27	27	27

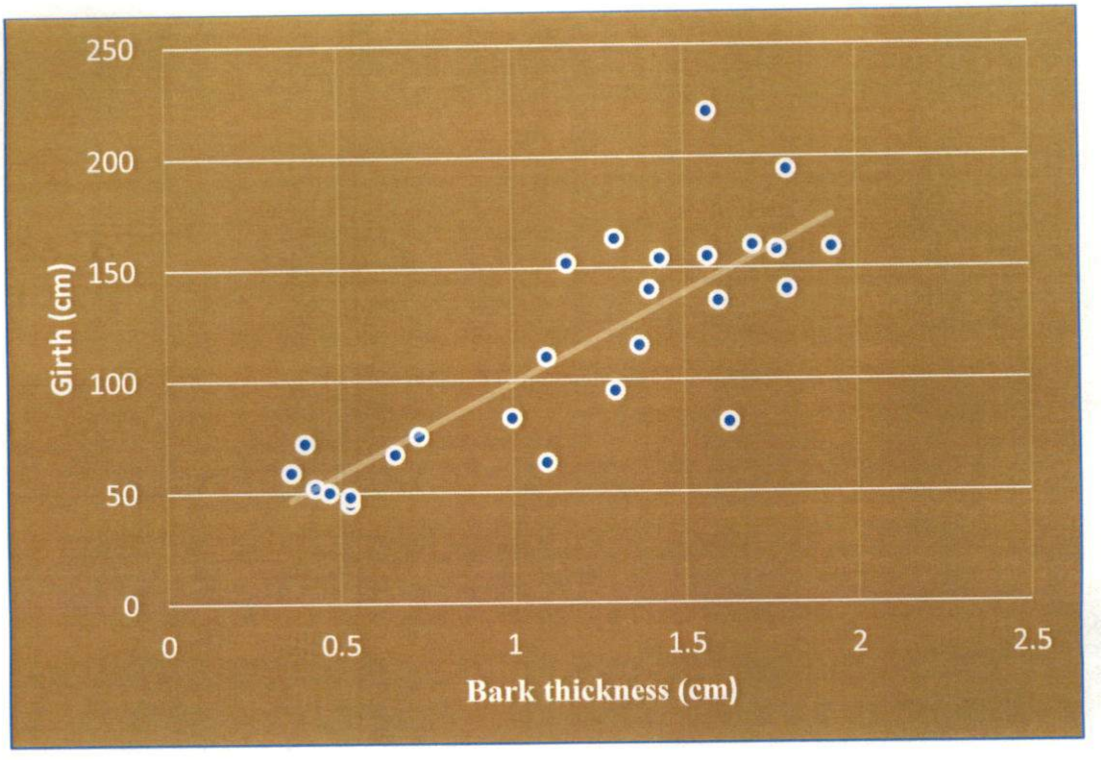


Fig 32. Correlation between girth and bark thickness (r = 0.82**).

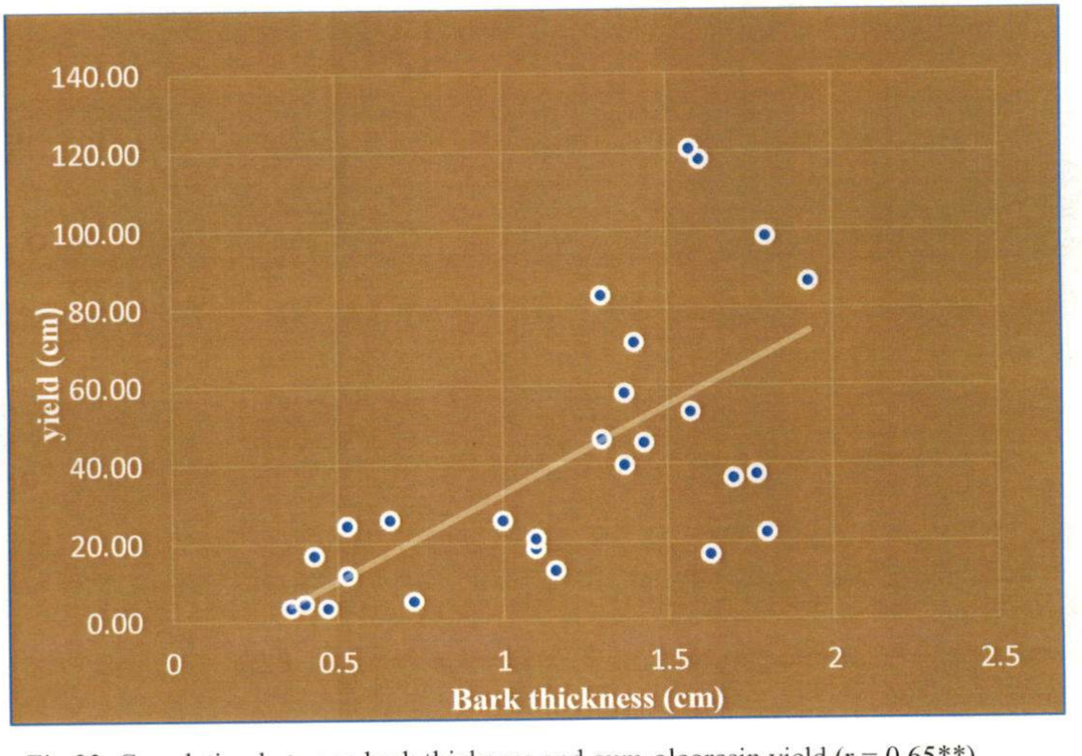


Fig 33. Correlation between bark thickness and gum-oleoresin yield (r = 0.65**).

4.7 EFFECT OF CLIMATIC PARAMETER IN GUM-OLEORESIN PRODUCTION.

Based on the correlation studies, none of the climatic parameter found to be non-significant in gum-oleoresin production, However, temperature correlation coefficient (-0.53) which negatively correlated at 10 % significant level (Table. 19). Similarly, the present study revealed that other climatic parameters like relative humidity, rainfall, rainy days, sunshine hours and windspeed are found to be correlated as the r Value is not zero but it was found to non-significant it might be due to less number of observation as the study period consist of twelve months only.

Table 19. Correlation studies of meteorological parameters with gum-oleoresin production

		Mean tempt (^{0}C)	Mean RH(%)	Rainfall (mm)	Rainy days	Mean sunshine hours	Mean wind speed (Km/hr)	Resin yield (gm)
Gum-oleoresin yield (g)	Pearson correlation	-0.53	0.38	0.30	0.36	-0.41	-0.49	1
	Sig.(2-tailed)	0.08	0.221	0.34	0.25	0.19	0.11	
	N	12	12	12	12	12	12	12

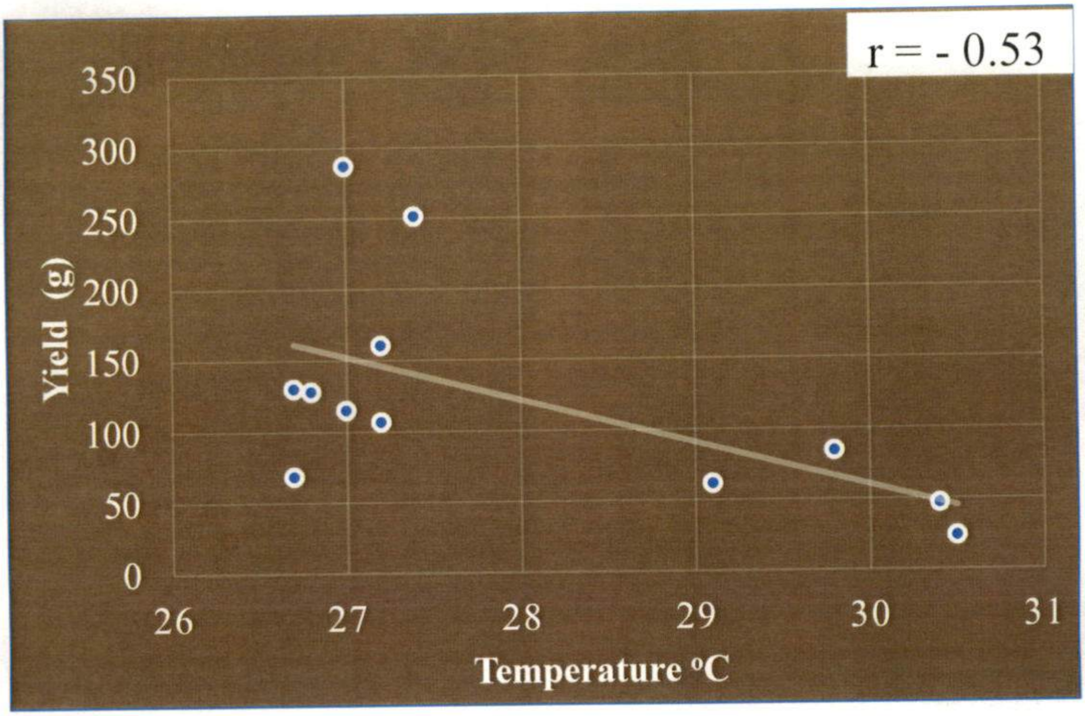


Fig 34. Effect of temperature on gum-oleoresin yield

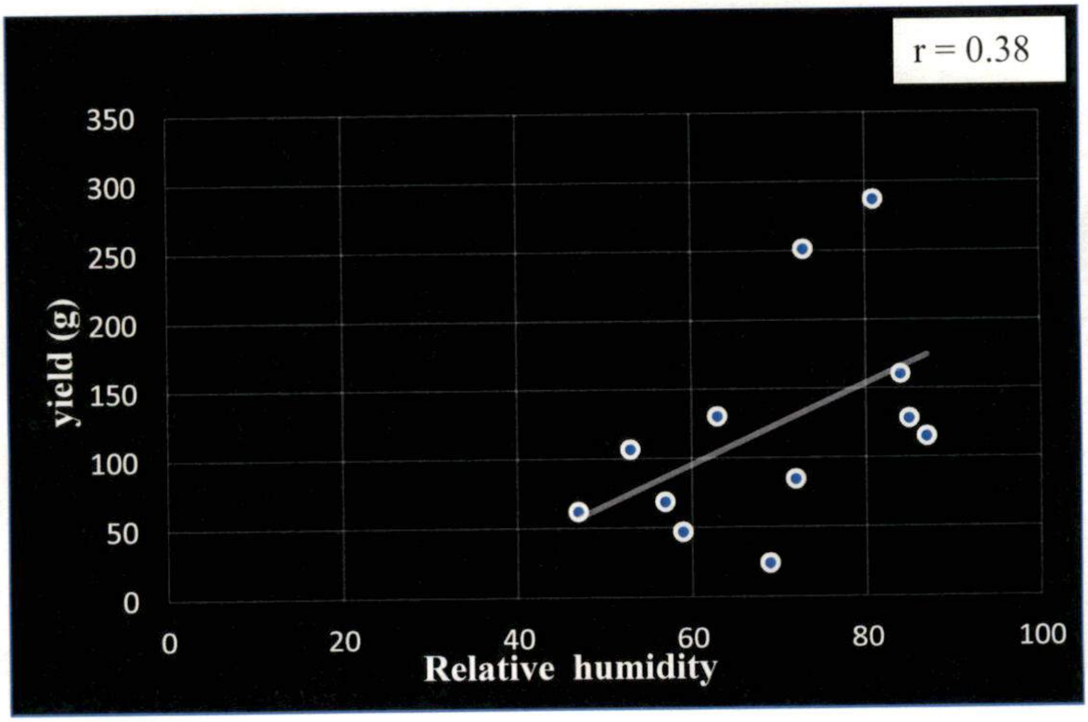


Fig 35. Effect of relative humidity on gum-oleoresin yield

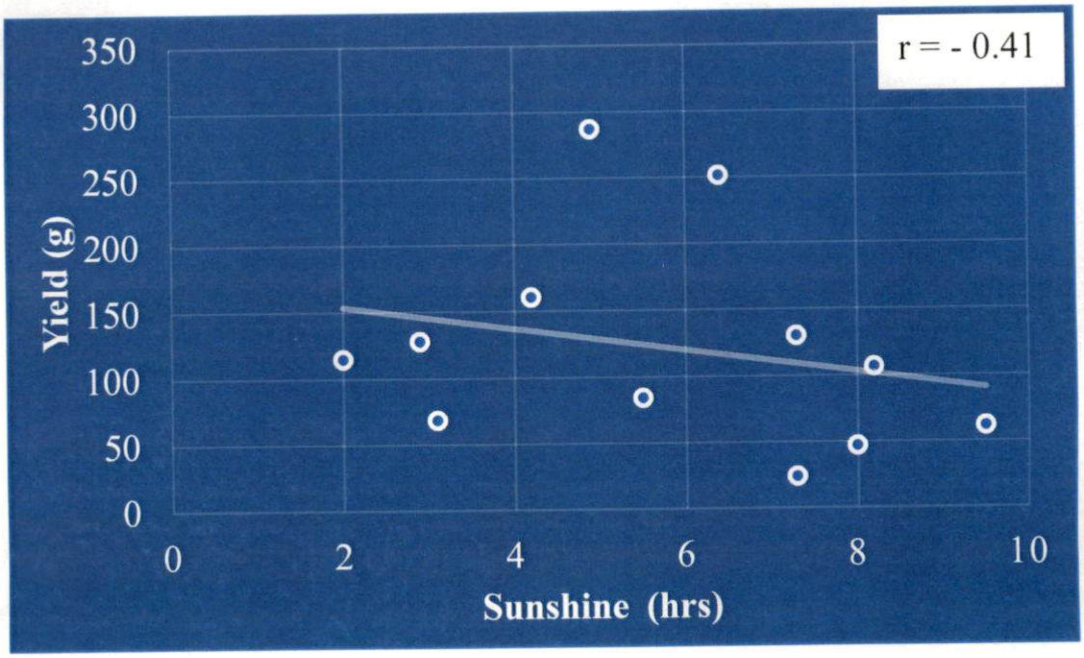


Fig 36. Effect of sunshine (hrs) in gum-oleoresin yield

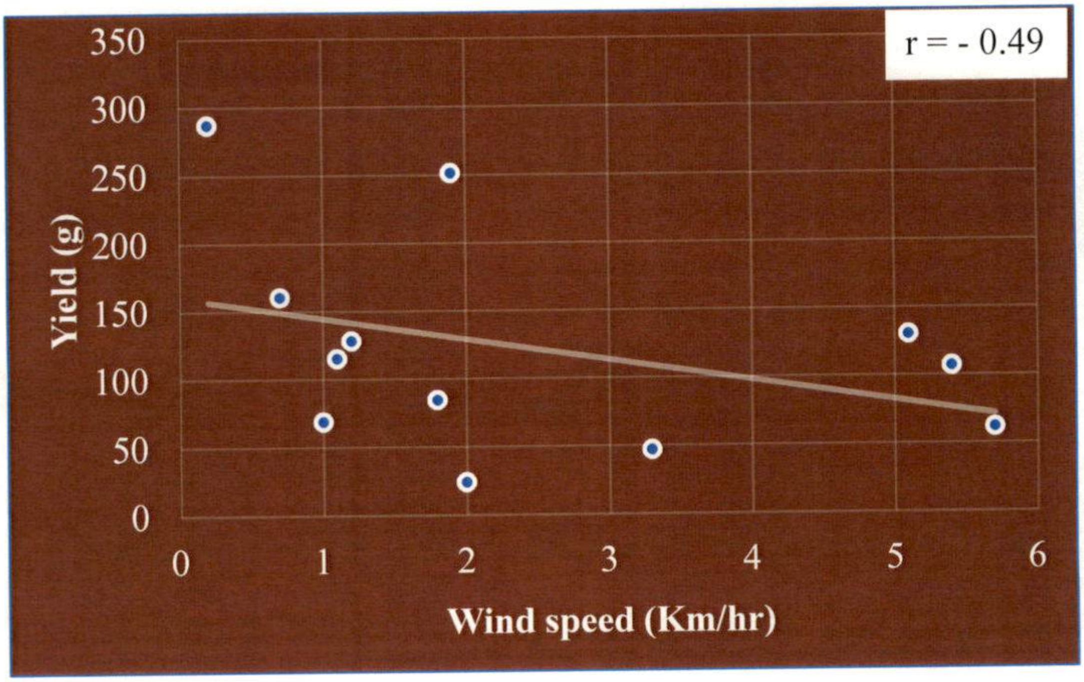


Fig 37. Effect of wind speed in gum-oleoresin yield

DISCUSSION

DISCUSSION

Data generated on the gum-oleoresin yield from *Ailanthus triphysa* tree grown in Instructional Farm, College of Forestry, Kerala Agricultural University under three different girth classes (<75 cm, 75-150 cm, >150 cm) and with three different extraction techniques (V-Shaped method, Cup and lip method and Straight-cut method) and the anatomical findings of *Ailanthus triphysa* wood are discussed here under following headings:-

- Effect of dimensional properties on gum-oleoresin yield.
- Effect of different extraction techniques on gum-oleoresin yield.
- Anatomical features of *Ailanthus triphysa* wood.
- Effect of bark thickness on gum-oleoresin yield.
- Effect of climatic parameter gum-oleoresin yield.

5.1 EFFECT OF DIMENSIONAL PROPERTIES ON GUM-OLEORESIN YIELD.

Gum-oleoresin production at monthly intervals showed a significant variation with regards to tree dimensions. It was observed that <75 girth class produced lesser gum-oleoresin compared to >75. The same findings were observed by many researchers and this could be due to more number of vessels and rays cells in trees with greater diameter. Grithlare (2017) and Das *et al.* (2014) reported that gum production was positively correlated with tree girth. Arya and Chaudhary (2002) had reported five times more gum yield (88 g) in 52 months old irrigated trees having higher girth than control (18 g). Therefore, girth is a suitable criteria for selecting a tree for gum tapping.

Unanaonwi and Bada (2013) also found similar effect of girth on gum yield of gum arabic *(Acacia senegal)*. Three girth classes were selected for study and results showed that the gum yield increased as tree girth goes higher from 35-54 cm (163.6 - 209.7 g). Tree girth significantly affected gum yield ($p <= 0.05$) and tree girth higher than 54 cm (maximum of 65 cm) produced the highest mean gum yield. Sharma and Prasad (2013) found similar result in both the mechanical and chemical methods of gum tapping techniques in *Sterculia urens* that higher diameter of tree yields more gum.

Vidyasagaran *et al.* (2016) reported similar result in *Canarium strictum* and *Vateria indica.* The rate of gum exudation from different girth classes found to be significantly different in both the tree species. They obtained highest amount of resin from trees in >150 cm girth classes, followed by 100-150 cm girth classes, then 50- 100 cm and least in <50 cm girth classes in both the tree species. Sharma and Dutt (2016) studied six diameter class (D1 to D6) in *Pinus roxburgii* and reported that maximum oleoresin yield was obtained from diameter class of >55 cm. Similar result was found in *Pinus kesiya* that oleoresins yield was maximum for >50 diameter class followed by 40-50 diameter class and least in 30-40 diameter class (Mahapatra *et al.,* 2017).

5.2 EFFECT OF EXTRACTION TECHNIQUES ON GUM-OLEORESIN YIELD.

Millions of people worldwide depend on the harvest of non-timber forest products (NTFP) for their livelihoods. The importance of understanding the complex relationships between NTFP harvest and conservation is increasingly recognized because an increase in the consumption of NGRs critically affect its biodiversity, thereby a multitude of indigenous plants are in the verge of extinction (Varghese *et al.,* 2008). This was mainly due to wide variation in harvesting pattern and resin collection in different trees species in different locality. Varghese *et al.* (2008) reported three different pattern of resin harvesting was observed *Canarium stritum.* The first type involves the collection of resin formed natural fissures of tree, the second type of resin collection by making incisions to promote resin flow (largely employed by harvesters), the third type of resin-collection strategy involves setting a low fire at the base of the tree followed by incisions and resin collection. Its indicates there is no standard method of tapping in tree species.

In the case of *C. strictum*, several authors have expressed concerns that populations are disappearing due to tapping practices (Kannan, 1992, Augustine and Krishnan, 2006), similar report has been given by Bhatt *et al.* (1989) in *Commiphora wightii*. So, standardisation of tapping techniques should be evolved for all the gums and resins yielding tree species so that their population can be conserved. A good effort was taken by Indian Council of Agricultural Research (ICAR) for evolving a standard tapping method for all gums and resin tree species.

The exudate of *Ailanthus triphysa* (Halmaddi) has much use from the ancient times, and recently had become important in national and global gum/gum-resin trade because of its immense medicinal, confectionary, and other uses. But owing to lack of adequate scientific technique of tapping and collection procedure, it has become difficult to optimize the utilization of this indigenous natural resource. The present study reveals that extraction techniques had non-significant effect on gum-oleoresin production (Table 17). The mean value registered highest for the Cup and Lip method followed by V-Shaped method and least in Straight-Cut method. this might be due to several reasons 1) The length of injury of all the tapping methods were appropriately same dimensions. 2) it might be due to genetic variation present among the samples trees where the experiment was conducted. 3) the experiment was conducted on small number of populations i.e., only 27 trees. 3) It might be because of the intensity of injury and also due to the horizontal cut of all different types of tapping methods as it was substantiated by the anatomical studies (Plate 4). Since the alignment of vessel are vertical. The resin flow is more when the cut is applied on the horizontal direction.

It might be due to rapturing of vessels, because each anatomical trait, or combination of traits, plays a role in favouring one or more xylem functions, namely water transport, mechanical stability, biological defence, and storage and mobilisation of metabolites (Beeckman, 2016). Kathe *et al*. (2010) also reported a new "Rill Method" for obtaining *Ailanthus triphysa* resin involving specially designed tools to increase resin production. This method was highly successful and resulted in sustainably produced resin of exceptional quality in Karnataka which gives more quantity from traditional method of tapping.

Similar Cup and lip method of extraction technique is famous in rubber for extracting its latex and practiced throughout India which was standardised by Rubber Research Board, Kerala. The availabitity of literature on tapping techniques in Ailanthus was not found but others gums and resins producing trees species were seen. In *Canarium strictum,* Vidyasagaran *et al*. (2016) found that strip cut method to be more efficient in resin extraction. As in this method, a small portion of bark was removed from canarium tree and half blown polythene cover was fixed underneath the cut for collecting the gum.

Similarly, Vashishth (2017) evolved Bore-hole method as standard tapping-techniques for gum extraction in *Lannea coromendelica*. Similar result was found by (Sharma and Dutt, 2016 and Mohapatra *et al.,* 2016 for *Pinus roxburgii* and *Pinus kesiya* respectively.

5.3 ANATOMICAL FEATURES OF *AILANTHUS TRIPHYSA* WOOD.

Analysis of wood anatomical features of *Ailanthus triphysa* revealed the absence of specialised wood "gum canal" or "gum ducts" in the sap wood as is mostly found in other trees species which exudate gums and resins. However, light yellow coloured deposits were frequently found inside the vessels and the gum-oleoresin exudate was of same colour. It's indicates that the light yellow coloured material seen inside the vessel was gum-oleoresin. Natural phenomena called "vessel occlusion" which can occur through tyloses or gums deposition, with aging and heartwood formation, however in sapwood, it is seen in response to vessel embolism. These types of vessel occlusion play a crucial role to limit the spread of pathogens and wood decay organisms. In the sapwood, they can be considered an effective stress response as they form part of compartmentalization after wounding. Similar finding was reported by De Micco *et.al.* (2016). Catesson and Moreau (1985) has also described that gums as amorphous material do occlude vascular tissues or intercellular spaces. Hillis (1987) also reported that many secondary metabolites stored in vessels have been referred to as gums, although they are not water-soluble compounds as gums are by definition.

Further analysis of the sapwood anatomy of *Ailanthus triphysa* revealed that the deposition found in vessels might have occurred through the pits (as the surrounding cells were also filled with same colour deposition and looks little degenerated) by radial conduction that is mainly done through radial parenchyma, which usually takes place across the diameter. Bonsen and Kučera (1990) and Bonsen (1991) also found that, like tyloses, gums occluding vessels derive from contact parenchyma cells. Gums in vessels can be either produced by the secretory activity of surrounding living cells (mainly ray cells) and deposited directly into the adjacent vessel lumen, or more rarely, can be secreted by a previously formed tylosis as in *Eucalyptus blakleyi* (Chattaway, 1949). Like tyloses, gums have been reported by many authors as occurring both in heartwood and sapwood, either due to natural aging or to factors triggering embolism. The appearance of gums in heartwood has been categorised into four groups: 1) partitions across the vessel lumen, 2) irregular lumps on the inner vessel wall, 3) small droplets on the vessel-parenchyma pits, and 4) thin layers lining the inner vessel wall (Saitoh *et al.,* 1993). The present study showed a pattern of deposition of gum-oleoresin in sapwood which represent the gum-oleoresin as irregular lumps on the inner vessel wall. It was also found as thin layers lining the inner vessel wall in some of the vessel lumen. Similar appearance of gums and tyloses was observed in heartwood of many trees species (Saitoh *et al.,* 1993).

Similarly, the present study also revealed that the inflow of gum-oleoresin through the pits in radial conduction. As the gum-oleoresin are found on the vessel wall which proves that vessel occlusion is mainly to provide immunity to plants. The vessels are water conducting tissues in which suction power is more than any other tissue present in plant. So when the tree is wounded, in self-defence some of the radial parenchyma will degenerate and move through the pits. It enter the vessel so the opening space could be blocked so that less pathogen can enter inside the vessel (vessel occlusions) which prevent spreading of pathogens as it form an obstruction. Vessel occlusion can be due to the formation of tyloses or due to the deposition of gums. Although a common feature of heartwood, these organic occlusions can also occur in sapwood both normally and after wounding (Gerry, 1914; Klein, 1923; Murmanis, 1975). This view is also supported by Rioux *et al.* (1998). Gums produced in response to fungal attack, phenolic fungitoxic substances have been reported both filling the tyloses and in the suberised layer. Phenolics, anti-feeding deterrents, can be variously located in plant tissues and have been observed also in vessels of young twigs of *Rhamnus californica* (De Micco and Aronne, 2012).

Similar, immunocytochemical studies of *Populus basalmifera*, *Ulmus americana,* and *Quercus rubra* led Rioux *et al*. (1998) to hypothesise that gum production can be related to tyloses formation. They found that antibodies directed against pectins labelled a material both present in the external layer of the tyloses middle lamella and accumulating outside it, particularly in pit chambers.

The same authors suggested a mechanism of secretion of pectic substances across the tylosis primary wall since both the latter and some other compounds within the tyloses were intensely labelled for pectins. Such a mechanism could be similar to that associated with the formation of gums in vessel elements. (Rioux *et al.*, 1998).

5.5 EFFECT OF BARK THICKNESS ON GUM-OLEORESIN YIELD

Bark is a term loosely applied to the outermost covering of tree stems. It can be defined anatomically as the complex of tissues located outside the vascular cambium, generally includes both live and dead cells produced by two cambia, sometimes supplemented by the products of continued cell division in primary tissues. Furthermore, the components of bark develop from different primary tissues in shoots and roots. Thus, treating bark as a single unit can obscure important aspects of biochemistry, physiology etc. As the inner bark is produced by and therefore adjacent to the vascular cambium which is composed of living secondary phloem, the tissue responsible for translocation of photosynthates and other metabolites around trees and shrubs (Romero, 2006). Beeckman (2016) reported each anatomical trait, or combination of traits, plays a role in favouring one or more xylem functions, namely water transport, mechanical stability, biological defence, and storage and mobilisation of metabolites.

Based on the correlation studies, it indicates that bark thickness and girth of tree is positively correlated with the gum-oleoresin production that means greater the girth class greater the bark thickness, consequently greater the gum-oleoresin production. It might because of the greater girth tree has more thickness of bark. Responses to stem damage might be another reason which involve interactions of anatomical, phylogenetic, physiological, and ecological factors. Very few literature are available pertaining gum-oleoresin yield with bark thickness production.

5.5 EFFECT OF CLIMATIC PARAMETER GUM-OLEORESIN.

The rate of gum exudation was found to be more in post-monsoon season followed by rainy season and least in summer season (Fig. 25 and Fig. 26). It indicates that the seasonal changes has more influence on gum-oleoresin production as many meteorological factors or parameters changes from one season to another season. It might be due to the process of gummosis which is very much influenced by the temperature and relative humidity as in general, peak gum production is apparently as the rainy season ended and air temperature rises. This was supported by many researchers that relative humidity and temperature has major role in gum-oleoresin production as its has direct effect on secondary metabolism. Tewari *et al.* (2014) reported that many of the gum yielding tree species produce gums in dry period. However, present study revealed that there is no significance different between various climatic parameters with gum-oleoresin production. But for temperature, it can be told at 10% significance level it is negatively correlated. Tewari *et al.*, (2014) found similar result in *Commiphora wightii* (guggul) where with an increase in temperature, the production of oleo-gums-resin decreased sharply. The present study also revealed that others climatic factors like relative humidity, sunshine hours and wind speed are correlated as their r value is not zero but they found to be non-significant (Table 19) it might be due to 1) Few number of samples trees on which experiment was conducted. 2) the study period was 12 months. 3) the experiment was conducted on trees having genetic variation.

The post monsoon period produces more resin than rainy and Summer seasons which indicates the gum-oleoresin production is more when relative humidity is higher. It might be due to Kerala receive rainfall from North -East monsoon. Similar trial was done by Tewari *et al.* (2014) in *Acacia senegal* and *Acacia tortilis* which yield less amount that is (15-25gm/tree) in traditional tapping techniques which when experimented with CAZRI gum inducer + irrigation + manuring which resulted in more production of gums. This means irrigation plays an important role in increasing the production of gums as it might increased the relative humidity of nearby area. Ballal *et al.* (2005a) have also reported that highest yield per tree in all types of stands is obtained in early (1 October to 1 November) tapping. Dione and Vessal (1998) that the temperature variations and effect on gum yield reported similar result. The low temperature and high temperature at tapping seems to seal off the gum exudation points.

Ailanthus triphysa flowering in India and Nepal is between February and March, fruiting follows in April-May (Orwa *et al.*, 2009: Chandrasekar, 1996) which is reported as the energy demanding process like bud growth/shoot development occurs during this period. The present study also found that maximum gum-oleoresin yield obtained in post monsoon and monsoon seasons. It clearly indicates that the reserve metabolities are understandly high in wood parenchyma in post-monsoon and monsoon season where no phenological events take place.

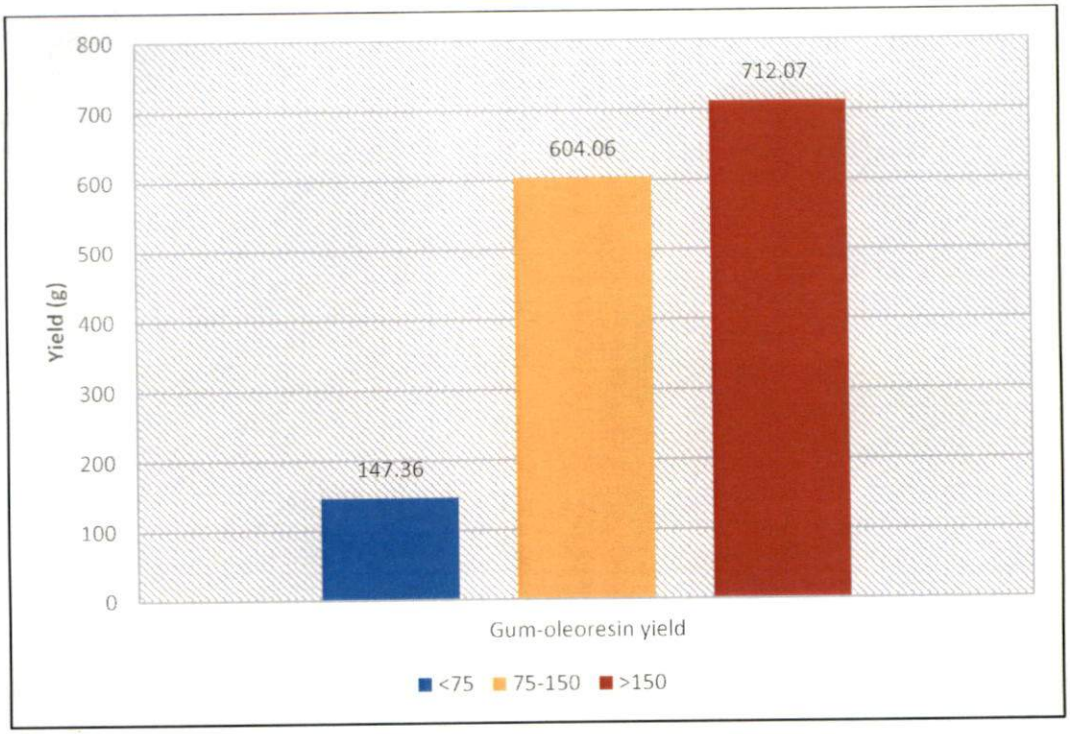


Fig 38. Effect of girth classes on gum-oleoresin yield.

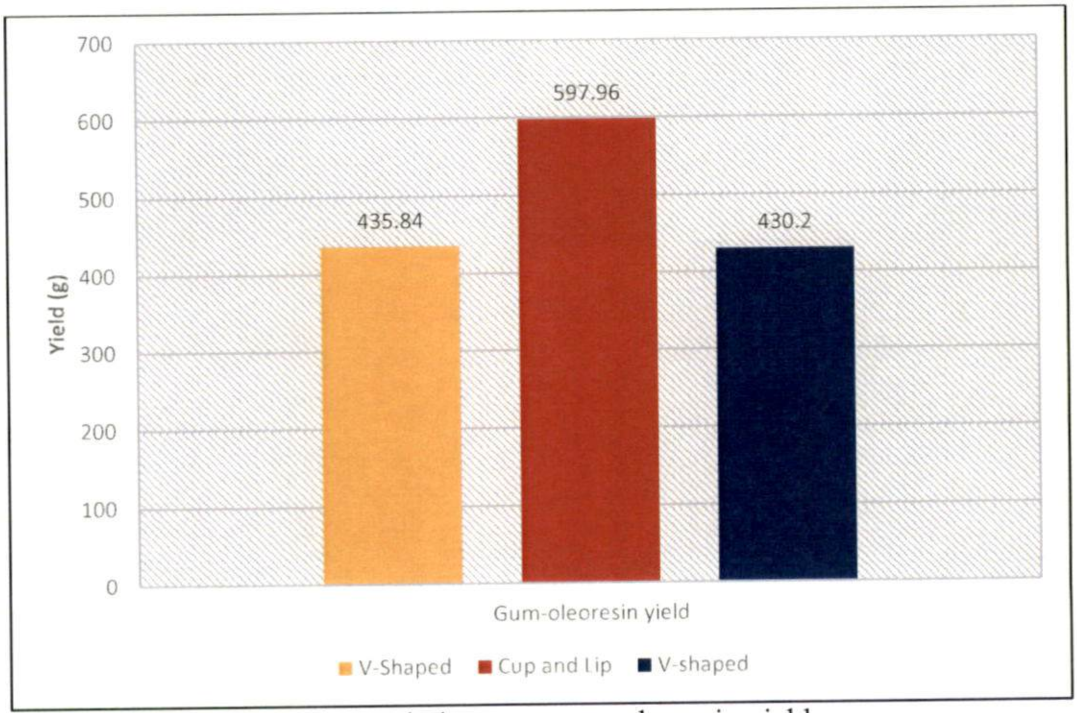


Fig 39. Effect of extraction techniques on gum-oleoresin yield

5.6 CONCLUSION

Standardisation of extraction technique in *Ailanthus triphysa* is very important in the present context for their future survival because the traditional extraction techniques used are brutal and injurious to the plants, often leading to their death. The technology available is old and the innovations are essential for sustainable yield and quality control. Synthetic products are preferred by the industry because of the uncertain supply and cost of natural gums. However, unstable oil prices, decreased production and high costs of the synthetic material create a promising future for natural gums and resins. In spite of the competition from synthetic products, natural gum and resins are preferred in certain industries as they are superior.

In the present study, all the three extraction techniques (V-Shaped method, Cup and Lip method and Straight-Cut method) was found to be non-significantly different from each other. It indicates all the three methods are not influencing gum-oleoresin yield hence all extraction techniques can be used. However, on the basis on mean value the Cup and Lip Method was found to best across all the girth classes (<75 cm, 75-150 cm, >150 cm). This also supported by the anatomical findings as the alignment of vessel are vertical. Tapping can be done in opposite direction of vessel alignment in order to extract more gum-oleoresin. It is assesing suitable method for extraction because the trees distributed only in Western Ghats in India where rubber plantation are found abundantly and this Cup and Lip method is modification of Rubber tapping. So, since people of south are acquainted with rubber tapping adopting this method in *Ailanthus triphysa* will be much easier.

The present study observed that the <75 cm girth class trees are producing negligible quantity of gum-oleoresin. So, trees with girth above 75cm should be prefered for gum-oleoresin tapping in *Ailanthus triphysa*. The present study also revealed that the gum-oleoresin production are more in post monsoon and monsoon season. The tree can be tapped during this period whereas summer season can be kept as rest period.

The study also revealed that some trees having girth >75 girth class also not producing good quantity of gum-oleoresin which clearly indicates that there is need to research into genetic variation, genetic improvement and selection of species for production of gums and resins. Therefore, establishment of plantation of these species that will be commercially viable so that common people can go for establishment of gums and resin trees species. Gum and resin industry can provide employment and a steady additional income to rural people and thereby stop their migration into the towns and cities. Sustainable extraction technique will lead to sustained production of gum-oleoresin. By adopting sustainable extraction technique we can contribute in **Sustainable Development Goals** (No poverty, Zero hunger, Good health, Good education, Climate action) **Goals To Transform the World.**

SUMMARY

SUMMARY

The study on standardisation of extraction technique of gum-oleoresin in Matti (*Ailanthus triphysa* (Dennst.) Alston.) carried out at Instructional Farm, College of Forestry, KAU, Vellanikkara revealed significant information on gum-oleoresin yield based on the influence of girth classes and tapping methods in 25 years old *Ailanthus triphysa* plantation. The study also explored the anatomical features with gum-oleoresin production. The results obtained from the study are summarized in this chapter.

1. The gum-oleoresin yield of *Ailanthus triphysa* in monthly intervals was found to be significantly different in every months (except August) due to different girth classes and it was mostly found that the tree with girth <75 cm was significantly different from 75-150 cm and >150 cm girth class. Extraction techniques were found to be non-significantly different. However, most of the months, Cup and Lip method of extraction technique produced more gum-oleoresin compared to other two techniques. Overall rate of gum exudation (g/tree/month) was observed in their decreasing order: Oct (96.66 g) >Nov (83.77 g) >Sept (53.5 g) >Dec (43.36 g) >July (42.66 g) >June (38.29 g)> June (38.29 g) >May (28.1 g) > Aug (22.84 g) >Feb (20.59 g) >Mar (15.66 g) >Apr (8.00 g).

2. The exudation of gum-oleoresin was found to be more in post-monsoon, followed by monsoon and least during summer. In all the seasons same trends was observed in gum-oleoresin production across different girth classes. On comparing different extraction techniques with girth class (treatment) to three different seasons (monsoon, post-monsoon and Summer). The treatment (G1S1, G2S2 and G3S3) are found to be significantly different from other

treatment. G1S1 record for lowest yield (3.73 g) whereas G2C2 and G3S3 record for highest yield (67.04 g and 61.93 g) respectively.

3. The rate of gum exudation (g) was maximum in the month of October in all the experimental trees for all the different girth classes. *i.e.* <75 cm girth class, 75-150 cm girth class and >150 cm girth class in the experimental year 2017 and 2018. Amongst the different girth classes, the highest amount of gum-oleoresin was obtained from >150 girth class (59.34 g) whereas (50.33 g) in 75-150 girth class and least in <75 girth class (12.3 g) only.

4. Anatomical study indicated that the gum-oleoresin deposition in vessels through the pits was present on the walls of vessels and the ray parenchyma play an important role in production of gum-oleoresin as the rays are mainly meant for radial conduction.

5. The correlation studies of bark thickness on production of gum-oleoresin was found to be significant with correlation coefficient 0.65.

6. All the climatic parameters were found to be non-significant on production of gum-oleoresin. The temperature was found to be effected negatively on gum-oleoresin production.

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APPENDICES

Appendix

ANOVA TABLE FOR ANALYSIS ON MONTHLY INTERVAL BASIS.

Tests of Between-Subjects Effects

MAY

	Sum of Squares	df	Mean Square	F	Sig.
girth	3796.963	2	1898.481	8.983	.002
tapping	2067.630	2	1033.815	4.892	.022
girth * tapping	185.037	4	46.259	.219	.924
replication	85.852	2	42.926	.203	.818
Error	3381.481	16	211.343		
Total	30741.000	27			
Corrected Total	9516.963	26			

JUNE

	Sum of Squares	df	Mean Square	F	Sig.
girth	8848.963	2	4424.481	5.037	.020
tapping	636.741	2	318.370	.362	.702
girth * tapping	1201.481	4	300.370	.342	.846
replication	1814.296	2	907.148	1.033	.379
Error	14053.704	16	878.356		
Total	66077.000	27			
Corrected Total	26555.185	26			

JULY

	Sum of Squares	df	Mean Square	F	Sig.
girth	10817.852	2	5408.926	3.226	.067
tapping	3252.519	2	1626.259	.970	.400
girth * tapping	871.037	4	217.759	.130	.969
replication	6222.519	2	3111.259	1.855	.189
Error	26830.815	16	1676.926		
Total	96806.000	27			
Corrected Total	47994.741	26			

AUGUST

	Sum of Squares	df	Mean Square	F	Sig.
girth	4636.222	2	2318.111	2.387	.124
tapping	1156.222	2	578.111	.595	.563
girth * tapping	520.222	4	130.056	.134	.968
replication	3658.667	2	1829.333	1.883	.184
Error	15541.333	16	971.333		
Total	39658.000	27			
Corrected Total	25512.667	26			

SEPTEMBER

	Sum of Squares	df	Mean Square	F	Sig.
girth	12535.407	2	6267.704	4.659	.025
tapping	5280.519	2	2640.259	1.963	.173
girth * tapping	81.481	4	20.370	.015	.999
replication	6037.852	2	3018.926	2.244	.138
Error	21523.481	16	1345.218		
Total	122686.000	27			
Corrected Total	45458.741	26			

OCTOBER

	Sum of Squares	df	Mean Square	F	Sig.
girth	45867.630	2	22933.815	5.554	.015
tapping	16985.185	2	8492.593	2.057	.160
girth * tapping	8249.037	4	2062.259	.499	.737
replication	21441.185	2	10720.593	2.596	.106
Error	66063.481	16	4128.968		
Total	410520.000	27			
Corrected Total	158606.519	26			

NOVEMBER

	Sum of Squares	df	Mean Square	F	Sig.
girth	45196.222	2	22598.111	5.220	.018
tapping	7874.667	2	3937.333	.910	.423
girth * tapping	3428.444	4	857.111	.198	.936
replication	19554.667	2	9777.333	2.259	.137
Error	69262.667	16	4328.917		
Total	340902.000	27			
Corrected Total	145316.667	26			

DECEMBER

	Sum of Squares	df	Mean Square	F	Sig.
girth	20488.963	2	10244.481	7.286	.006
tapping	745.852	2	372.926	.265	.770
girth * tapping	3410.815	4	852.704	.606	.664
replication	2611.185	2	1305.593	.929	.415
Error	22496.815	16	1406.051		
Total	100367.000	27			
Corrected Total	49753.630	26			

JANUARY

	Sum of Squares	df	Mean Square	F	Sig.
girth	10862.741	2	5431.370	8.323	.003
tapping	206.741	2	103.370	.158	.855
girth * tapping	1383.259	4	345.815	.530	.716
replication	3622.296	2	1811.148	2.775	.092
Error	10441.704	16	652.606		
Total	60579.000	27			
Corrected Total	26516.741	26			

FEBRUARY

	Sum of Squares	df	Mean Square	F	Sig.
girth	6202.296	2	3101.148	4.151	.035
tapping	773.852	2	386.926	.518	.605
girth * tapping	1591.704	4	397.926	.533	.714
replication	946.074	2	473.037	.633	.544
Error	11954.593	16	747.162		
Total	32918.000	27			
Corrected Total	21468.519	26			

MARCH

	Sum of Squares	df	Mean Square	F	Sig.
girth	3548.222	2	1774.111	6.984	.007
tapping	50.667	2	25.333	.100	.906
girth * tapping	101.778	4	25.444	.100	.981
replication	432.889	2	216.444	.852	.445
Error	4064.444	16	254.028		
Total	14825.000	27			
Corrected Total	8198.000	26			

APRIL

	Sum of Squares	df	Mean Square	F	Sig.
girth	869.556	2	434.778	5.954	.012
tapping	12.667	2	6.333	.087	.917
girth * tapping	11.111	4	2.778	.038	.997
replication	76.222	2	38.111	.522	.603
Error	1168.444	16	73.028		
Total	3866.000	27			
Corrected Total	2138.000	26			

ANOVA TABLE OF DIFFERENT SEASONS (MONSOON, POST-MONSOON, SUMMER)

MONSOON SEASON

	Sum of Squares	df	Mean Square	F	Sig.
girth	8859.932	2	4429.966	4.008	.039
tapping	1875.672	2	937.836	.849	.446
girth * tapping	319.017	4	79.754	.072	.990
replication	4160.483	2	2080.241	1.882	.184
Error	17683.370	16	1105.211		
Total	74631.150	27			
Corrected Total	32898.474	26			

POST-MONSOON SEASON

	Sum of Squares	df	Mean Square	F	Sig.
girth	27944.145	2	13972.073	6.519	.008
tapping	3042.743	2	1521.371	.710	.507
girth * tapping	3099.433	4	774.858	.362	.832
replication	9848.074	2	4924.037	2.297	.133
Error	34292.013	16	2143.251		
Total	192835.030	27			
Corrected Total	78226.407	26			

SUMMER SEASON

	Sum of Squares	df	Mean Square	F	Sig.
girth	3177.352	2	1588.676	7.554	.005
tapping	23.144	2	11.572	.055	.947
girth * tapping	93.231	4	23.308	.111	.977
replication	240.588	2	120.294	.572	.576
Error	3365.162	16	210.323		
Total	15719.625	27			
Corrected Total	6899.477	26			

ANOVA TABLE FOR WHOLE STUDY PERIOD (May 2017- April 2018)

	Sum of Squares	df	Mean Square	F	Sig.
girth	11159.443	2	5579.721	6.136	.011
tapping	1133.764	2	566.882	.623	.549
girth * tapping	705.139	4	176.285	.194	.938
replication	3506.778	2	1753.389	1.928	.178
Error	14550.116	16	909.382		
Total	76067.457	27			
Corrected Total	31055.240	26			

ABSTRACT

141

STANDARDISATION OF GUM-OLEORESIN EXTRACTION TECHNIQUE IN MATTI (*Ailanthus triphysa* (Dennst.) Alston.)

by

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ABSTRACT OF THE THESIS

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2018

ABSTRACT

The research work entitled "Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.) Alston.)" was carried out April 2017 to April 2018. The experiment was carried out in the field of Instructional Farm, College of Horticulture, KAU, Vellanikkara. The main objective was to develop an appropriate technique for extraction of gum-oleoresin and also to study the correlation between tree dimension and anatomical features with gum-oleoresin production in *Ailanthus triphysa*.

A total of twenty-seven trees were selected for conducting the study in which three girth classes (<75, 75-150, >150) and three extraction technique each with three replication were taken. Data analysis done for monthly interval, showed significant difference in girth class except in the month of July and August and for extraction technique it was found to be non-significant difference for all the months except May.

Data analysed for different seasons revealed that the girth class <75 was found to be significantly different from other girth classes i.e., 75-150 and >150. Different extraction techniques were found to be non-significant for all the three seasons. Effect of season and treatment (girth x extraction techniques) on gum-oleoresin yield was found to be significantly different. The highest quantity of gum oleoresin was reported in post-monsoon season (65.15 g/tree/season) followed by monsoon (39.23 g/tree/season) and least in summer season (18.08 g/tree).

Analysis for whole study period revealed that girth class <75 was found to be significantly different from girth classes >75. As the amount of gum-oleoresin yield was obtained from girth class >150 cm (712.07 g/year) and in 75-150 cm girth class, (604.06 g/year) and least in girth class <75cm (147.64 g/year). It was found to be non-significant for different extraction techniques.

Anatomical study unveiled the deposition of gum-oleoresin in vessels through the pits present on the walls of vessels and it was also observed that the ray parenchyma was playing an important role in production of gum-oleoresin as the rays are mainly meant for radial conduction.

The effect of bark thickness and girth on production of gum-oleoresin was found to be significant with correlation coefficient 0.65 and 0.82 respectively.

The climatic parameters like temperature, relative humidity, Rainfall, number of rainy days, sunshine hours, wind speed was found to be non-significantly related with gum-oleoresin production.

The present study carried out during April 2017 to April 2018, concluded that the trees having <75 girth should not be tapped as its yield was found to be very low. For the extraction of gum oleoresin, all the three methods can be used as it has no effect on the gum-oleoresin production. The present study also revealed that the gum-oleoresin production was less during the summer season. So, the tapping can be avoided during that period.