Physico-chemical characterization of gum-oleoresin from *Ailanthus* triphysa (Dennst.) Alston and effect of ethephon on gum-oleoresin yield.

By

LATHA K J

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THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Physico-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst.) Alston and effect of ethephon on gum-oleoresin yield"** is a bonafide record of research done by me during the course of research and that this 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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CERTIFICATE

Certified that the thesis, entitled **"Physico-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst.) Alston and effect of ethephon on gum-oleoresin yield"** is a record of research work done independently by Latha K J (2017-17-012) under my guidance and supervision and that it is not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory Committee of **Ms. LATHA K J (2017-17-012),** a candidate for the degree of **Master of Science in Forestry** with major in Natural Resource Management, agree that this thesis entitled "Physico-chemical characterization of gum-oleoresin from *Ailanthus* triphysa (Dennst.) Alston and effect of ethephon on gum-oleoresin yield" may be submitted by her in partial fulfillment of the requirement for the degree.

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INTRODUCTION

Non-Timber Forest Products (NTFPs) play an important role in the livelihoods of the rural poor, as a source of food, medicine, construction materials, and income. NTFP gained global importance in recent times through its contribution to income, food security and employment for indigenous and rural communities, enabling forest-based enterprise, potential for export market and biodiversity conservation. NTFPs are collected for livelihood support of indigenous people to generate additional income during off-farm seasons and supply as supplementary foods during food scarcity. NTFP species can have both consumptive and non consumptive benefits at household level. The forest products that are edible add flavor, colour and ensures the nutrient as well as dietary requirements. The leaves, tuber, rhizomes, fruits and nuts will make the diet perfect. The resins, tans, dyes, oils, medicinal plants and gums have their own significant benefaction to the life of people.

Gum and resins are low volume, high value produce and important non-timber forest produce and viable income sources for thousands of forest dwellers, especially for tribal's in India (Pal *et al*., 2012). Gums are the natural biopolymers having large applications in pharmaceutical and food industry. The FDA (Food and Drug Administration, USA) considered most of them are safe and biodegradable. Because of their no toxicity, biocompatibility, low price, eco-friendly processing and easy availability, these are selected over synthetic polymers in pharmaceutical, cosmetic and food industries.

Natural Gums and Resins (NGRs) are used by humankind around the world since time immemorial. It still serves as an irreplaceable unique raw material in human society. 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).

There are more than 15,000 plant species including about 120 gum yielding plants found in India, it is one of the rich country in plant biodiversity. Indonesia, Sudan, India and China are the leading producers of gums and resins (FAO, 2003). India produces yearly about 2, 81,000 tons of gum and resins and about 1500 tons of gum-resins. People all over world, particularly in developing countries their livelihood depends on collection of resin, gum, and latex. An analysis by Belcher *et al.* (2004) identified different economic strategies of people that sell or export NTFPs, ranging from supplemental income to other subsistence livelihood activities to more specialize production where more than 50% of the household income is produced by NTFPs and labor input into their production is high. NTFPs are generally seen as favorable compared to agriculture or timber extraction, but in many cases ecological or biodiversity impacts of NTFP production have not been assessed. As demand is increasing now a days, people are giving more emphasis to natural products that are environment friendly.

Tree based farming system are getting wider recognition in tropics on account of multitude of benefits such as timber, firewood, fodder and 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 tree species are known for quality timber production and high Mean Annual Increment. Now a day's indirect benefits are getting much more attention than what they used to get few decades back. Among these is 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 triphysa also called as matti belongs to family Simaroubaceae. It is a medium to tall evergreen tree which exudates a viscous sticky fluid (oleoresin) called as Halmaddi in Karnataka, after the local name for the tree itself. *Ailanthus triphysa* exudates a highly viscous aromatic resin which preclude the necessity of dipping the splints in the wax and hence, this matti tree has been counted as best matchwood species (Indira, 1996). It is mainly used for making high value incense stick (Nagchampa) which is used nationally as well as in other countries like USA, UK and Tibet etc. and are generally considered to be the best Indian tree species for match splints. *A. triphysa* is one of the major tree species that was commercially harvested for gum oleo-resin throughout South India and Southeast Asia.

Ailanthus species are most suitable for tree-based farming systems. It occurs in all physiographic provenances except in high hills and it tolerates wide range of soils (Kumar *et al*., 1994). Untimely *A. triphysa* was grown as mixed plantation in association with *Tectona grandis*, *Evodia* sp. and *Bombax* sp. Since 1980, this species is being raised as pure plantations. *Ailanthus* is thought to be less competitive with associated crops, consequently many field crops such as ginger can be cultivated in association with *Ailanthus* (Kumar *et al.,* 2000). It is a prominent MPT in traditional land use system of Kerala. *Ailanthus* wood is considered as best wood for match splint. *Ailanthus* species are fast growing tree that can be successfully incorporated in Agro-forestry systems, mixed plantation and boundary plantations etc.

Its bark is used for many medicinal formulations by local vaidya. It is also used for the treatment of dyspepsia, bronchitis, ophthalmia and snakebite. Traditional method of tapping gum resin tree species differs all over the world. However, the destructive methods of tapping i.e., blazing, cutting with axe are brutal and injurious for plant and causes species reduction or due to crude extraction methods which resulted in trees dying. Uncontrolled extraction due to high demand or population pressures can cause forest degradation or species extinction. The unscientific methods of harvesting of NGRs not only affect its resource base but also hamper the quality of the products. Due to unsustainable tapping practices, populations of NGRs tree species are fast disappearing. This call 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 compared 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.

The idea of new tapping methods using ethephon a plant growth regulator, which is inexpensive, safe and nontoxic have enhanced exudation of gum/gum-resin in few plants such as *Acacia senegal*, *Mangifera indica*, *Anogiessus latifolia* and *Sterculia urens*. An improved tapping method based on application of ethephon yielded about 466-fold increases in gum (Bhatt, 1987).

In Kerala, there are about 2500 ha of mixed plantations and 533 ha of pure plantations (Anon.1991). So, there is wide scope for gum oleo-resin extraction in Kerala. By using ethephon a plant growth regulator has increased exudation of gum and resin and on the other hand, it will be a good opportunity for the people of Kerala to generate extra income from the tree, which will generate self-employment and increase standard of living among the rural communities. It has tremendous potential and ability to create livelihood opportunities for rural women of Kerala. This study will also help in extraction and utilization of resin without harming the wood quality as it is widely growing in non-forest areas (plains and homesteads) of Kerala. So, there is an urgent need of 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.

The present status and potential production of gum and resin yielding trees in India have occupied an important place in the international markets; ample opportunities exist for enhancing export earnings by developing appropriate facilities for processing, storage, packaging and marketing.

The physical and functional properties of plant-based gums depend on their chemical compositions and molecular structures. Recently, there is a substantial interest to elucidate the relationship between the chemical composition, molecular structure and physical characteristics and functional properties of plant gum exudates. The polysaccharide gums represent one of the most abundant raw materials. The researchers have mainly studied the polysaccharide gums due to their sustainable, biodegradable and biosafe characteristics (Rana *et al*., 2011).

A large number of plants based pharmaceutical recipients are available today. Gums and mucilage's are the most commonly available plant ingredients with a wide range of applications in pharmaceutical and cosmetic industries. They are being used due to their abundance in nature, safety and economy. They have been extensively explored as pharmaceutical recipients. They are biocompatible, cheap and easily available. Natural materials have advantages over synthetic ones since they are chemically inert, nontoxic, less expensive, biodegradable and widely available. They can also be modified in different ways to obtain tailor-made materials for drug delivery systems and thus can compete with the available synthetic recipients. Recent trend toward the use of plant based and natural products demands the replacement of synthetic additives with natural ones. In this review, we describe the pharmaceutical applications of various natural gums, mucilage's and their modified forms for the development of various drug delivery systems.

Different diameter classes are considered to study the effect of different concentration of ethephon on gum-oleoresin production. Ethephon helps in the production of more yields. The basic information like physical and chemical properties of gum-oleoresin is essentially required for the industrial point of view and helps in value addition and product development including the industrial and pharmaceutical utilization. It may go a long way in raising the socio-economical status of tribal communities. Hence, the present research work entitled "Physico-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst)

Alston and effect of ethephon on gum-oleoresin yield.” Taken up with following objectives,

1. The main objective is to assess the effect of ethephon on gum-oleoresin production from *Ailanthus triphysa* trees of different diameter classes.
2. The physico-chemical characteristics of gum-oleoresin from *Ailanthus triphysa*.

REVIEW OF LITERATURE

A brief review of research work about the physico-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on gum-oleoresin yield is depicted here under,

2.1 SPECIES INTRODUCTION

The Simaroubaceae family comprises of 32 genera and more than 170 species of trees and brushes of pan tropical distribution. It is characterized by presence of bitter substances, mostly applied for its pharmaceutical properties (Fernando and Quinn, 1992; Muhammad *et al.*, 2004). This genus includes about 8 species of lofty trees and shrubs. Four species occur in India viz. *Ailanthus altissima*, *Ailanthus triphysa* Alston, *Ailanthus grandis* Prain, *Ailanthus excelsa* Roxb.

It is a prominent Multipurpose Tree Species (MPT) 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). *Ailanthus triphysa* also called as Matti, which is widely distributed over North Australia and Asia (Kundu and Laskar, 2010). In India it occurs mainly in natural evergreen forest of Western Ghats (PID, 1948). *Ailanthus triphysa* is a evergreen tree with cylindrical trunk attaining a diameter of 1.2 m height of about 30 m 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 are 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).

2.1.1 Suitability for agro forestry

Ailanthus generally considered being the best Indian tree species for match splints. *Ailanthus triphysa* is characterized by small compact crown. Considering the crown architecture, growth, leaf phenology and branching pattern, *Ailanthus* could be classified into the KORIBA's architecture model (Chandrashekar, 1996). Owing to the small crown, moderate root spread and deep rooting tendency, *Ailanthus* is thought to be less competitive with associated crops (Mathew *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)

2.1.2 Utilization

The oleoresin oozes out from the wounded trunk of the Ailanthus trees are aromatic and it 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) *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) *Ailanthus triphysa* species has been considered as best matchwood species as it produces a highly viscous aromatic oleoresin that averts 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).

The bark of *Ailanthus* has expectorant, febrifuge, antispasmodic properties and it is used against bronchitis, asthma and dysentery (Anon, 1972). It is claimed to be useful in bronchitis and dysentery (Dury, 1978). Several chemical compounds belonging to different classes such as triterpenoids, nortriterpenoids, alkaloids, quassinoids and have been previously reported from different parts of *Ailanthus triphysa* (Aono *et al*., 1994; Hitotsuyanagi *et al*., 2001). Therefore, *Ailanthus* trees are often debarked by Vaidyas (local people who prepare and provide herbal medicine).

Kirtikar and Basu (1933) reported that bark of *A. triphysa* is considered as a febrifuge, valuable tonic, carminative and the juice of the fresh bark is used as a remedy for dysentery, asthma and bronchitis. Dastur (1951) stated that root bark of *A. triphysa* is used in case of snake bite; it is bruised and kept in gingelly oil and especially in case of cobra bite it is given internally as an anti-dote. Nadkarni (1954) observed that *Ailanthus triphysa* used as a treatment for bronchitis, dysentry, opthalmia, snake bites and dyspepsia. Decoction of the bark is reported to be given in typhoid and constipation (Chopra *et al.,* 1956).

2.2 RESINS AND GUMS - AN OVERVIEW

Gums and Resins are classified mainly into four classes which are Hard resin, True gums and Oleo-resins and Gum-resins (FRI, 1972). Gums are usually obtained from plants, are solid consisting of mixtures of polysaccharides 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. 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 ether, alcohol, carbon bi-sulphite and certain other solvents. Gums exudation usually noticed from the stem of a tree but in a few cases from the root. Gums are also isolated from the endosperm portion of seeds of some marine algae (FAO, 1995). 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 little 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 gamboge, asafoetida, myrrh, galbanum, and frankincense (FRI, 1972).

2.3 EFFECT OF CHEMICAL TREATMENT ON GUM-OLEORESIN PRODUCTION

2.3.1 Traditional method of tapping

Siddiqui *et al*. (2016) reported that 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. Bhatt *et al*. (1989) stated that ancient people have adopted many unsustainable extraction methods which are unproductive, injurious, destructive and brutal to plants, often leading to their death. Due to this, the natural germplasm of tree of the semi-arid regions of India has declined. Many of the Natural gum and resins (NGR) trees comes under critically endangered, endangered, threatened categories. Innovations are essential for sustainable yield and quality control (IUCN, 2017).

There are three main types of resin collection in Kerala, each practiced within a specific 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 produced by setting a low fire followed by incisions and collection. This method is used in Nilambur region in Kerala.

Anita and Tamara, (2008) found similar findings that in order 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. 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 harvesters 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 (Kannan, 1992; Augustine and Krishnan, 2006).

Torquebiau (1984) gives a good description of tapping practiced on *Shorea javanica* in Sumatra. Traditional methods of tapping trees involve removal of wood from the stem in order to obtain dammar. 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 attain approximately 25 cm in diameter first cut is made which is several centimeters wide at first and becomes enlarged at every tapping and eventually becomes a hole of 15-20 cm in depth and width.

FAO (1995) reported that in karaya (*Sterculia urens*) 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.

Ravikumar and Ved (2000) reported that due to un-sustainable tapping practices populations of *Canarium strictum* are fast disappearing and this tree is considered to be vulnerable in southern India. Similar study reported by Nair (2003) that the commercial tapping of *Sterculia urens* is done by blazing or peeling or by making deep cuts at the base of tree by using axe, these methods often lead to the death of the tapped tree.

2.3.2 Improved tapping technique and gum yield

Bhatt *et al*. (1989) reported that 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. 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. Marked correlation in resin yield with diameter from chirpine tree varying from 30 cm to 60 cm tapped by cup and lip method and reported 10 % increase in yield with increase of 5 cm in diameter and diameter range of 37.5-48.5 cm had maximum yield had been reported by Lohani (1985).

Nair (2003) reported that artificial incisions are made in the tree trunk and the bark is slashed in *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.

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

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, 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.

Kuruwanshi (2017) conducted four mechanical methods for standardizing a method of tapping in *Sterculia urens* and *Anogesssius latifolia*, he found out that Die method was significantly different from other tapping method. It produces 110.60gm of gum whereas the controlled yield was 29.38gm in *Sterculia urens*. In *Anogessius latifolia* again the die method was proved to be best as it produced 90.32gm whereas only 28.82gm in controlled.

Ghritlahare (2017) also had a similar kind of study on four experimental trees i.e., *Anogeissus latifolia, Soymida febrifuga, Terminalia tomentosa* and *Buchanania lanzan* in winter and summer season. He found out that semi arc method of mechanical tapping is best for all the four tree species especially for *Terminalia tomentosa*, 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.

2.3.3 Effect of ethephon on gum oleoresin yield

In recent days an advanced improved method is being used for extracting natural gum-resin to enhance the production for commercial purpose. Bhatt, (1987) noted that an improved tapping method along with application of ethephon yielded about 466-fold increase of gum in *Anogeissus latifolia.* Use of plant growth regulator like ethephon, has increased exudation of gum and resin in certain plants such as *Mangifera indica, Acacia senegal, Commiphora wightii*, and *Sterculia urens*. (Bhatt *et al*., 1989; Bhatt and Ram, 1990).

Bhatt *et al*. (1987) experimented that an improved tapping method for *Commiphora wightii* in which ethephon (2-chloroethylphosphonic acid) was applied to the tree 48 hours before tapping. It was noted that the yield of resin was higher as compared to controlled tapping. Similar trial was done in *Acacia tortilis* and *Acacia senegal* by Tewari *et al*. (2014) which yield less amount that is 15-25gm/tree in traditional tapping techniques, 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 can Produce 5-6 kg gum/ha.

Bhatt *et al*. (1984) found 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 in April and May than in December and January. Bhatt *et al*. (1989) conducted preliminary trial made in different concentrations of the active substances used and safe dose determined. As concentrations above 400 mg of ethephon induced shoot desiccation and dieback in *Commiphora wightii*.

Bhatt (1987) reported the improved gum tapping method by ethephon treatment in trunk by placing 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 become 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.

Bhatt and Ram (1990) studied the six Gum Arabic trees growing on the Chambal ravines, near Barhi, Madhya Pradesh. Five trees were treated with ethephon by introducing 4 ml solution of different concentration ethephon containing 480, 720 and 960 mg active ingredient were injected through a hole of 5 cm deep and 2.5 cm wide, slanting downwards and made using a hammer and chisel at 1-1.5 m above ground. 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.

Garasiya *et al*. (2013) experimented the effect of ethephon application on gum production from *Acacia senegal* L. during summer 2012 at Grassland Research Station, Dhari. Total 10 treatments with different concentrations of ethephon (100 to 900 ppm) along with control (water spray) were injected in plants of *Acacia* through a hole. Total 30 trees were selected for this purpose to complete the study in Randomized Block Design with three replications. The Result revealed that the minimum days (13.33 days) taken for first oozing was observed in T10 (900 ppm ethephon). Similarly, the length (186.33 mm) and width (67.33) of harvested gum as well as gum yield per plant (386 gm) at harvest was recorded maximum in T10 (900 ppm ethephon).

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

Vasishth (2017) studied to standardize 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 bore hole tapping method and 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 144.2gm/tree. However, lower concentration of sulphuric acid did not show significant results.

2.4 GUM YIELD AND OTHER FACTORS

2.4.1 Gum yield and dimensional properties of trees

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 and Chaudhary (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.

Sharma and Prasad (2013) studied nine trees of *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 studies, where they investigated the effects of height and girth on gum yield of gum *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 m, gum yield increased as tree girth goes higher from 35-54 cm (163.6-209.7 gm). 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.

Vidyasagran *et al.* (2016) studied four girth classes i.e. less than 50cm, 51-100cm,101-150cm and greater than 150 in *Canarium strictum and Vateria indica* and they found out a complementary relationship 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 was obtained from lowest borehole height.

Patel *et al*, (2016) reported that chemical method is producing more gums resins in certain trees. In *Sterculia urens* 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.

Choudhury (2018) studied the effect of girth classes on gum-oleoresin yield and observed that rate of gum exudation (gm) was maximum in the month of October in all the experimental trees for all the different girth classes. i.e. <75cm girth class, 75-150cm girth class and >150cm 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 (59.34gm) whereas (50.33gm) in 75-150 girth class and least in <75 girth class (12.3gm)

2.4.2 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 occur due to degeneration of cells. The gummosis process results in the depletion of starch in cells and in many cases appear 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)

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 *et al*., 1977).

Choudhury (2018) reported the anatomical features of *Ailanthus triphysa* wood. 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.

2.4.3 Gum yield and other parameters

Dione and Vessal (1998) observed the impact of temperature and rainfall 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.

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

Choudhury (2018) studied the effect of climatic factors on gum-oleoresin yield, all the climatic parameters were found to be non-significant on production of gum-oleoresin. The temperature was found to be affected negatively on gum-oleoresin production.

2.4 PHYSICAL AND CHEMICAL PROPERTIES OF GUM-OLEORESIN

2.4.1 Physical properties of gum-oleoresin

Plant polysaccharide gums can be used as dietary fiber, texture modifiers, gelling agents, thickeners, emulsifiers, stabilizers, coating agents and packaging films (Clements, 2005). In the recent years, the demand for plant-based gums in food systems, medicines and drug delivery systems has been considerably increased because they are the most notable ingredient in liquid and semisolid foods (Williams and Phillips, 2009). However, the market still desires new sources of plant-based gum to meet the demand for ingredients with more usefulness in food systems. The physical and structural features of plant gum exudates are defined by molecular weight, monosaccharide composition, and sequence of monosaccharide, conformation and configuration, position of glycoside linkages, particle size, solubility and rheological properties (Zhang *et al.*, 2007).

Begum *et al.* (2000) studied on the phytochemical and pharmacological properties of babul gum. Herbal medicines have been the basis of treatment and cure for various diseases and physiological conditions in traditional methods of practice such as Unani, Ayurveda and Siddha. Medicinal plants are the valuable and cheap source of unique phytochemicals which are frequently used in the development of drugs against various diseases. The use of plants and plant products in medicines is getting popularized because the herbal medicines are cheap, easily available and have natural origin with higher safety margins and lesser or no side effects. In Unani system of medicine Babool (*Acacia Arabica*) is considered as plant having medicinal properties on various system of human body.

Anderson *et al.* (1968) investigated that the pH value of Gum Arabic *(Acacia senegal)* to be 4.4 and it is slightly acidic because of the presence of few free carboxyl groups of its constituent acidic residue, *viz.* D-glucuronic acid and its 4-O-methyl derivative. Glicksman (1969) reported that the most widely used exudate gums in the food industry, gum arabic, gum tragacanth and gum karaya have the respective pH ranges 4.5-5.5, 5.6 and 4.4-4.7.

Seigler (2003) observed the physico-chemical properties of Babool *(Acacia nilotica)* have 13 % moisture content, 38 % solubility, 300-320 0C melting temperature, 3.54 ash content, 2.71 % protein and 78.15 % total soluble fibre.. Similar study was conducted by El-kheir *et al.* (2008) studied in physico-chemical properties of Gum Arabic (*Acacia senegal*) collected from Kordofan (Central Sudan) and Damazin (Western Sudan). The results showed significant differences in moisture content, protein content and relative viscosity between Kordofan and Damazin gums. Damazin gum contained higher protein (3 %) and characterized by higher viscosity (24.81) compared to Kordofan gum.

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

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

2.4.2 Chemical composition of gum oleoresin

Nadkarni (1976) reported that *A. triphysa* contains wax like, reddish brown, water soluble having bitter principle, known as ailantic acid. It is given as a tonic and alternative in dyspepsia and constipation.

Papageorgiou *et al*. (1991) estimated the essential oil from two qualities mastic gum, which was obtained by steam distillation, was subjected to analysis by Gas chromatography and GC/MS. It was found that the oil comprises of 62 compounds, 61 of which were identified. The main components were α-pinene (58.86–77.10%), β-pinene (1.26–2.46%), camphene (0.75–1.04%), myrcene (0.23–12.27%), β-caryophyllene (0.70–1.47%) and linalool (0.45– 3.71%). Similar work reported by Aono *et al.* (1994) from the wood of *Ailanthus triphysa* found new indole alkaloid and new C_{19} and C_{20} skeleton quassinoids were isolated. Their structures were determined by spectroscopic and X-ray analysis. In addition, six known alkaloids, canthin-6-one, canthin-6-one-3-N-oxide, I-hydroxycanthin-6-one, I-ethyl-β-carboline, I-ethy-4-methoxy-β-car-boline, and β-carboline-I-propionic acid, and a quassinoid, chaparrinone, were also identified.

Hakeem *et al*. (2008) studied the Physico-chemical properties of Cashew gum were compared to those of gum Arabic. Parameters studied included total insoluble matter (1.9 - 4.8%). Ash (0.5 - 1.2%), pH (3.8 - 4.2), protein content (1.27 - 1.80%), total phenols (0.21 - 2.26%), total sugars (0.96 - 2.10 mg/g), and moisture content (9.8 - 13.2%).Gum from mature trees was generally found to have more levels of moisture, sugars, protein, and phenols than that from young trees, with the exception of pH which was lower in gum from mature trees. There were also variations in some of the physico-chemical properties of the gum from the different locations. The predominant minerals in cashew tree gum were K, Na, Ca and Fe and their nutritional benefits is examined.

Yebeyen *et al*. (2009) by using standard laboratory procedures studied the physico-chemical properties of gum obtained from *Acacia senegal* and found that it yielded ash content of 3.56%, intrinsic viscosity of 1.19 ml per gm, pH on 25% solution of 4.04, specific rotation of 32.5, moisture content of 15%, Nitrogen content of 0.35%, protein content of 2.31% and with no tannin content.

Ali *et al*. (2009) reported that essential oil extracted from the gum-oleo resin of *Commiphora habessinica* (Berg.) Engl. was analyzed by gas chromatography-mass spectrometry and thirteen compounds were identified in that the major constituents were β-elemene (32.1 %) followed by α-selinene (18.9 %), cadina-1, 4-diene (7.5 %), germacrene B (3.6 %), α-copaene (3.5 %), t-muurolol (3.0 %) caryophyllene oxide (2.9 %) and α-cadinol (2.6 %). Kundu and Laskar (2010) observed that plants from *Ailanthus* genus are widely used for a number of therapeutic applications, including bronchitis, anthelmintic, diarrhea, antispasmodic, nervous diseases, epilepsy, and hypertension, and contain various natural product classes, consist of alkaloids, coumarins, phenolic glycosides flavonoids, terpenoids, and steroids.

Jalali *et al*. (2011) studied the chemical composition of oleo-gum-resin from *Ferula gummosa*. The major families of terpenoids and terpenes were identified employing gas chromatography coupled with mass spectrometry detector. Almost 25 wt. % of oleo-gum-resin was insoluble in ethanol and, according to wet chemistry analyses, assigned to arabinogalactane structurally associated with protein Complex (AGP).

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

Eddy *et al*. (2014) examined the physical parameter like color, pH, odor solubility in various solvent and chemical analysis using GCMS and FTIR to study characteristics of *Ficus benjamina* gum and result revealed that the gum is yellowish in colour, mildly acidic and ionic in nature. Major constituents of the gums were found to be d-glucose and sucrose which constituted 60.92 % of its chemical constituents while various hexadecanoic acid (4.41 %); carboxylic acids (albietic acid (1.00 %); stearic acid (3.01 %); oleic acid (0.10 %); octadecanoic acid (9.12 %); 9octadecanoic acid (1.00 %), and 6,13 pentacenequinone (20.43 %) accounted for the remaining constituents.

Achanta *et al.* (2015) observed that ten malabaricane type triterpenes were isolated from the oleoresin of *Ailanthus triphysa*, out of which six (1–6) were new. For three of the known compounds (7–9), NMR assignments are being reported for the first time. Compound 10, a known one, is a new report from this source. The structures were established by extensive 1D and 2DNMR spectroscopy. The oleoresin and some of 16 the isolates did not possess antimicrobial activity and did not lyse RBCs.

Kuruwanshi *et al*. (2017) reported that quality of gum and its physicochemical properties i.e. pH, solubility, viscosity and protein content were not affected significantly by the methods of gum tapping (i.e. mechanical and chemical) in all the experimental trees.

MATERIAL AND METHODS

The present study entitled “Physio-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on gum-oleoresin yield” was carried out at Arboretum, near KAU School, College of Forestry, Vellanikkara during the year 2018-2019.

The main objective of the study was to assess the effect of different concentration of ethephon on gum-oleoresin production and also to study the effect of diameter classes on production of gum-oleoresin and study will also attempt to know the physical and chemical characteristics of gum-oleoresin from *Ailanthus triphysa* such as Solubility, pH, Viscosity, Moisture level, Color parameters, Ash content and Analysis of chemical composition and minerals of gum-oleoresin.

3.1 LOCATION

The present study was conducted in a 30year old plantation of *Ailanthus triphysa* (Dennst) Alston. Stand in an experimental site located at Arboretum, near KAU School, College of Forestry, Vellanikkara, Thrissur, Kerala at **N 10^{0} 32’** latitude and **E 76^{0} 10’** longitude, and 22.5 m above mean sea level. The study was conducted for a period of one year (May 2018 to April 2019).

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 Vellanikkara is 2387.7 mm and the mean minimum temperature is ranged from **21.1^{0}C to 24.9^{0}C**. The mean maximum temperature varied from **30.1^{0} C to 36.7^{0}C**. The soil of experimental site is deep well drained sandy clay loam of ultisol having pH of 5.5.

Plate: 1 Ailanthus trees in Arboretum, near KAU School, College of Forestry, Vellanikkara

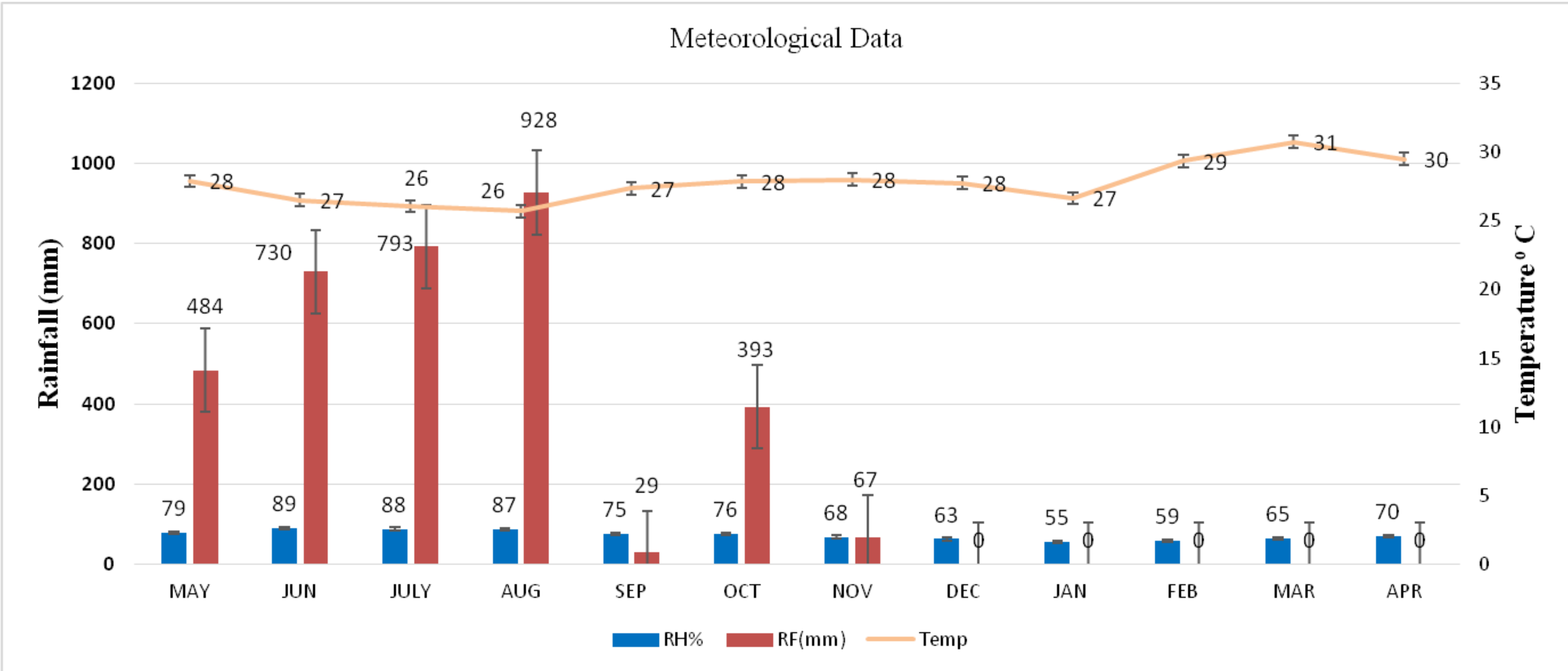


Fig.1 Meteorological data (May 2018 - June 2019) collected from Department of Meteorology, College of Horticulture, Kerala Agricultural University, Vellanikkara

3.3 MATERIALS

3.3.1 *Ailanthus triphysa* Plantation

Ailanthus triphysa is also popularly known as Matti, is a multipurpose tree species. It is a semi evergreen tree having cylindrical trunk with moderate root spread and deep rooting tendency. It is a fast growing tree species with compact crown which makes its suitable for intercropping in different agro forestry system. Its wood is used for making match splint, bark is used for medicinal purposes. It produces a viscous aromatic resin which is 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 oleoresin. Black colour cups were used for collection.

3.3.2.2 Cup holder

Cup holder is made up of aluminium metal in specified arrangements, readily available in market. It plays major role in extraction of quality 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 oleoresin flows down from the tree trunk to collection cup. It was attached to the end of the tapping cut. It avoids spreading of oleoresin on tree trunk thereby provides resin without much impurities.

3.3.2.4 Rope

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

3.3.2.5 Tapping Knife

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

3.3.2.6. Haglof bark gauge

It is an instrument used 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 millimeter or inch. The bark gauge is having 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 read from the calibrated shaft.

3.4 METHODS

Ailanthus triphysa trees were selected through primary surveys. Samples trees were selected based on different girth classes viz. 70-110 cm and 111-150 cm for studying yield and at standard cutting height of 1.5 m. Twenty four (2×4×3) sample trees were marked for analyzing the yield statistic for different girth classes. Collection was done in monthly intervals. Statistical analysis was carried out to estimate the relationship between gum-oleoresin production with different girth class and ethephon concentration.

3.4.1 Design and Layout of the experiment

Design: Factorial Randomized block design (FRBD).

Treatments: 8

Replication: 3

3.4.2 Treatment details

T1: control Treatment

T2: Ethephon (2.34 %)

T3: Ethephon (3.12%)

T4: Ethephon (3.9%)

3.5 TAPPING METHOD

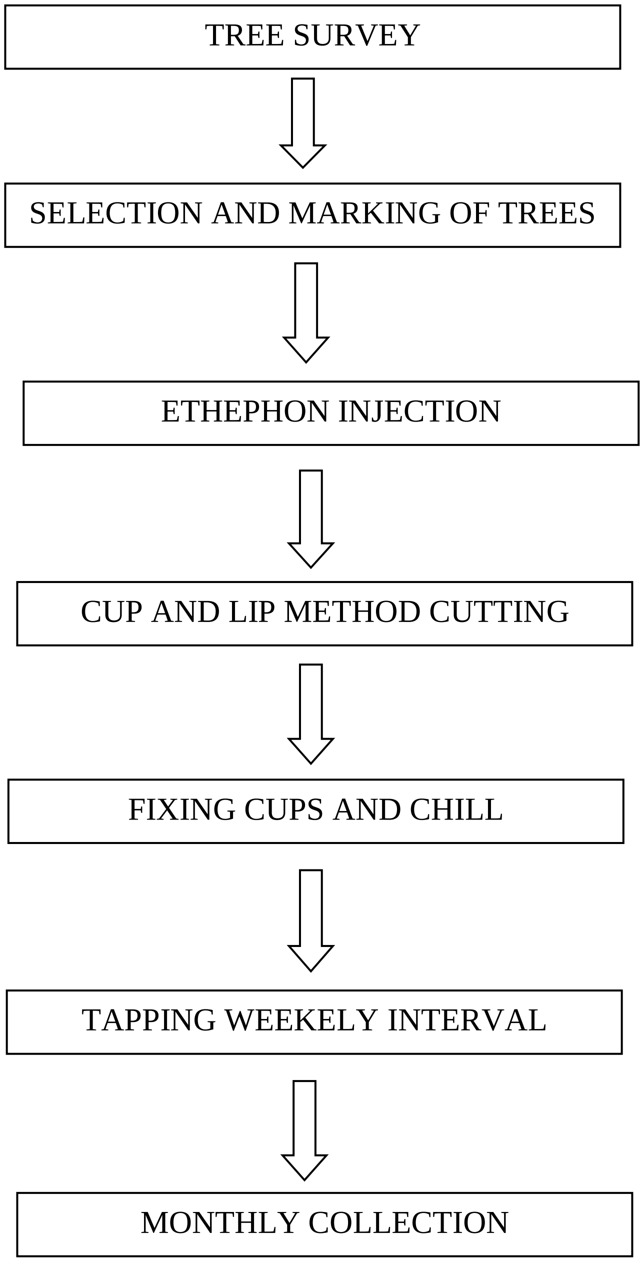
3.5.1 Cup and Lip method

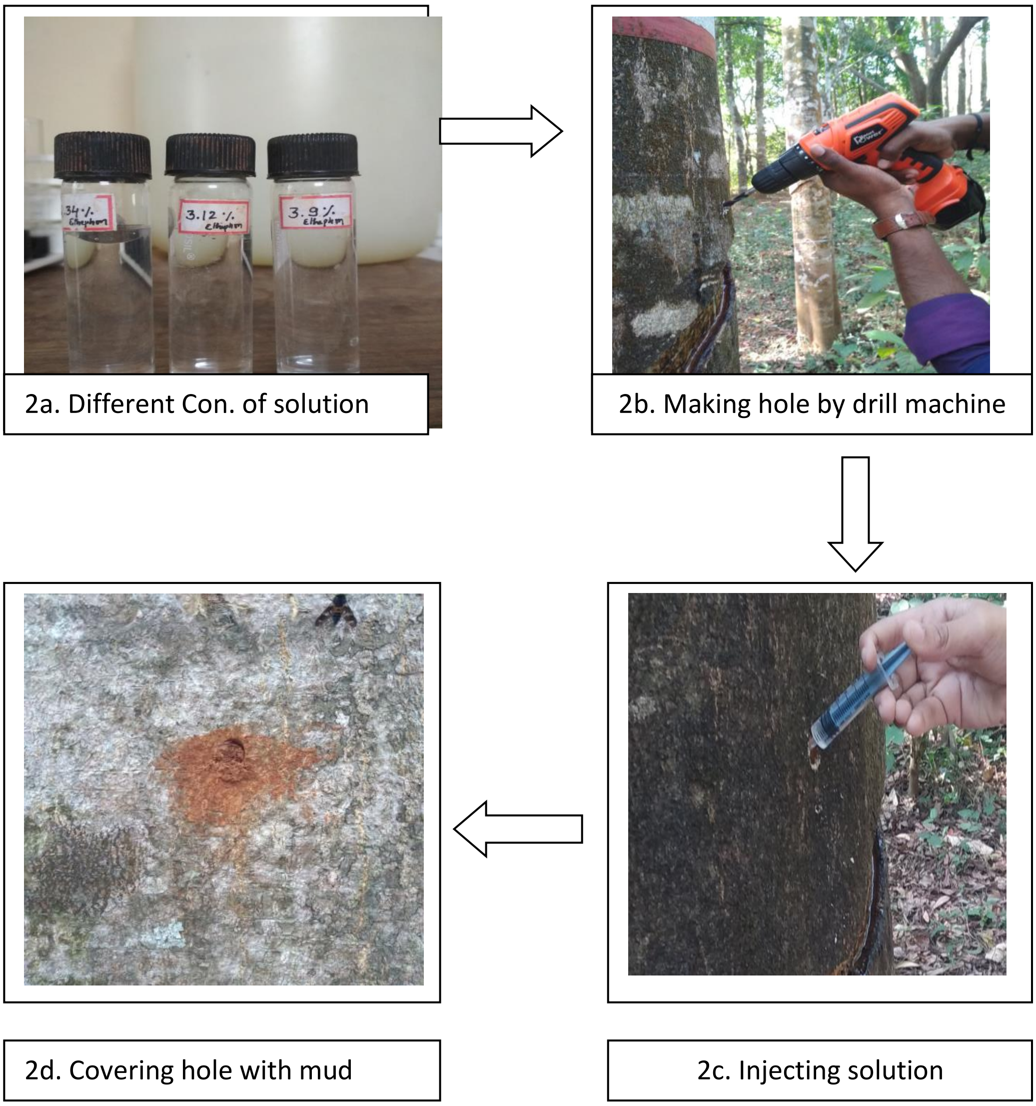
In this method, a slanting cut of 40-50 cm was made on the bark depending upon the girth class which includes the removal of bark nearly on horizontal plane and injuring the sapwood. Then a chill is fitted to the end of the cut and collecting vessel was placed right below the chill for easy collection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

3.5.2 Chemical tapping technique

The chemical oleoresin tapping of selected trees was initiated using different doses of ethephon (2-chloro-ethyl-phosphonic acid) (trade name Ethrel) having 2.34 %, 3.12%, 3.9%, in the tree trunk by hand operated drill machine to induce gummosis. The whole treatments were made through a syringe of 10 ml volume. The 2 ml gum enhancer was injected thrice during the whole period of tapping. The drilling was done by using drill machine in clock wise up to 2.5 cm deep and 4 mm diameter upward inclined hole (slant hole) and ethephon was injected in hole and covered with mud immediately. Total three injections were given in four month intervals during one-year data collection. First, second and third injections were given in the month of May, September and January respectively.

Fig 2. PROCEDURE FOR EXTRACTION OF GUM-OLEORESIN





2a. Different Con. of solution

2b. Making hole by drill machine

2c. Injecting solution

2d. Covering hole with mud

Plate 2. Systematic representation of ethephon treatment

3a. GUM-OLEORESIN FLOW

3b. COLLECTING IN CUP

3c. CUP AND LIP CUT METHOD

3d. SAMPLE COLLECTED IN POLYTHENE COVERS

Plate 3. Gum-oleoresin flow and collection

3.6 PHYSICO-CHEMICAL PROPERTIES

Different physical properties of gum-oleoresin such as solubility, pH, moisture level, color parameter, viscosity and ash content and heavy metals were analyzed and the essential oil extracted from the gum-oleoresin sample analyzed by using standard techniques.

3.6.1 Solubility

Solubility is defined as the amount of substance that passes into solution to achieve a saturated solution at constant temperature and pressure. Solubility is expressed in terms of maximum volume or mass of the solute that dissolves in a given volume or mass of a solvent.

The solubility of the gum-oleoresin was determined in cold water, hot water, acetone, chloroform, xylene, n-butyl alcohol and ethanol. 3 gm sample of the gum-oleoresin was weighed (plate 4a) and added to 50 ml of each of the above-mentioned solvents and left overnight (plate 4b). 25 ml of the clear supernatants were taken in small pre-weighted evaporating dishes and heated to dryness over a digital thermostatic water bath. The weights of the residue with reference to the volume of the solutions were determined using a digital top loading balance and expressed as the percentage solubility of the gum-oleoresin in the solvents (Mohsenin, 1978).

Water solubility index %= $\frac{Wds}{Ws} \times 100$

Where,

Wds= Weight of dissolve gum-oleoresin sample in solution (gm)

Ws= Weight of gum-oleoresin sample (gm)

3.6.2 Determination of pH

The hydrogen ion concentration plays great importance in the chemistry and industry of the gum-oleoresin. The change in the concentration of hydrogen ion may determine the solubility of gum-oleoresin and the precipitation of protein, therefore functional properties of a gum-oleoresin may be affected by change in pH for example viscosity and emulsifying power. pH can be determined by using pH meter (Plate 4c).

3.6.3 Determination of colour

The colour of the gums varies from almost colourless through various shades of yellow, orange to dark brown. Color of gum-oleoresin was determined by using Munsell color system by using external appearance of gum-oleoresin. 1994 Revised edition of Munsell color chart is used. The colour gum-oleoresin obtained from *Ailanthus triphysa* varies from fresh collection (Plate 4d) to freshly collected sample (Plate 4e) and also to partially dried sample (Plate 4f).

3.6.4 Determination of viscosity

The viscosity of a liquid is its resistance to shearing, to stirring in capillary tube. Viscosity was considered as one of the most important analytical and commercial parameters, since it is a factor involving the size and the shape of the macro-molecule. The viscosity of the gum was measured using a digital Brookfield viscometer (Plate 5a). The resistance to movement of a spindle is measured and expressed in terms of viscosity. Sample was added to 50% methanol and aqueous solution.

3.6.5 Determination of moisture content

Moisture content of gum-oleoresin samples was determined by drying 5g of the gum-oleoresin sample to constant weight at 105 ^{0}C using hot air oven (Plate 5b). Dried samples were cooled in desiccators before weighing. Moisture content was expressed as % of mass loss from the original mass as described by Yusuf (2011). The moisture content was calculated using the following expression,

$$MC = \frac{Wm}{Wm + Wa} \times 100$$

Where, Wm = wt of fresh sample (gm)

Wa = wt of bone-dry material (gm)

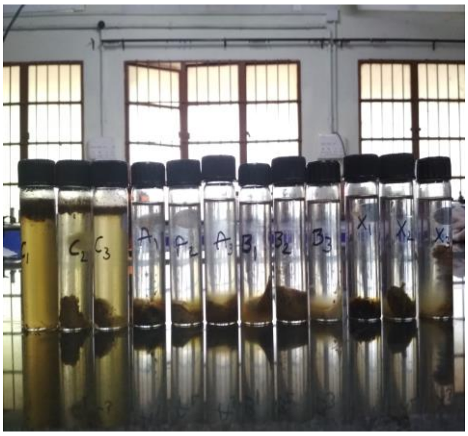
3.6.6 Ash content

Ash content of the gum-oleoresin samples was determined by burning 5 g of gum-oleoresin sample (Plate 5c) in a muffle furnace (Plate d) at **600 ^{0}C** for 4 hours. The ash content was expressed as a % ratio of the weight of ash to weight of the sample.

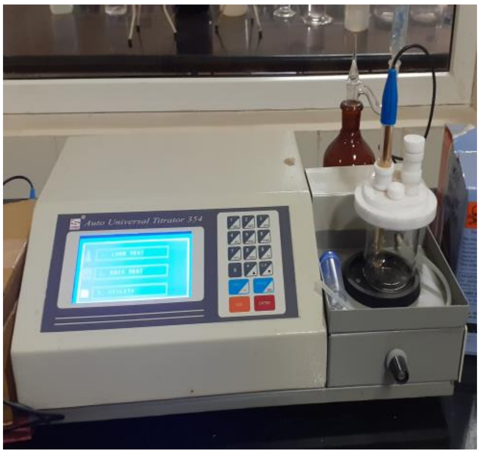
3.6.7 Determination of heavy metals

Heavy metals such as Ir, K, N, Co, Mg, Zn, Ca are detected by using Inductively coupled plasma mass spectrometry (ICP-MS). Sample is introduced into the instrument using a peristaltic pump, into a nebulizer. The nebulizer nebulizes the sample into small droplets and passes it into argon based high temperature plasma. Energy transfer from the plasma to the sample stream causes desolvation, atomization, and ionization of target analytes. Ions generated by this energy – transfer processes are extracted from the plasma through a differential vacuum interface, and separated on the basis of their mass-to-charge ratio by mass spectrometer. The ions passing through the mass spectrometer are counted by an electron multiplier detector.

4a. Weighing sample



4b. Solubility in different solvents



4c. pH meter

4d. Fresh flow

4e. Freshly collected sample

4f. Partially dried sample

Plate.4 Determing solubility, pH and colour of the gum-oleoresin.

5a. Brookfield viscometer

5b. Hot air oven

5c. Samples kept in muffle furnace

5d. Muffle furnace

Plate.5. Instruments used for viscosity, moisture content and ash content determination.

3.7 ANALYSIS OF CHEMICAL COMPOSITION OF GUM-OLEORESIN

Identification of chemical compounds from gum-oleoresin was done by using Gas chromatography - mass spectrometry (GC-MS).

3.7.1 Sample preparation

Samples were extracted out in two organic solvents i.e., acetone and methanol to check the expression of different compounds in different solvents. Sample extraction was performed with Soxhlet apparatus (plate 6a) using acetone and methanol as the solvent. 5 gm of gum-oleoresin was extracted for 6 hr and then the solvent was evaporated by using a rotary evaporator (plate 6b) at 50°C.

From acetone extracted sample, 0.20μm of sample was injected for analysis in GC-MS (plate 6c) and helium was used as a carrier gas. Column Oven Temp. - 60.0°C, Injection Temp. -260.00°C, Injection Mode-Splitless Sampling Time- 2.00 min, Flow Control Mode-Linear Velocity, Pressure- 57.4 kPa, Total Flow-54.0 mL/min, Column Flow- 1.00 mL/min, Linear Velocity - 36.5 cm/sec, Purge Flow - 3.0 mL/min Split Ratio : 50.0

Methanol extracted sample of 1.0 μm quantity was injected for analysis and helium is used as carrier gas. Column Oven Temp. : 80.0 °C, Injection Temp. : 260.00 °C, Injection Mode : Splitless , Sampling Time : 2.00 min, Flow Control Mode : Linear Velocity, Pressure : 65.2 kPa, Total Flow : 24.0 mL/min, Column Flow : 1.00 mL/min Linear, Velocity : 36.8 cm/sec ,Purge Flow : 3.0 mL/min, Split Ratio : 20.0.

3.7.2 Identification of compound

Interpretation of mass spectrum of GC-MS is done using the database of National Institute of Standard and Technology (NIST 11). The spectrum of the unknown component is compared with the spectrum of the known components stored in the inbuilt library.

6a. SOXHLET EXTRACTION METHOD

6b. ROTARY EVAPORATOR

6c. Gas chromatography and Mass Spectrometry

Plate.6. Instruments used for analysis of chemical composition of gum-oleoresin

3.8 STATISTICAL ANALYSIS

The data were subjected to statistical analysis using ANOVA in SPSS Version 21.0 to ascertain the significance of various parameters. 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

The study on “Physico-chemical characterization of oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on oleoresin yield” carried out at Vellanikkara revealed significant information on gum-oleoresin yield based on the influence of girth classes and tapping methods in 28 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 ethephon treatment and girth classes on gum-oleoresin yield at monthly basis (May 2018- April 2019)
- Effect of different seasons on gum-oleoresin yield. i.e., (monsoon, post monsoon and summer season).
- Effect of different seasons, girth and ethephon treatment on gum-oleoresin yield
- Effect Ethephon treatment and girth classes on gum-oleoresin yield
- Effect of bark thickness on gum-oleoresin yield
- Effect of climatic parameters on gum-oleoresin production
- Analysis of Physical parameters on gum-oleoresin yield
- Analysis of chemical composition using GC-MS

4.1 EFFECT OF ETHEPHON TREATMENTS AND GIRTH CLASSES ON GUM-OLEORESIN YIELD AT MONTHLY BASIS (MAY 2018- APRIL 2019)

4.1.1 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month May 2018.

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of May ranged from 7.45gm to 34.33gm for 70-110cm girth class, 14.55gm to 41.41gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be non-significant during the month of May (Table 1). Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 7.45gm to 14.55gm in T1(control), 16gm to 17.67gm in T2 (2.34% ethephon), 9.97gm to 18.33gm in T3 (3.12% ethephon) and 34.33gm to 41.41gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatment (Table 1) was observed. The study revealed that T4 (3.12%) is significantly different from other concentration of ethephon treatment in gum-oleoresin production.

Table 1. Gum-oleoresin yield from *Ailanthus triphysa* during the month of May 2018

Factors	Gum-oleoresin yield (gm)			
	Girth classes			
Treatments	G1 (70-110 cm)	G 2 (111-150 cm)	T (mean)	P-value (T)
T1 (CM)	7.45	14.55	11.01[a]	**0.001
T2 (2.34%)	16.00	17.67	16.83[a]	C.D
T3 (3.12%)	9.97	18.33	14.15[a]	(14.94)
T4 (3.9%)	34.33	41.41	37.87[b]	
Girth mean	16.94	22.99		
P-value for girth	0.24 ns			

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

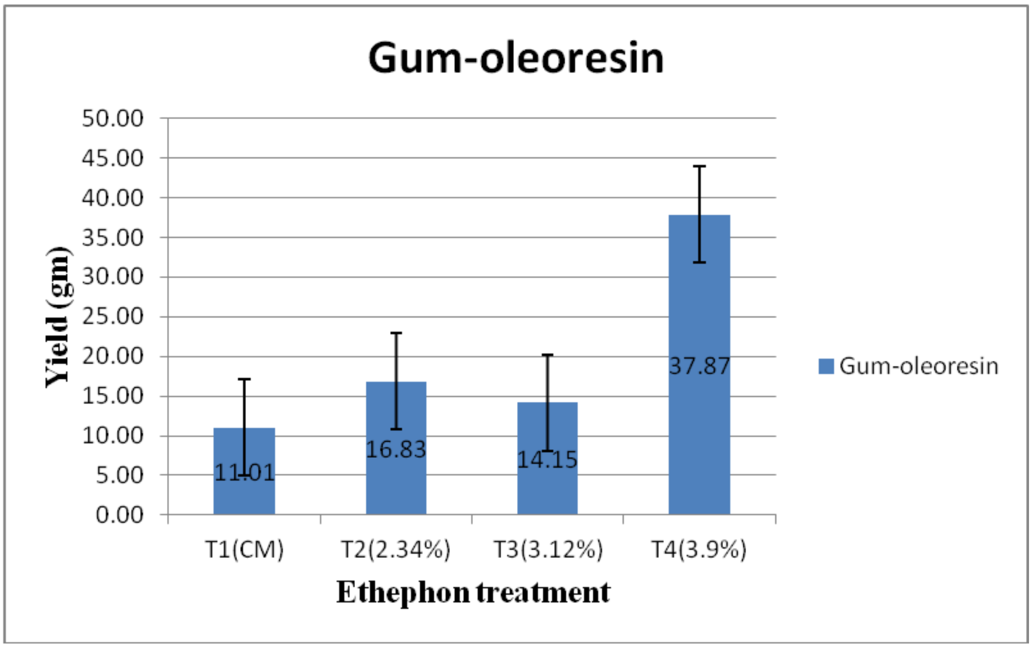


Fig 3. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of May 2018

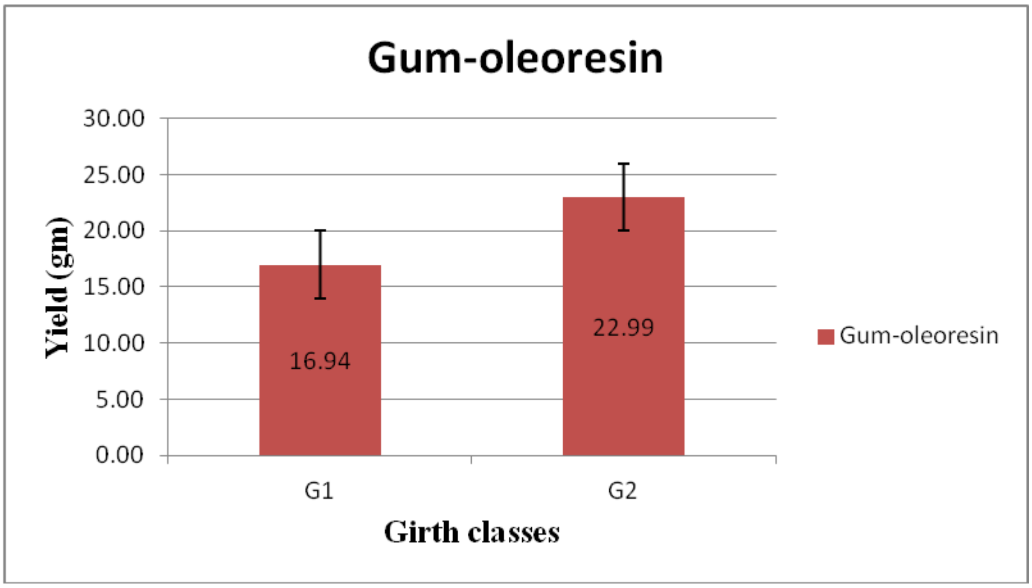


Fig 4. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of May 2018

4.1.2 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month June 2018.

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of June ranged from 16gm to 28.67gm for 70-110cm girth class, 16.33gm to 58.66gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of June.

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 13.33gm to 16.33gm in T1(control), 16gm to 28.67gm in T2 (2.34% ethephon), 28.67gm to 28.33gm in T3 (3.12% ethephon) and 28.33gm to 58.66 gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 2) could be observed. The study revealed that the T4 (3.12%) is significantly different from other concentration of ethephon treatment in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	13.33	16.33	14.83^{a}	0.016* C.D (16.76)
T2 (2.34%)	16.00	28.67	22.33^{a}	
T3 (3.12%)	28.67	28.33	25.00^{a}	
T4 (3.9%)	28.33	58.66	43.50^{b}	
Girth mean	19.83^{a}	33.00^{b}		
P-value for girth	0.032* C.D (11.86)			

*- significant difference at 5 %

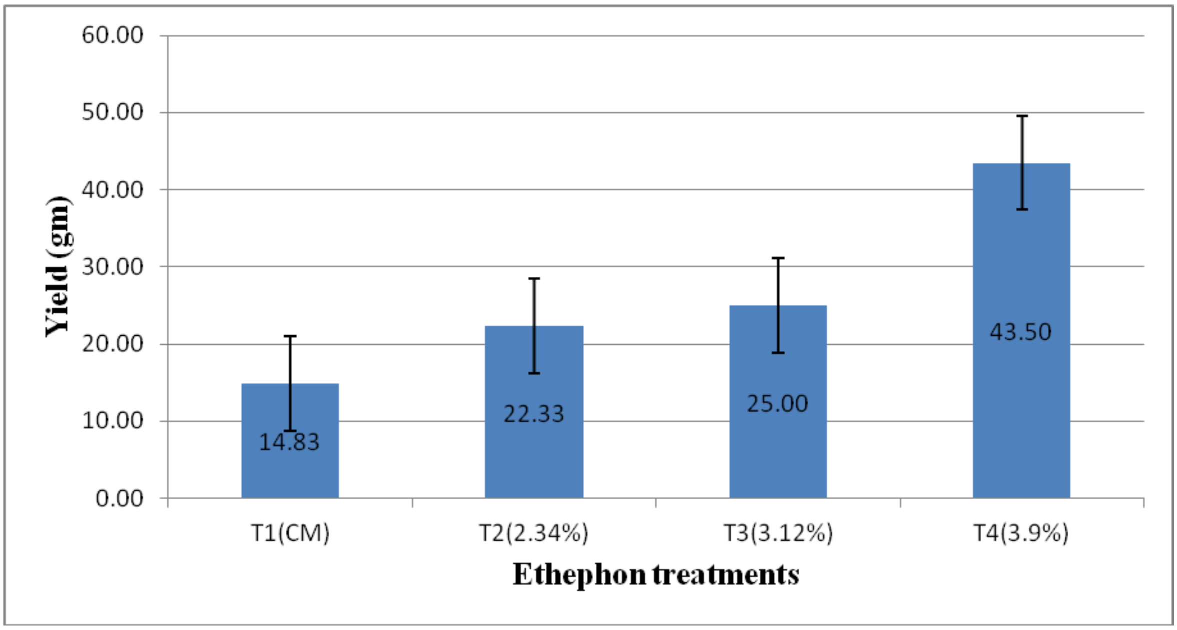


Fig 5. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of June

Fig 6. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of June

4.1.3 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month July 2018

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of July ranged from 6gm to 18.33gm for 70-110cm girth class, 14.67gm to 41gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of July.

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 6gm to 14.67gm in T1(control), 13.67gm to 29.67gm in T2 (2.34% ethephon), 18.33gm to 28.67gm in T3 (3.12% ethephon) and 14gm to 41 gm in T4 (3.9% ethephon). No significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 3) was observed.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	6.00	14.67	10.33	0.205 ns
T2 (2.34%)	13.67	29.67	21.67	
T3 (3.12%)	18.33	28.67	23.50	
T4 (3.9%)	14.00	41.00	27.50	
Girth mean	13.00^{a}	28.50^{b}		
P-value for girth	0.015* C.D (11.96)			

*- significant difference at 5 %, ns -non-significant difference at 5 %

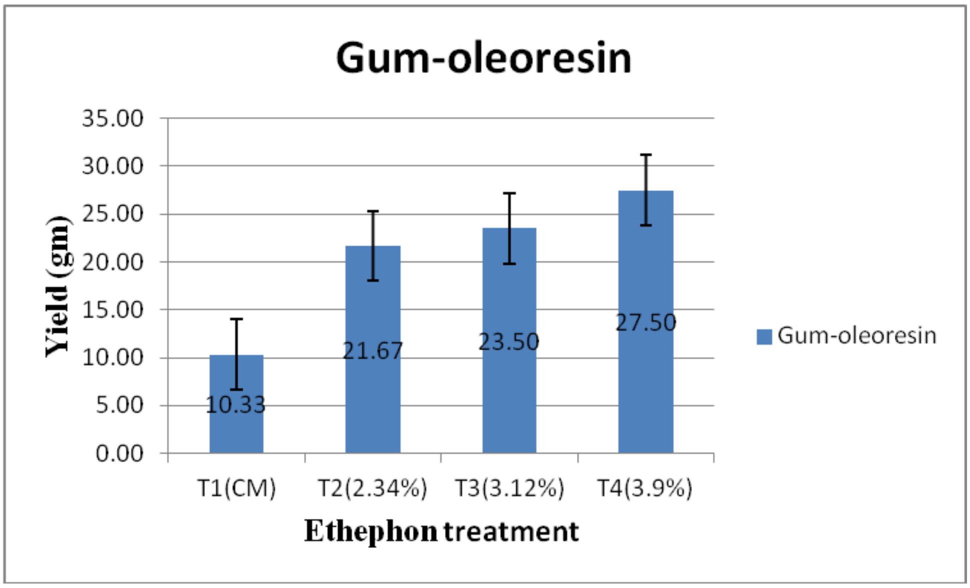


Fig 7. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of July

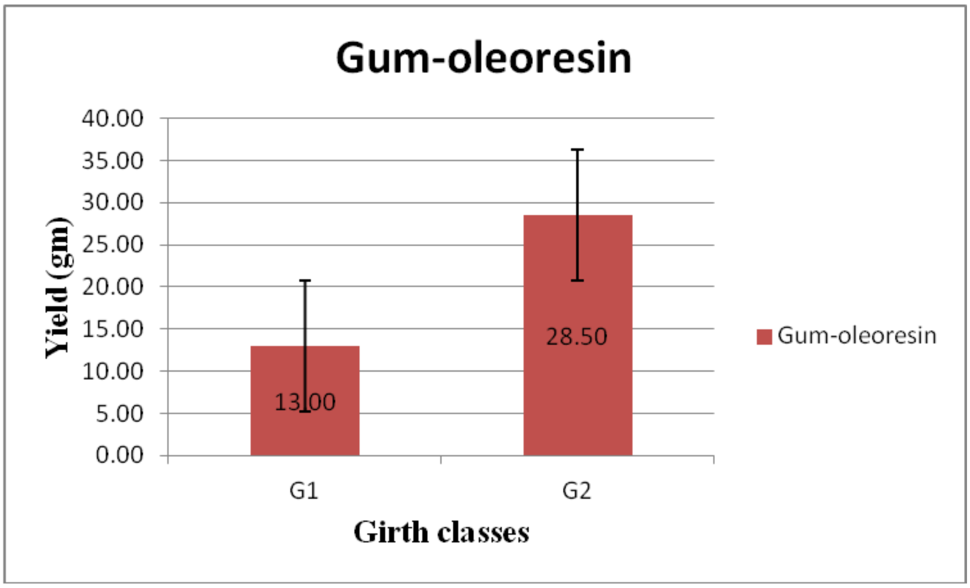


Fig 8. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of July

4.1.4 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month August 2018.

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of August ranged from 14.73gm to 41.58gm for 70-110cm girth class, 15.52gm to 63.86gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of August.

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 14.73gm to 15.52gm in T1(control), 31.42gm to 69.09gm in T2 (2.34% ethephon), 40.93gm to 50.41gm in T3 (3.12% ethephon) and 41.58 gm to 63.86gm in T4 (3.9% ethephon). It is found significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 4). The study revealed that the T2 (2.34%), T3 (3.12%) were on par withT4 (3.9%) and is significantly different from T1 (control method) in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	14.73	15.52	15.12^{a}	0.01** C.D (23.23)
T2 (2.34%)	31.42	69.09	50.25^{b}	
T3 (3.12%)	40.93	50.41	45.67^{b}	
T4 (3.9%)	41.58	63.86	52.72^{b}	
Girth mean	32.16^{a}	49.72^{b}		
P-value for girth	0.035* C.D (16.43)			

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

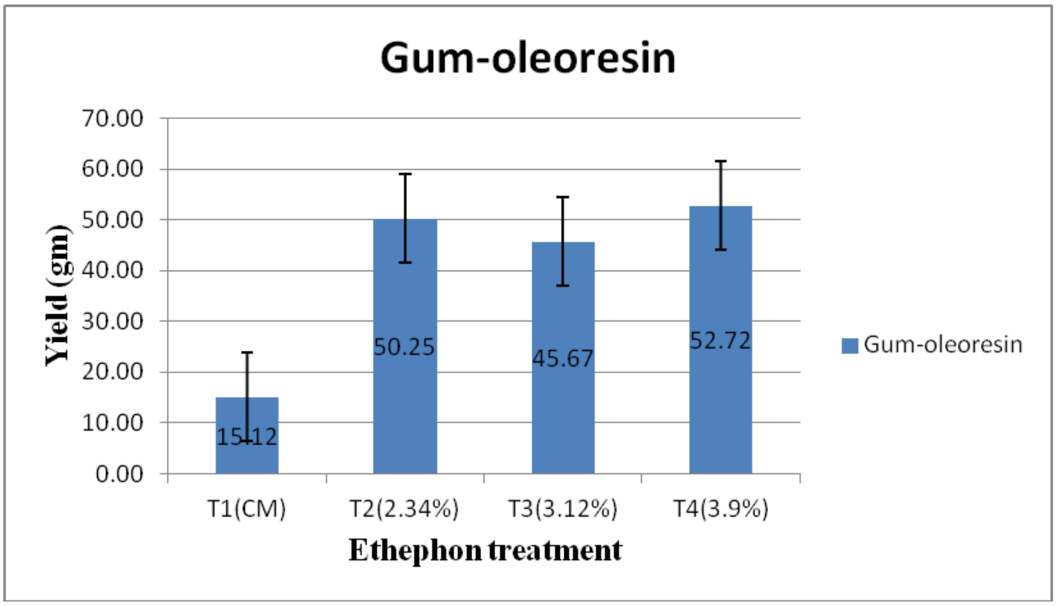


Fig 9. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different Ethephon treatments during month of August

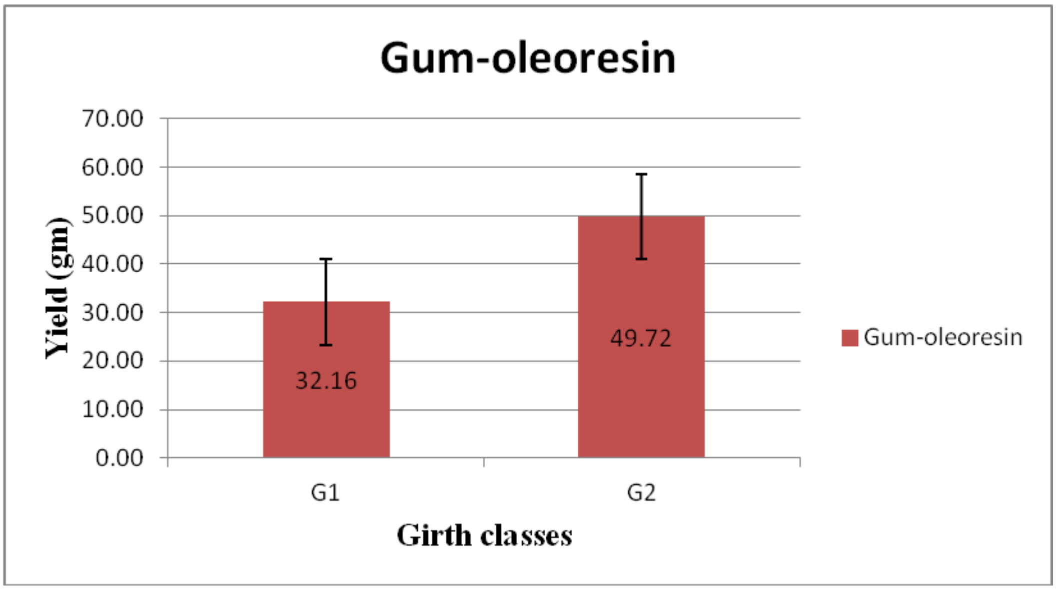


Fig 10. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of August

4.1.5 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month September 2018

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of September ranged from 28.17gm to 125.16gm for 70-110cm girth class, 15.52gm to 63.86gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was not found to be significant during the month of September.

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 28.17gm to 37.76gm in T1(control), 70.86gm to 114.48gm in T2 (2.34% ethephon), 76.18gm to 122.45gm in T3 (3.12% ethephon) and 125.16gm to 122.81gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 5) is evident. The study revealed that the ethephon treatmet T4 (3.9%) is on par with T3 (3.12%) and T2 (2.34%) is significantly different from T1 (CM).

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	28.17	37.76	32.97^{a}	0.043*
T2 (2.34%)	70.86	114.48	92.67^{ab}	C.D (62.27)
T3 (3.12%)	76.18	122.45	99.32^{b}	
T4 (3.9%)	125.16	122.81	123.99^{b}	
Girth mean	75.09	99.38		
P-value for girth	0.257 ns			

*- significant difference at 5 %, ns -non-significant difference at 5 %

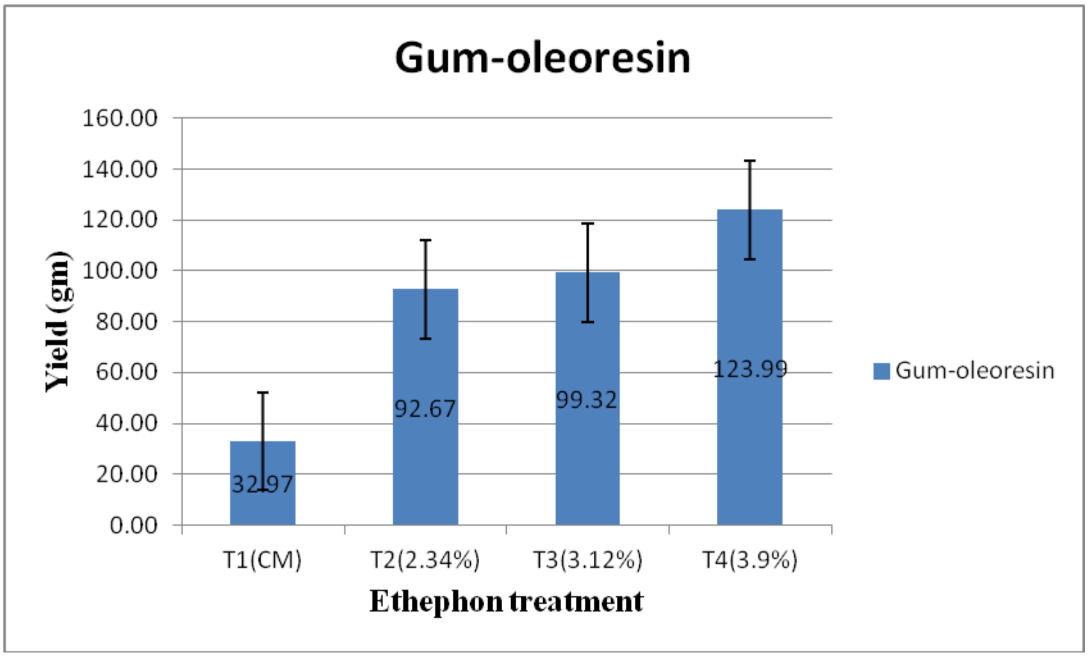


Fig 11. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatment the during month of September

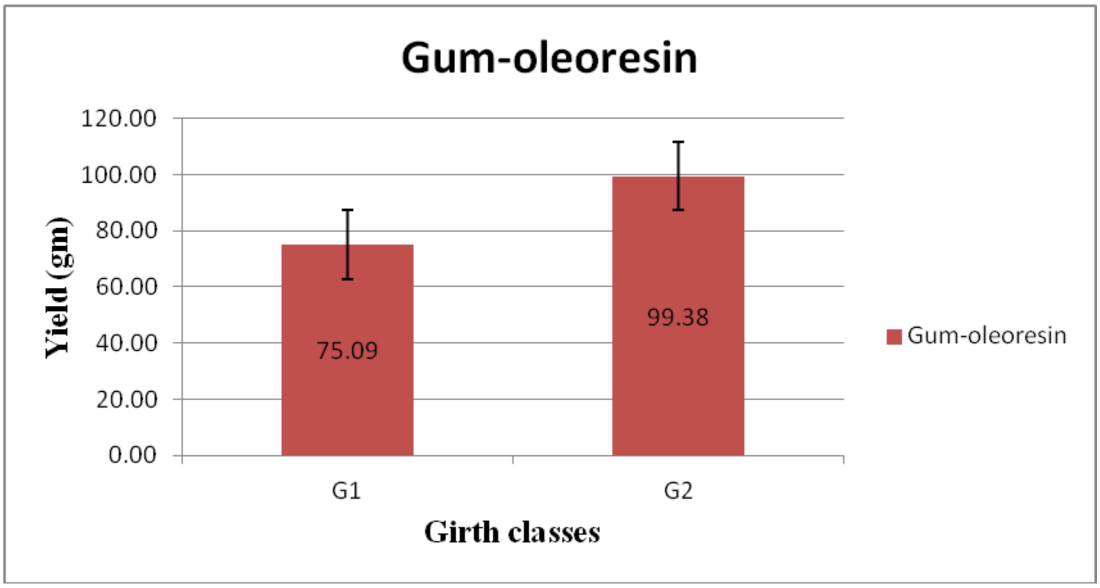


Fig 12. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of September

4.1.6 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month October 2018

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of October ranged from 29.58gm to 94.73gm for 70-110cm girth class, 32.94gm to 115.98gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was not found to be significant during the month of October.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 29.58gm to 32.94gm in T1 (control method), 44.21gm to 102.22gm in T2 (2.34% ethephon), 49.42 gm to 92.37 gm in T3 (3.12% ethephon) and 94.73 gm to 115.98gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentrations of ethephon treatments (Table 6) was observed. The study revealed that the T4 (3.9%) is significantly different from T1 (CM) and it is on par with T2 (2.34%), T3 (3.12%).

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	29.58	32.94	31.26^{a}	0.045* C.D (49.37)
T2 (2.34%)	44.21	102.22	73.21^{ab}	
T3 (3.12%)	49.42	92.37	70.89^{ab}	
T4 (3.9%)	94.73	115.98	105.36^{b}	
Girth mean	54.48	85.88		
P-value for girth	0.074 ns			

*- significant difference at 5 %, ns -non-significant difference at 5 %

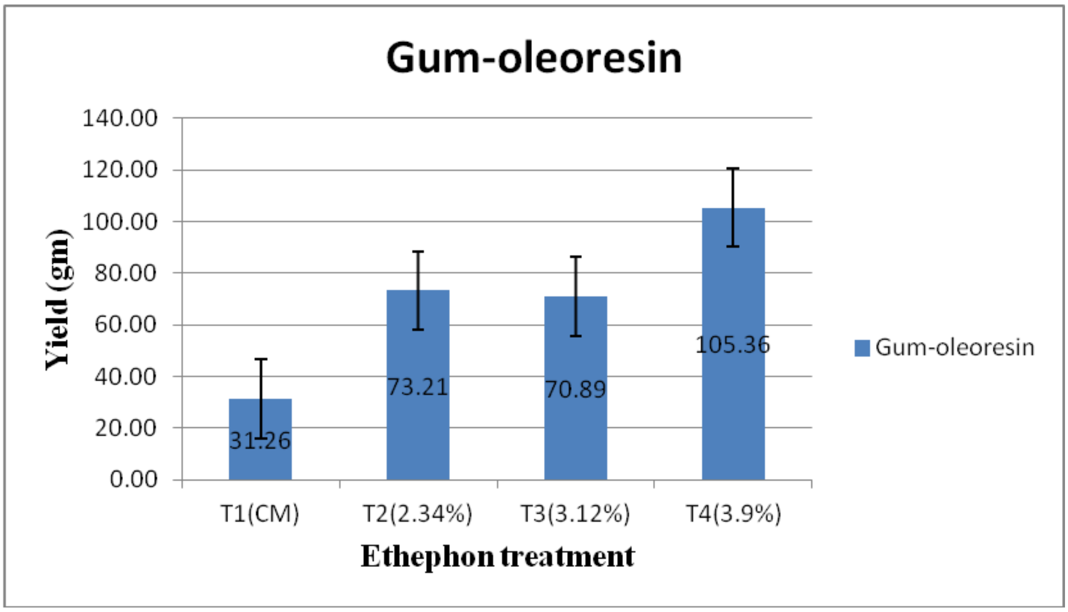


Fig 13. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments the during month of October

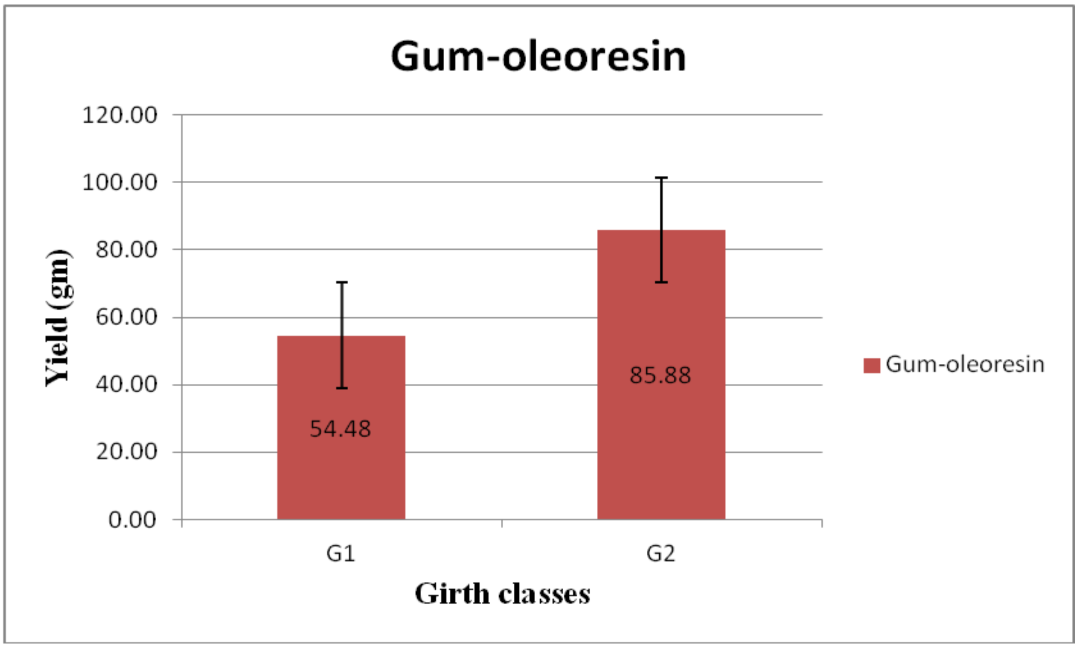


Fig 14. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of October

4.1.7 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month November 2018

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of November ranged from 31.61gm to 61.49gm for 70-110cm girth class, 28.60gm to 108.40gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of November.

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 28.60 gm to 31.61 gm in T1(control), 32.60gm to 78.95gm in T2 (2.34% ethephon), 42.46gm to 54.43gm in T3 (3.12% ethephon) and 61.49 gm to 108.40gm in T4 (3.9% ethephon). It is statistically found significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 7). The study revealed that the T4 (3.9%) is significantly different from other treatments in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	31.61	28.60	30.11^{a}	0.015* C.D (31.18)
T2 (2.34%)	32.60	78.95	55.78^{a}	
T3 (3.12%)	42.46	54.43	48.45^{a}	
T4 (3.9%)	61.49	108.40	84.94^{b}	
Girth mean	42.04^{a}	67.60^{b}		
P-value for girth	0.026* C.D (22.04)			

*- significant difference at 5 % level

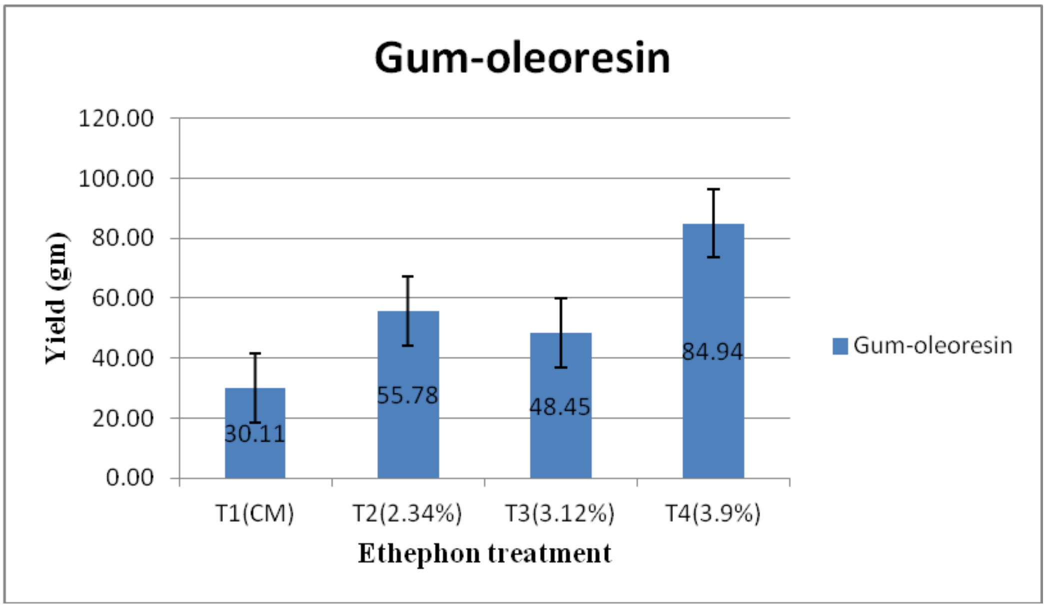


Fig 15. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of November

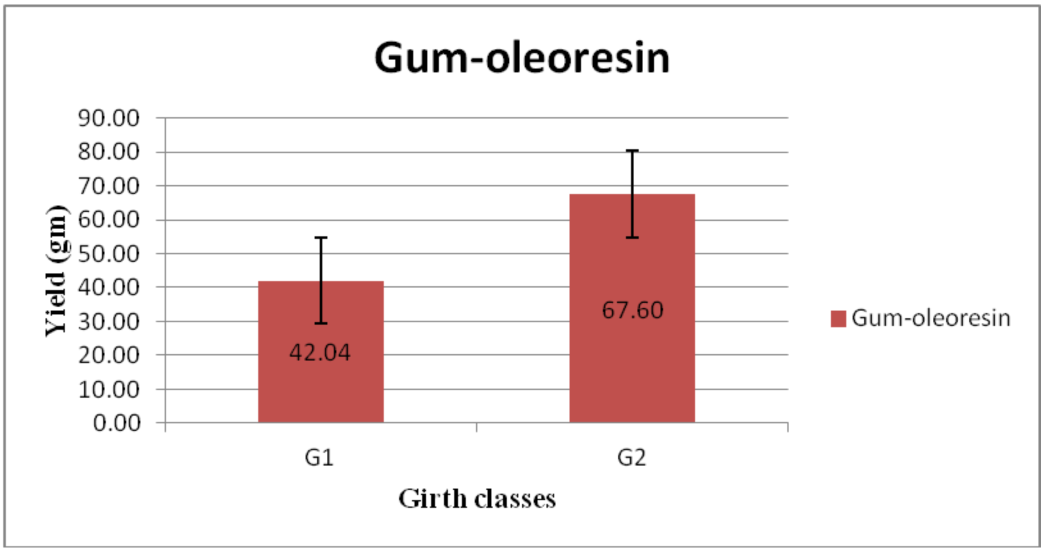


Fig 16. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of November

4.1.8 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month December 2018

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of December ranged from 21.35gm to 35.55gm for 70-110cm girth class, 23.35gm to 65.10gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of December.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 21.35gm to 23.35gm in T1(control), 23.66gm to 45.81gm in T2 (2.34% ethephon), 17.70gm to 28.77gm in T3 (3.12% ethephon) and 35.55gm to 65.10gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 8) were observed. The study revealed that the T4 (3.9%) is significantly different from other concentration of ethephon treatments in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	21.35	23.35	22.35^{a}	0.026*
T2 (2.34%)	23.66	45.81	34.74^{a}	C.D (19.29)
T3 (3.12%)	17.70	28.77	23.24^{a}	
T4 (3.9%)	35.55	65.10	50.33^{b}	
Girth mean	24.57^{a}	40.76^{b}		
P-value for girth	0.023* C.D (13.64)			

*- significant difference at 5 %

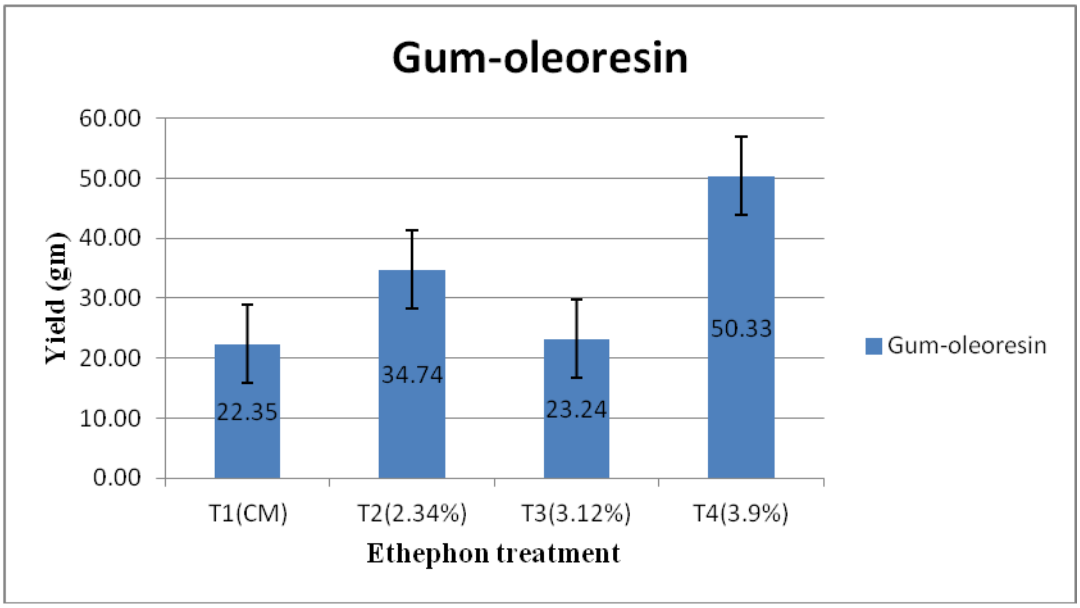


Fig 17. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during month of December

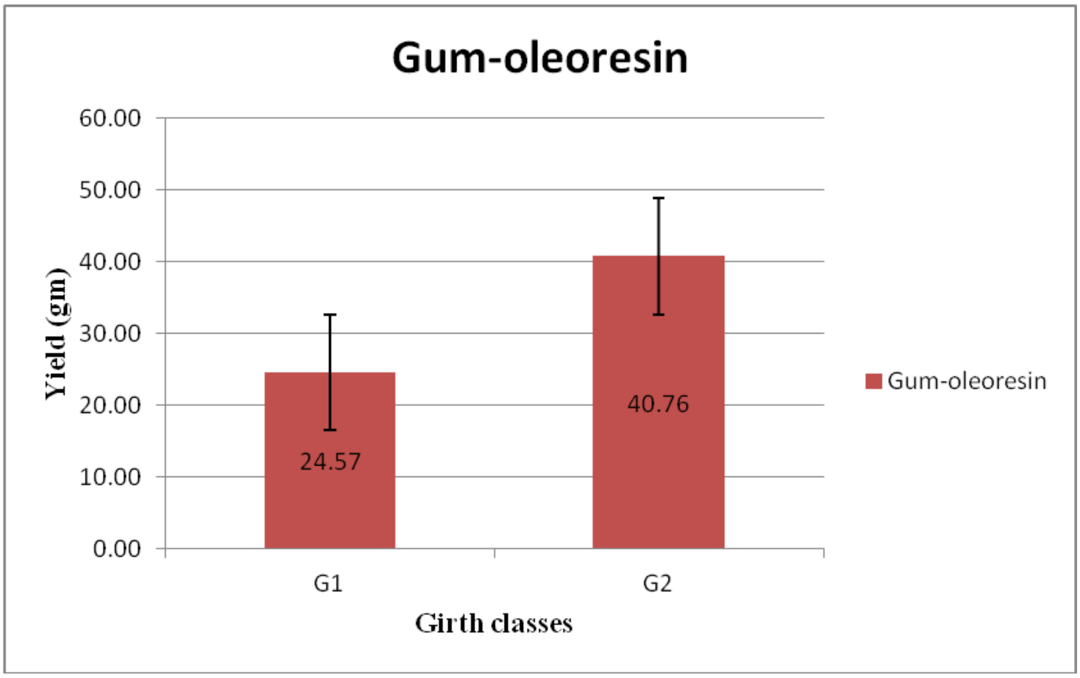


Fig18. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of December

4.1.9 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month January 2019.

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of January ranged from 9.61gm to 52.87gm for 70-110cm girth class, 33.56gm to 127.37gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be not significant during the month of January.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 9.61 gm to 33.56 gm in T1(control), 49.57gm to 82.34gm in T2 (2.34% ethephon), 26.90gm to 45.39gm in T3 (3.12% ethephon) and 125.42gm to 127.37gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 9) was evident. The study revealed that the T4 (3.9%) is significantly different from other concentration of ethephon treatments in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	9.61	33.56	21.59[a]	0.004** C.D (53.18)
T2 (2.34%)	49.57	82.34	65.96[a]	
T3 (3.12%)	26.90	45.39	36.14[a]	
T4 (3.9%)	125.42	127.37	126.39[b]	
Girth mean	52.87	72.17		
P-value for girth	0.290 ns			

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

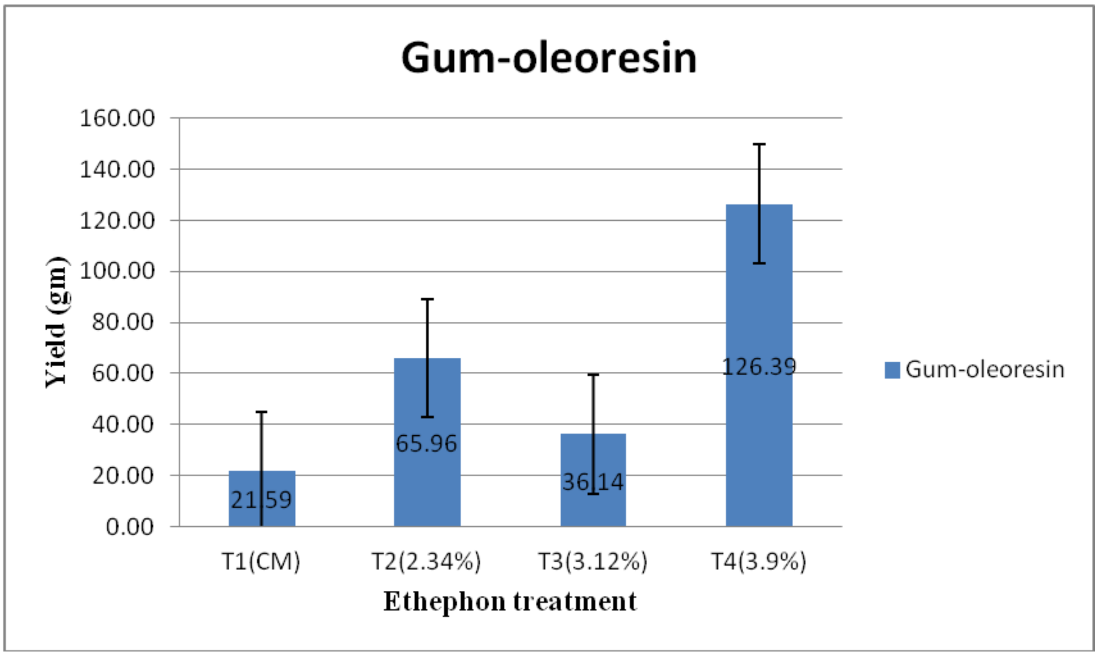


Fig 19. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of January

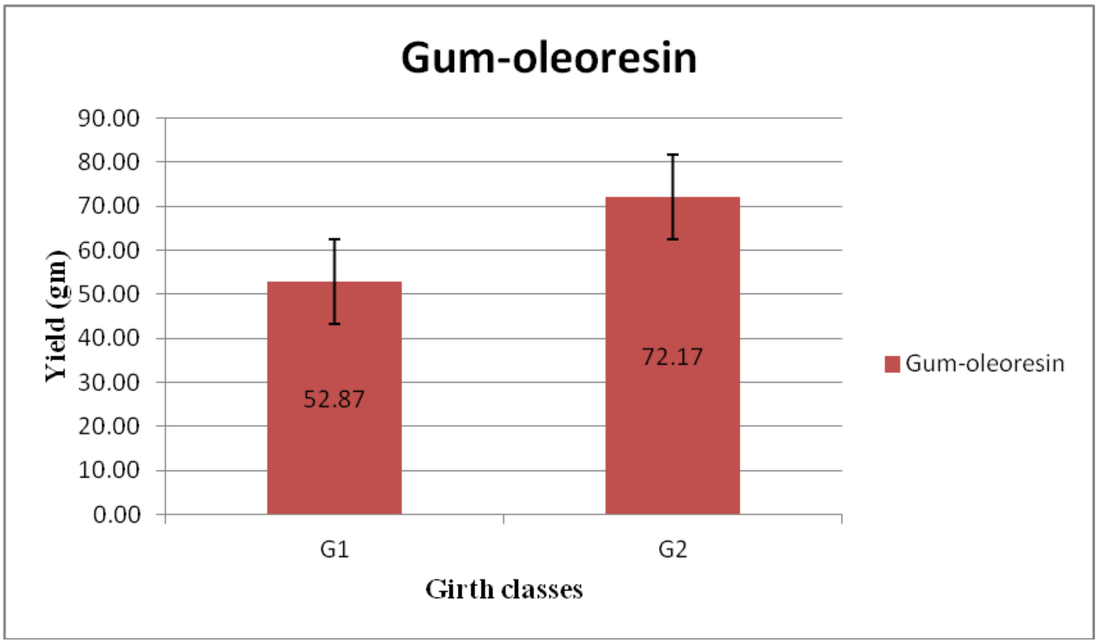


Fig 20. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of January

4.1.10 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month February 2019

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of February ranged from 10.83gm to 77.62gm for 70-110cm girth class, 23.15gm to 66.80gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be not significant during the month of February.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 10.83gm to 23.15gm in T1(control), 32.05gm to 32.15gm in T2 (2.34% ethephon), 22.75gm to 30.51gm in T3 (3.12% ethephon) and 66.80gm to 77.62gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 10) was observed. The study revealed that the T4 (3.9%) is significantly different from other concentration of ethephon treatments in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	10.83	23.15	16.95^{a}	0.005**
T2 (2.34%)	32.05	32.15	32.10^{a}	C.D (28.49)
T3 (3.12%)	22.75	30.51	26.63^{a}	
T4 (3.9%)	77.62	66.80	72.21^{b}	
Girth mean	35.81	38.13		
P-value for girth	0.809 ns			

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

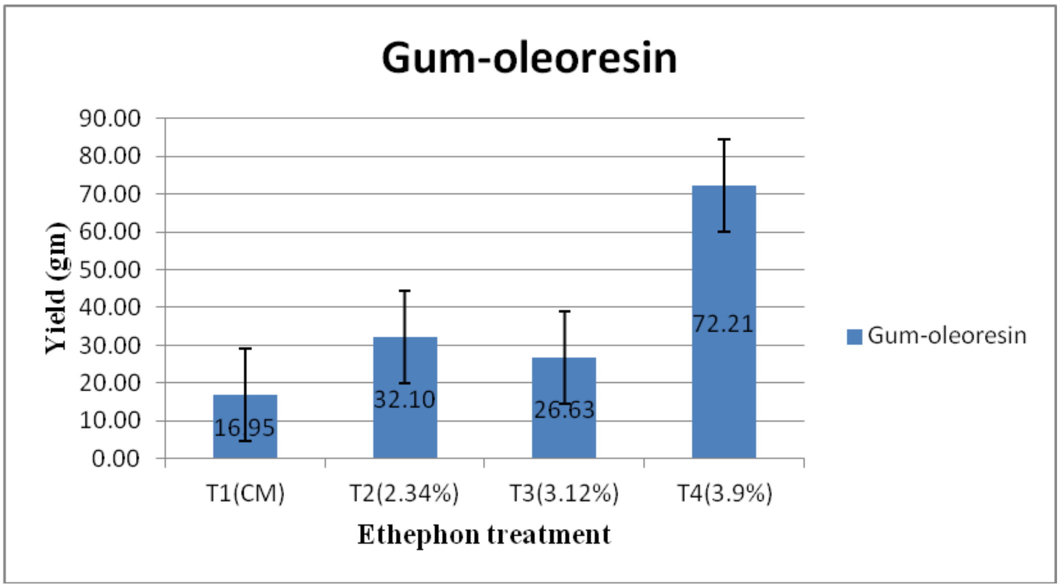


Fig 21. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of February

Fig 22. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of February

4.1.11 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month March 2019

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of March ranged from 9.80gm to 69.30gm for 70-110cm girth class, 17.89gm to 60.84gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be not significant during the month of March.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 9.80gm to 17.89gm in T1(control), 30.32gm to 32.32gm in T2 (2.34% ethephon), 24.75gm to 29.03gm in T3 (3.12% ethephon) and 60.84gm to 69.30gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 11). The study revealed that the T4 (3.9%) is significantly different from other concentration of ethephon treatments in gum-oleoresin production.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Etephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	9.80	17.89	13.84 [a]	0.005** C.D (25.59)
T2 (2.34%)	32.22	30.32	31.33 [a]	
T3 (3.12%)	24.75	29.03	26.89 [a]	
T4 (3.9%)	69.30	60.84	65.07[b]	
Girth mean	34.04	34.52		
P-value for girth	0.956 ns			

**- significant different at 5% and 1% level ns-no significant difference at 5 %,

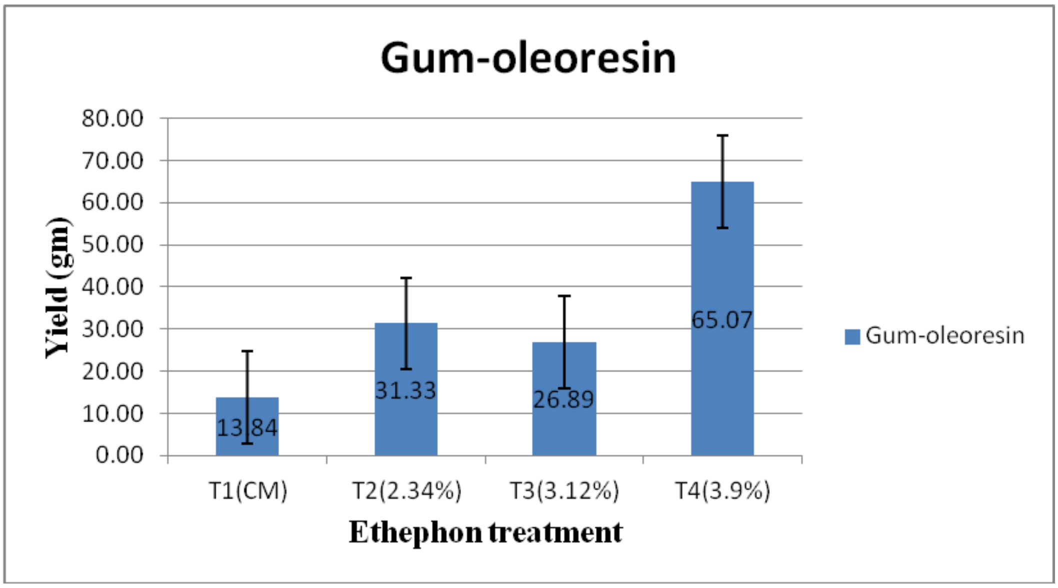


Fig 23. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatment during month of March

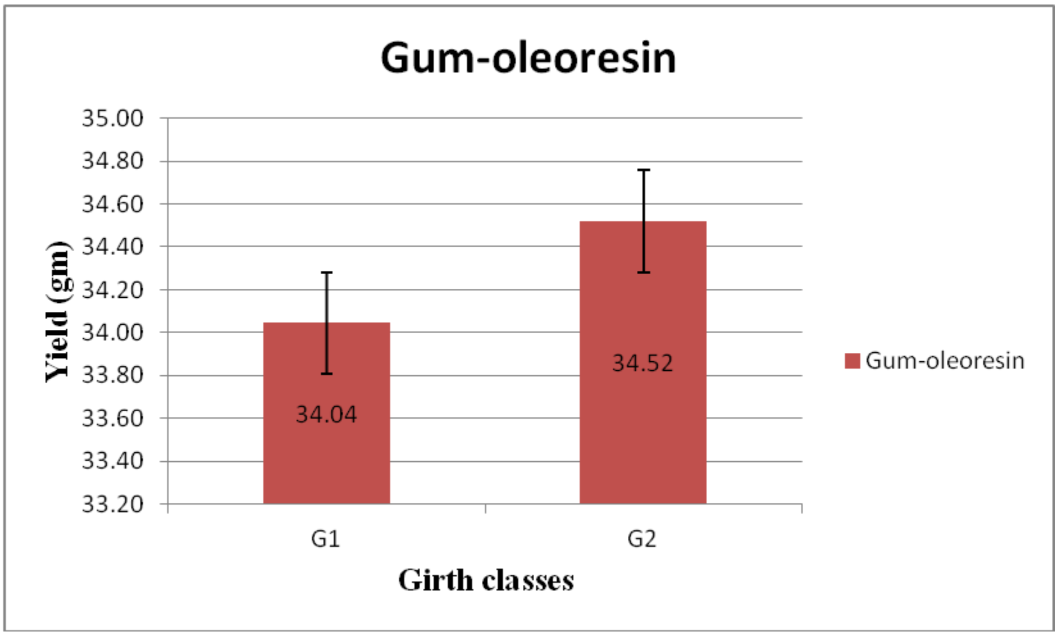


Fig 24. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of March

4.1.12 Effect of ethephon treatments and girth classes on gum-oleoresin yield in the month April 2019

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the month of April ranged from 5.58gm to 24.18gm for 70-110cm girth class, 6.02gm to 32.04gm for 111-150cm girth class. Difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of April.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 5.58gm to 6.02gm in T1(control), 14.18gm to 17.57gm in T2 (2.34% ethephon), 12.81gm to 22.21gm in T3 (3.12% ethephon) and 24.18gm to 32.04 gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatments (Table 12). The study revealed that the T4 (3.9%) is significantly different from other treatments.

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	5.58	6.02	5.80^{a}	0.01** CD (3.98)
T2 (2.34%)	14.18	17.57	15.88^{b}	
T3 (3.12%)	12.81	22.21	17.51^{b}	
T4 (3.9%)	24.18	32.04	28.11^{c}	
Girth mean	14.19	19.46		
P-value for girth	0.001** CD (2.81)			

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

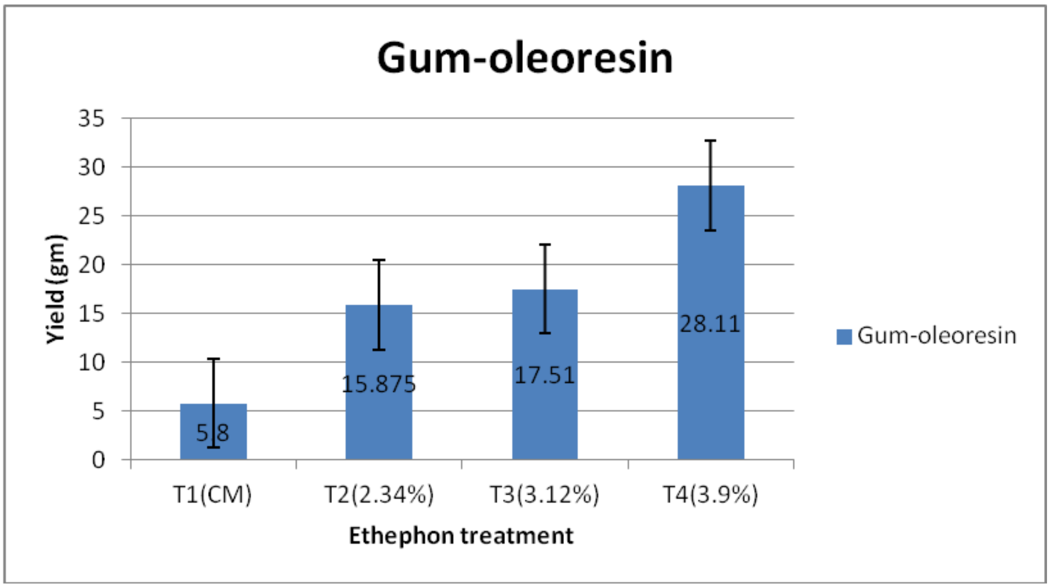


Fig 25. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different ethephon treatments during the month of April

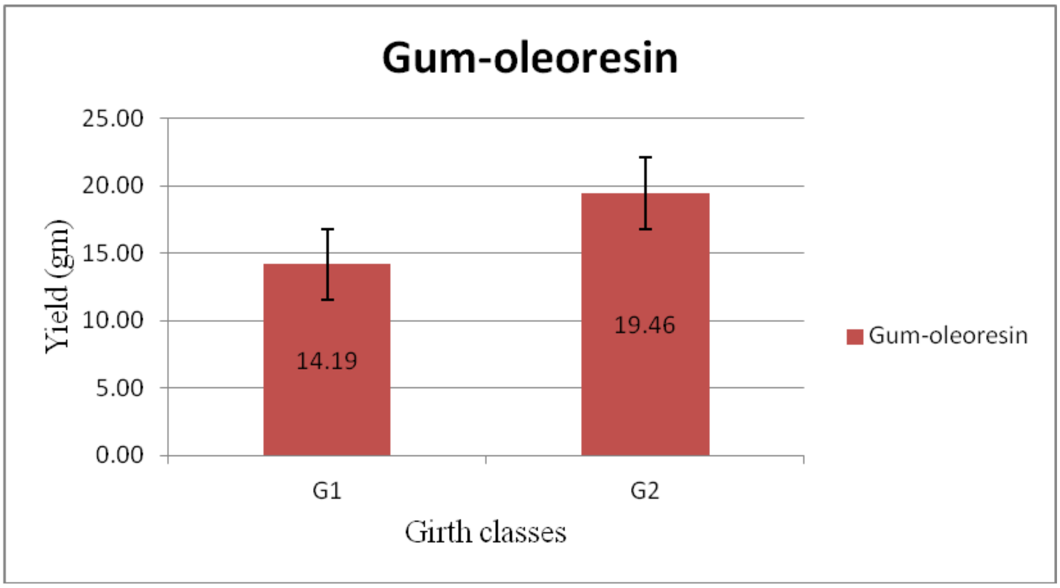


Fig 26. Gum-oleoresin yield of *Ailanthus triphysa* with respect to different girth classes during the month of April

4.2 EFFECT OF DIFFERENT SEASONS ON GUM-OLEORESIN YIELD.

4.2.1 Effect of monsoon season on gum-oleoresin yield

The gum-oleoresin yield from *Ailanthus* trees during the rainy season (June, July, August, and September) ranged from 15.56gm to 52.27gm for 70-110cm girth class, 21.05gm to 71.58gm for 111-150cm girth class. This revealed that no significant difference in gum-oleoresin yield due to girth class variation (Table 13).

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 15.56gm to 21.05gm in T1(control), 32.99gm to 60.48gm in T2 (2.34% ethephon), 39.28gm to 57.47gm in T3 (3.12% ethephon) and 52.27gm to 71.58gm in T4 (3.9% ethephon). It is observed that significant difference in gum-oleoresin yield due to different concentration of ethephon treatment (Table 13). The study reveals that the T4 (3.9%), T3 (3.12%) and T2 (2.34%) is on par and significantly different from T1 (control) treatment in gum-oleoresin production.

Table13. Gum-oleoresin yield from *Ailanthus triphysa* during the monsoon

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	15.56	21.05	18.31[a]	0.02* CD (26.38)
T2 (2.34%)	32.99	60.48	46.73[b]	
T3 (3.12%)	39.28	57.47	48.37[b]	
T4 (3.9%)	52.27	71.58	61.93[b]	
Girth mean	35.02	52.65		
P-value for (G)	0.62 ns			

*- significant difference at 5 %, ns -non-significant difference at 5 %

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

The gum-oleoresin yield from *Ailanthus* trees during the post-monsoon season which consists of (October November, December and January) ranged from 23.04gm to 79.30gm for 70-110cm girth class, 29.61gm to 104.21gm for 111-150cm girth class. This revealed that no significant difference in gum-oleoresin yield due to girth class variation (Table 14)

Similarly, the gum-oleoresin yield due to different concentration of ethephon ranged from 23.04 gm to 29.61gm in T1(control), 37.51gm to 77.33gm in T2 (2.34%), 34.12gm to 55.42gm in T3 (3.12%) and 79.30gm to 104.21 gm in T4 (3.9% ethephon). It is observed that significant difference in gum-oleoresin yield due to different concentrations of ethephon treatments (Table 15). The study revealed that the T4 (3.9%) is on par with T3 (3.12%) and T1 (CM), T2 (2.34%) is on par with T3 (3.12%).

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

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	23.04	29.61	26.33^{a}	0.01** CD(36.11)
T2 (2.34%)	37.51	77.33	57.42^{a}	
T3 (3.12%)	34.12	55.42	44.68^{ab}	
T4 (3.9%)	79.30	104.21	91.75^{b}	
Girth mean	43.49	66.60		
P-value (Girth)	0.07 ns			

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

4.2.3 Effect of gum-oleoresin yield in summer season.

The gum-oleoresin yield from *Ailanthus triphysa* trees during the summer season which consist of (February, march April and May) ranged from 8.42gm to 51.36gm for 70-110cm girth class, 15.38gm to 50.27gm for 111-150cm girth class. This revealed that no significant difference in gum-oleoresin yield due to girth class variation (Table 15)

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 8.42 gm to 15.38gm in T1(control method), 23.64gm to 24.43gm in T2 (2.34% ethephon), 17.57gm to 25.02 gm in T3 (3.12% ethephon) and 51.36gm to 50.27 gm in T4 (3.9% ethephon). It is statistically found significant difference in gum-oleoresin yield due to different concentrations of ethephon treatments (Table 15). The study reveals that the T4 (3.9%), is significantly different from T1 (control), T2 (2.34%) and T3 (3.12%) ethephon treatment in gum-oleoresin production.

Table 15. Gum-Oleoresin yield from *Ailanthus triphysa* during the summer season

FACTORS	GUM-OLEORESIN YIELD (gm)			
	GIRTH CLASSES			
Ethephon treatments	Girth class 1 (70-110cm)	Girth class 2 (111-150cm)	Treatment mean	P-value for treatment
T1 (CM)	8.42	15.38	11.90^{a}	0.001**
T2 (2.34%)	23.64	24.43	24.03^{a}	CD (16.04)
T3 (3.12%)	17.57	25.02	21.29^{a}	
T4 (3.9%)	51.36	50.27	50.82^{b}	
Girth mean	25.25	28.78		
P-value for girth	0.51 ns			

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

4.3 EFFECT OF DIFFERENT SEASON, GIRTH AND ETHEPHON TREATMENTS ON GUM-OLEORESIN YIELD.

The gum-oleoresin yield from *Ailanthus triphysa* trees during the different season (monsoon or rainy, post-monsoon and summer) found to be significant different from each other. The highest gum-oleoresin yield was found to be higher in post-monsoon season (55.06 gm) followed by monsoon season (43.78 gm) and then in summer season (27.01gm).

Table 16. Effect of different seasons, girth and ethephon treatments on gum-oleoresin yield (gm)

Treatment * Season mean table					
Treatment	Monsoon	Post monsoon	Summer	Total mean	P-value of treatment
G1T1	15.56	23.04	8.42	15.67	0.001**
G1T2	32.99	37.51	23.64	31.38	
G1T3	39.28	34.12	17.57	30.32	
G1T4	52.27	79.30	51.36	60.98	
G2T1	21.05	29.61	15.38	22.01	
G2T2	60.04	77.33	24.43	53.93	
G2T3	57.47	55.42	25.02	45.97	
G2T4	71.58	104.21	50.27	75.35	
Total mean	43.78^{a}	55.06^{b}	27.01^{a}		
P-value of season	0.001**				
P-value for interaction(S*T)	0.763 ns				

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

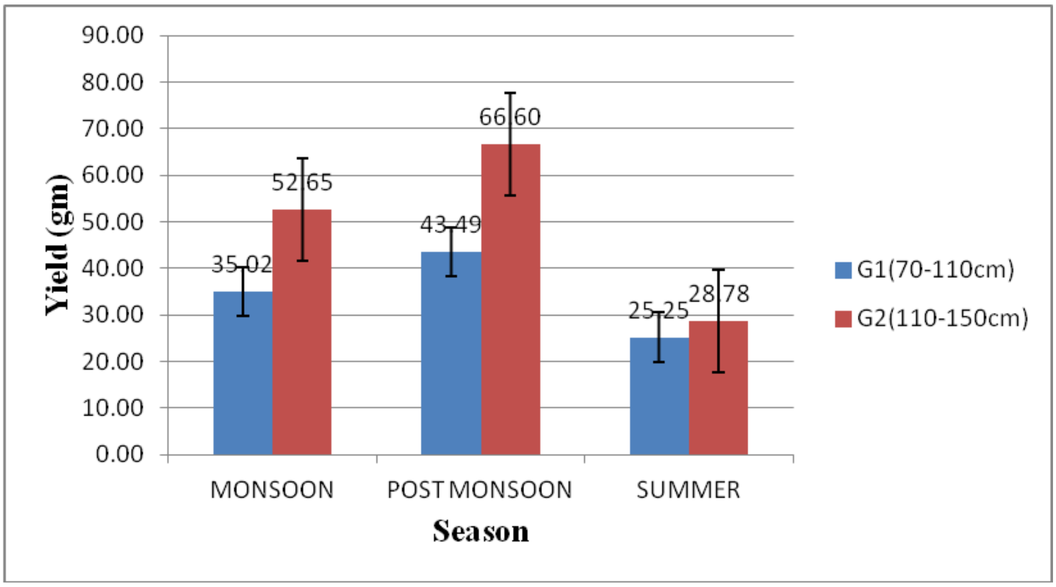


Fig 27. Gum-oleoresin yield of *Ailanthus triphysa* at different girth classes during different seasons

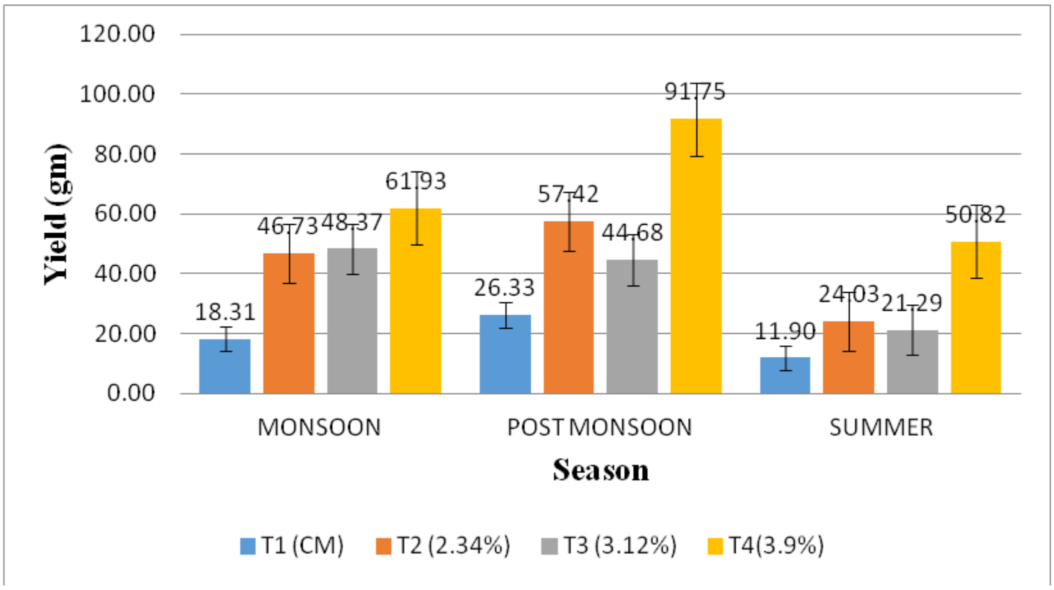


Fig 28. Gum-oleoresin yield obtained from different concentration of ethephon treatments on *Ailanthus triphysa* during different seasons

4.4 EFFECT OF GIRTH CLASSES AND TAPPING METHOD ON ANNUAL GUM-OLEORESIN YIELD.

Present study revealed that the gum-oleoresin yield from *Ailanthus* trees during the whole study period (May 2018 to April 2019) average yield ranged from 13.00gm to 99.38gm. Among the girth classes, it varied from 13gm to 75.09gm for 70-110cm girth class, 19.46gm to 99.38gm for 111-150cm girth class. Data presented on yearly basis showed almost similar trend as noticed at monthly intervals.

Similarly, the gum-oleoresin yield due to concentration of ethephon ranged from 5.80gm to 32.97gm in T1 (control), 15.88gm to 92.67gm in T2 (2.34% ethephon), 14.15 gm to 99.32gm in T3 (3.12% ethephon) and 28.11 gm to 123.99 gm in T4 (3.9% ethephon). Significant difference in gum-oleoresin yield due to different concentration of ethephon treatment (Table 17) could be observed. The study revealed that the T4 (3.9%) is significantly different from other concentration of ethephon treatment in gum-oleoresin production. In the month of September, it was found highest amount of gum-oleoresin yield i.e., 348.94gm.

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

Yield (grams)													
Girth class	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	Total
70-110cm	16.94	19.83	13.00	32.16	75.09	54.48	42.04	24.57	52.87	35.81	34.04	14.19	415.04
111-150cm	22.99	33.00	28.50	49.72	99.38	85.88	67.60	40.76	72.17	38.13	34.52	19.46	592.10
P-value (Girth)	0.516 ns												
Ethephon treatments													
T1(cm)	11.01	14.83	10.33	15.12	32.97	31.26	30.11	22.35	21.59	16.95	13.84	5.80	226.16[a]
T2 (2.34%)	16.83	22.33	21.76	50.25	92.67	73.21	55.78	34.74	65.96	32.10	31.33	15.88	512.74[a]
T3 (3.12%)	14.15	25.00	23.50	45.67	99.32	70.89	48.45	23.24	36.14	26.63	26.89	17.51	457.38[a]
T4 (3.9%)	37.87	43.50	27.50	52.72	123.99	105.36	84.94	50.33	126.39	72.21	65.07	28.11	817.99b
P-value (Treatment)	0.001**												
P-value (Interaction)	0.917 ns												

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

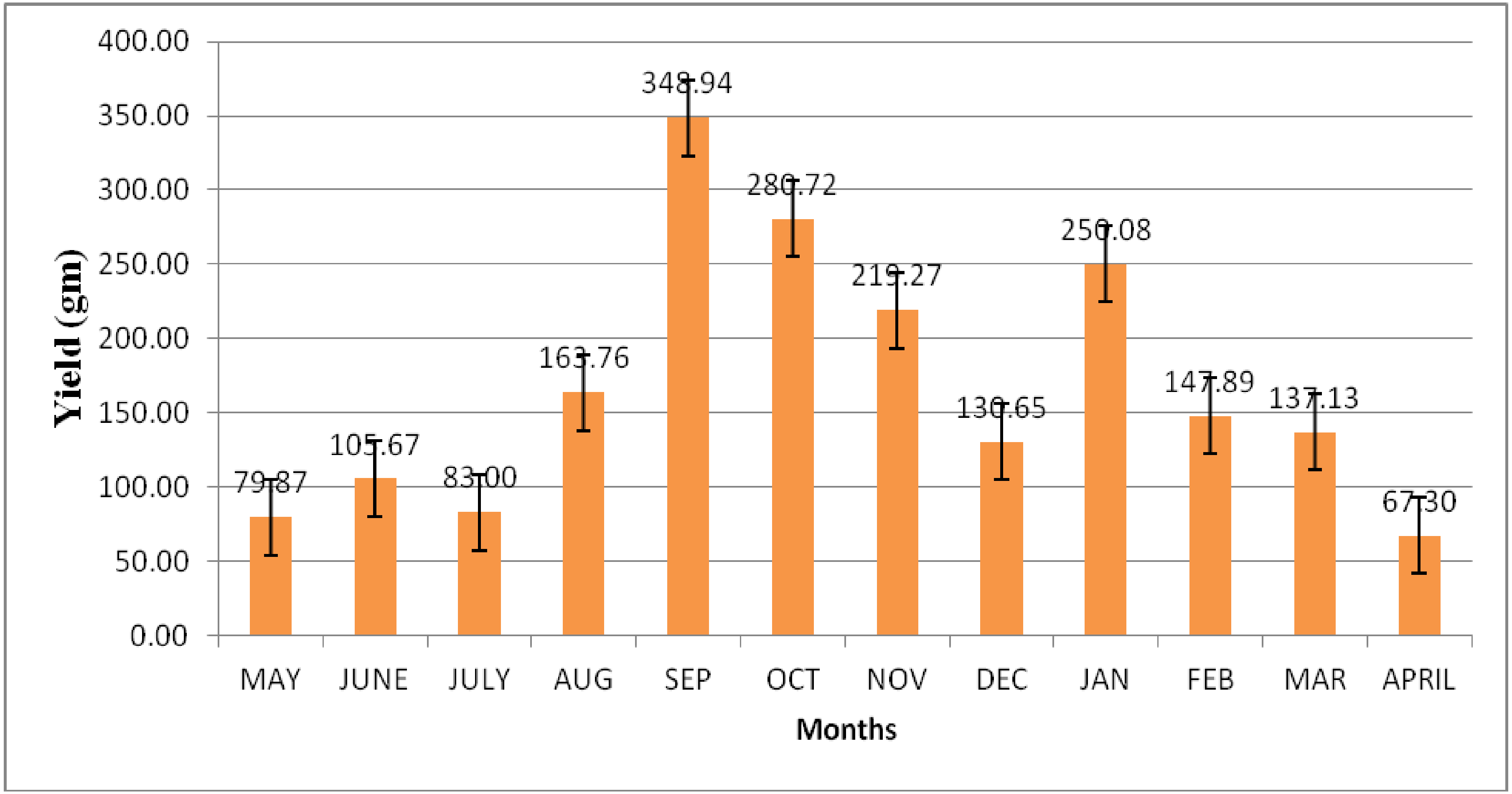


Fig 29. Gum-oleoresin yield obtained from different months during the whole study period (May 2018 to April 2019)

4.5 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 was found to be significantly different as the P value is found to be (0.039) is significant. It was observed from the correlation studies that as the girth class increases the bark thickness also increases. There is no significant difference between girth classes and gum-oleoresin production. The correlation coefficient ranges between -1 to +1. In the present study correlation coefficient between girth class and bark thickness was found to be 0.54, correlation between gum-oleoresin yield and bark thickness was found to be 0.42 and it indicates positive correlation with the gum-oleoresin production that greater the bark thickness, consequently greater the gum-oleoresin production. Correlation between gum-oleoresin yield and girth classes was found to be not significant (r = 0.36) that means there is no correlation between girth classes and gum-oleoresin production.

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

		Bark thickness	Girth class	Gum-oleoresin yield
Bark thickness (cm)	Pearson correlation	1		
	Sig. (2-tailed)			
	N	24		
Girth class (cm)	Pearson correlation	0.548**	1	
	Sig. (2-tailed)	0.006		
	N	24	24	
Gum-oleoresin yield (gm)	Pearson correlation	0.424*	0.361	
	Sig. (2-tailed)	0.039	0.083	
	N	24	24	24

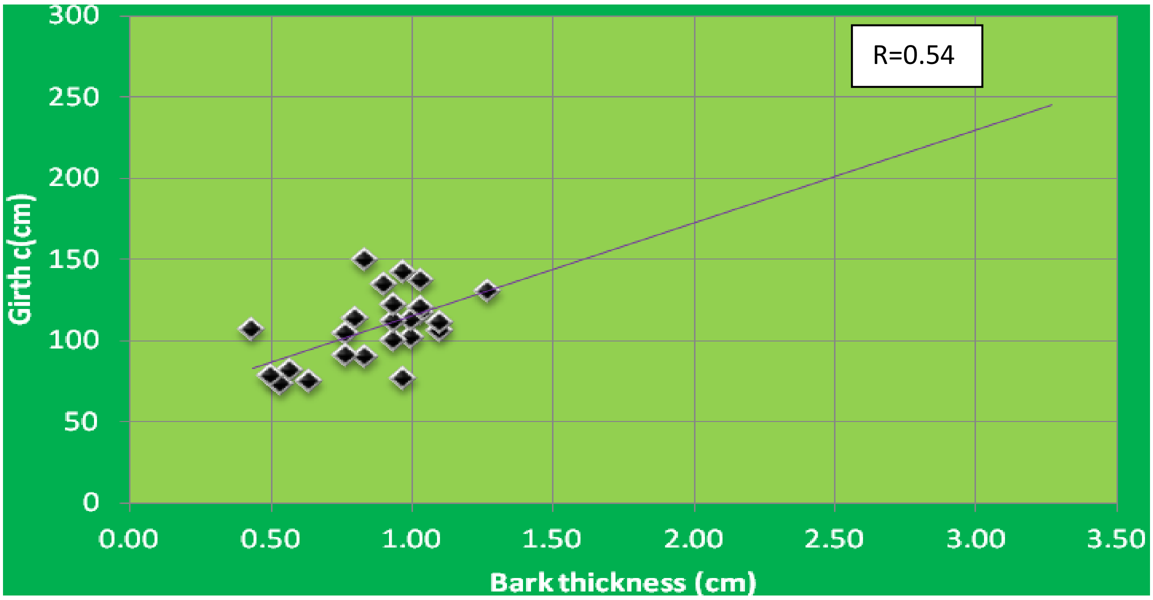


Fig 30. Correlation between girth and bark thickness (r =0.54)

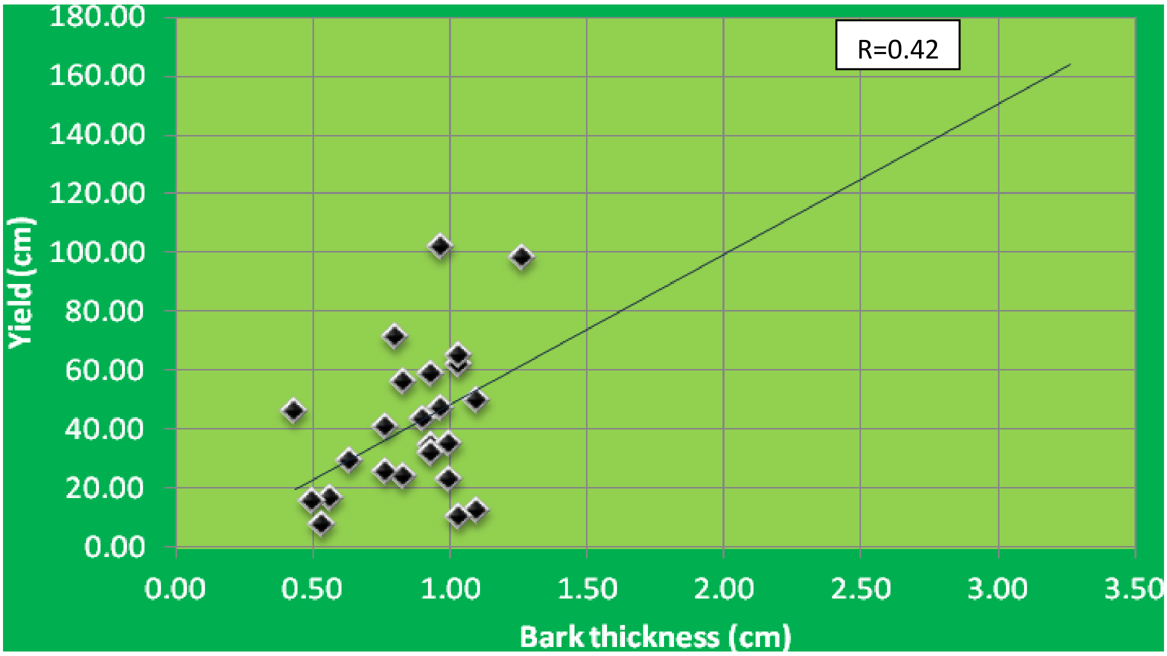


Fig 31. Correlation between bark thickness and gum-oleoresin yield (r =0.42)

4.6 EFFECT OF CLIMATIC PARAMETERS IN GUM-OLEORESIN PRODUCTION

Based on the correlation studies, none of the climatic parameter was found to be non-significant in gum-oleoresin production, However, the temperature was negatively correlated at 5 % significant level (Table.20). Similarly, the present study revealed that other climatic parameters like relative humidity (-0.24), rainfall (-0.30) were found to non-significant.

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

		Relative humidity (%)	Rainfall (mm)	Mean Temperature	Yield
Gum-oleoresin yield (g)	Pearson correlation	-0.241	-0.300	-0.299	-0.299
	Sig. (2-tailed)	0.451	0.343	0.345	0.345
	N	12	12	12	12

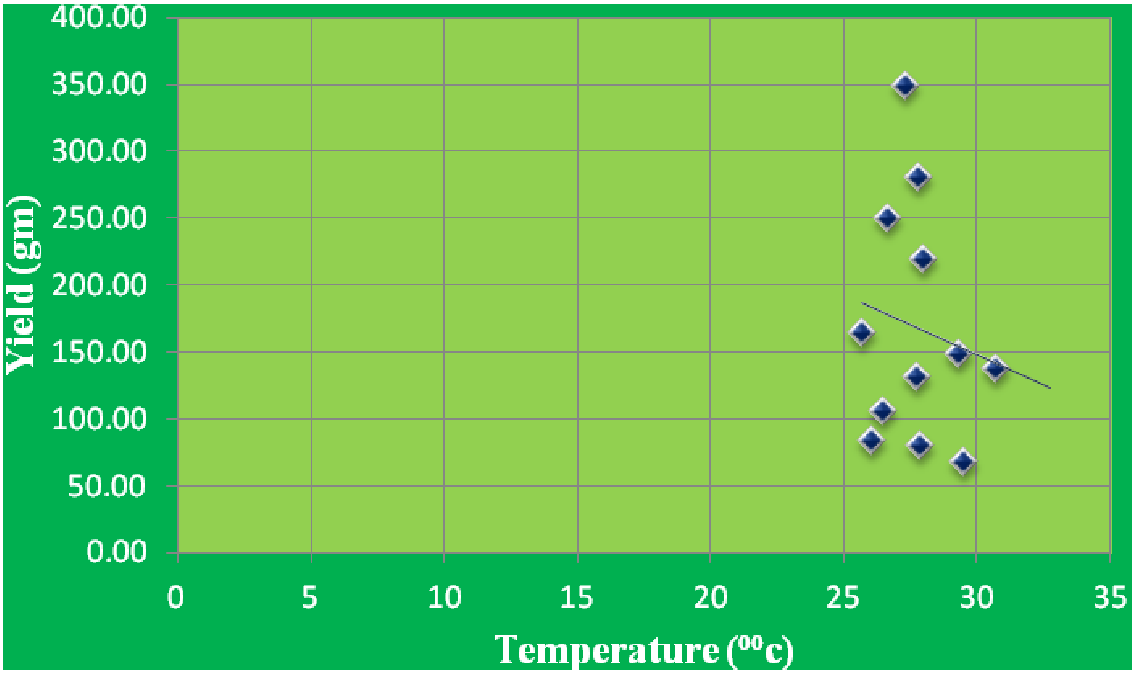


Fig 32. Effect of temperature on gum-oleoresin yield

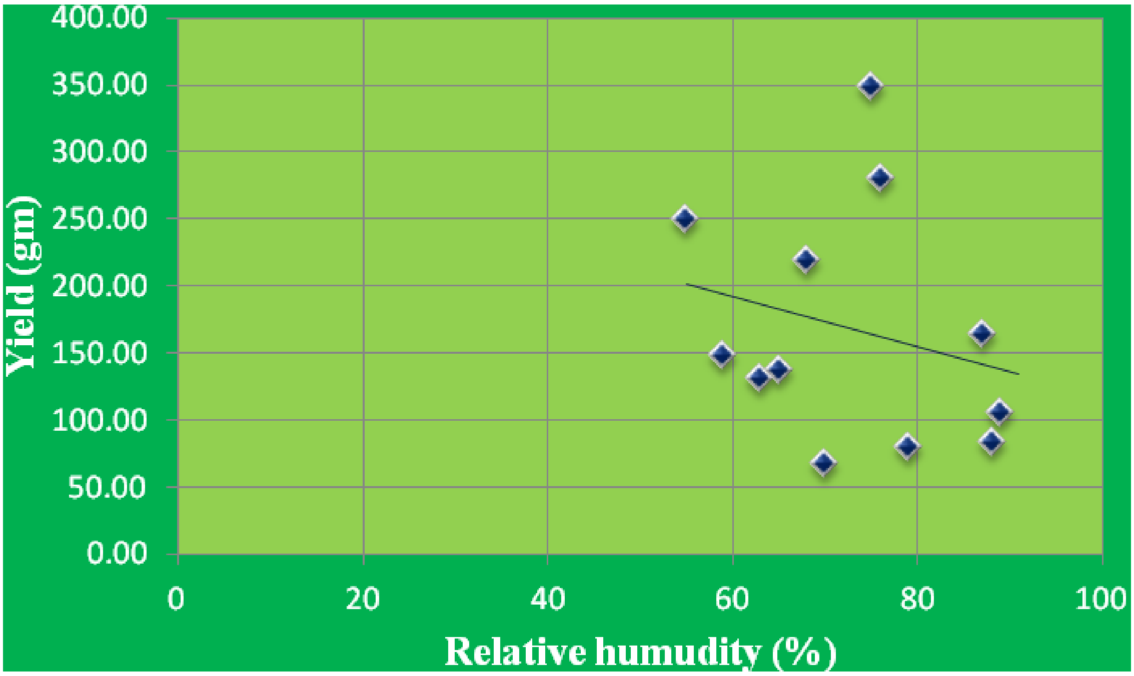


Fig 33. Effect of Relative humidity on gum-oleoresin yield

4.7 PHYSICAL PROPERTIES OF GUM-OLEORESIN FROM *AILANTHUS TRIPHYSA.*

The results of different physical properties such as solubility, pH, viscosity, moisture level, color parameters, ash content and heavy metals of gum-oleoresin are presented in the following section.

The solubility of *Ailanthus* gum-oleoresin was determined by using various solvents such as cold and hot distilled water, acetone, chloroform, xylene, n-butyl alcohol and ethanol and the results is summarized in Table 21. In case of water as solvent, the sample was found to be swollen in water. The solubility of gum-oleoresin was found higher in xylene (89.04%) followed by n-butyl alcohol. Gum-oleoresin samples were found to be soluble in other solvents.

Table 20. Solubility of gum-oleoresin in different solvents

Sl. No	Solvent	Solubility (%)
1	Acetone	62.83
2	Chloroform	62.58
3	Xylene	89.04
4	n-butyl alcohol	87.51
5	Ethanol	79.59

pH measurement showed that sample was traced to be strongly acidic. The pH value of *Ailanthus* sample was 5.5. The viscosity of *Ailanthus* gum-oleoresin was calculated by using Brookfield viscometer at 3 rpm per minute by using spindle number 62 and Viscosity observed was 2340 cps (centipoise). The viscosity also observed in 6 rpm per minute as 695 cps.

The moisture content was determined using hot air oven. The resulted moisture content was 5.17 %. The color of the gum-oleoresin observed to pale yellow in initial fresh collection, when it absorbs water, it becomes yellow white colour and becomes dark reddish brown colour when it dries up. The ash content was determined by muffle furnace and the value was found to be 1.66%.

Table 21. Physical properties of *Ailanthus triphysa* gum-oleoresin

Sl no	Physical properties	Values
1	Ph	5.5
2	Viscosity cps (3rpm/min) Viscosity cps (6rpm/min)	2340 695
3	Moisture content %	5.17
4	Ash content %	1.66

Heavy metals were detected by using inductively coupled plasma mass spectrometry and the results is shown in table below.

Table 22. Heavy metals detected from gum-oleoresin of *Ailanthus triphysa* sample

Sl. No.	PARAMETERS	Value
1	Iron mg/kg	9.18
2	Potassium mg/kg	775.21
3	Nitrogen %	0.10
4	Copper	NIL
5	Magnesium mg/kg	40.69
6	Zinc	Not detected
7	Calcium mg/kg	35.25

4.8 CHEMICAL COMPOSITION OF GUM-OLEORESIN

4.8.1 Acetone extract of gum-oleoresin

GC–MS analysis of acetone extracted sample led to the identification of 18 compounds from acetone extract which are listed in Table 24. A typical GC–MS chromatogram of the chemical compounds is illustrated in Fig 36. It shows that peak with 12.714 retention time found to be more in area beta.-caryophyllen (peak 4; 51.82 %) followed by Tetradecane with retention time 12.258 (peak 2; 10.45%) and 1, 3, 3-trimethyl-2-(2-methylcyclopropyl)-1-cyclohexene with retention time 20.831 (peak 13; 9.70 %). 1-octadecene with retention time 16.919 constituted least contribution (0.91%). The identification of the compounds was based on comparison of their mass spectra with those of NIST and Wiley libraries, as well as on comparison of their retention time and of the standard components analyzed.

4.8.2 Methanol extract of gum-oleoresin

The GC-MS spectrum of methanol extracted gum-oleoresin displayed 16 significant peaks. Since area under the chromatogram is proportional to concentration, area normalization was carried out and percentage concentrations of the respective chemical constituents were evaluated. The results obtained showed (table 25) that the most abundant component was caryophyllene (peak 2; 37.80 %) followed by 1,2-benzenedicarboxylic acid (peak 13; 20.63 %) and bicyclo [4.3.0] nonan-2-one, 8-isopropylidene-(peak 9; 17.57 %). The least abundant constituent was found to be 0.89 % of 3-hexadecene followed by 0.92 % of androst-1-en-3-one, 4,4-dimethyl-, (5. alpha.) and 0.96% of tetradecanal. This is showed in typical GC–MS chromatogram of the chemical compounds and is illustrated in Fig. 37 with its retention time.

Gum-oleoresin sample extracted from different solvents showed the presence of different compounds. There are only 5 common chemical compounds present in both solvents viz., acetone and methanol extract are represented in table 4, each chemical compound are identified in different retention time and area of percentage present in two solvents. Acetone extracts showed presence of more chemical compounds than methanol extracts. Expression of chemical compounds mainly depends on solvent used. beta-caryophyllen expressed more area in acetone extract whereas Caryophyllene expressed in methanol extract.

Table 23. Acetone extract of gum-oleoresin of *Ailanthus triphysa* sample

Sl no.	Compound name	Soxhlet extraction sample	
		(AREA %)	R. TIME
1	1-tridecene	1.43	12.125
2	Tetradecane	10.45	12.258
3	(-)-Isocaryophyllen	1.99	12.431
4	Beta –caryophyllene	51.82	12.714
5	Alpha-caryophyllene	4.05	13.119
6	Cyclododecene, (E)	2.30	14.409
7	3-hexadecene, (z)-	1.61	14.494
8	1-hexadecene	1.22	14.646
9	3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide	3.28	14.732
10	Tetradecanal	1.86	16.094
11	1-octadecene	0.91	16.919
12	2-Octanol, 2-methyl-6-methylene-	1.27	20.495
13	1,3,3-trimethyl-2-(2-methylcyclopropyl)-1-cyclohexene	9.70	20.831
14	Diepicedrene-1-oxide	2.23	21.218
15	.Gamma.-gurjunenepoxide-(1)	1.90	21.776
16	1-heptatriacotanol	1.16	21.868
17	Lilac alcohol epoxide	1.35	36.631
18	3,7,11,15-tetramethyl-2,6,10,14-hexadecatetraenyl acetate	1.48	37.210

Table 24. Methanol extract of gum-oleoresin of Ailanthus triphysa sample

Sl no.	Compound name	Soxhlet extraction sample	
		AREA %	R. TIME
1	Tetradecane	7.38	16.465
2	Caryophyllene	37.80	17.089
3	Alpha-caryophyllene	2.83	17.869
4	Cis-7-Dodecen-1-ol	1.61	20.653
5	3-hexadecene, (z)-	0.89	20.835
6	Caryophyllene oxide	2.42	21.010
7	Tetradecanal	0.96	23.965
8	Farnesol 3	1.11	24.018
9	Bicyclo[4.3.0]nonan-2-one, 8-isopropylidene-	17.57	33.026
10	Gamma. -gurjunenepoxide-(1)	1.28	33.207
11	Androst-1-en-3-one, 4,4-dimethyl-, (5. alpha.)-	0.92	33.575
12	Isoaromadendrene epoxide	1.20	34.989
13	1,2-benzenedicarboxylic acid	20.63	39.230
14	Tricyclo[20.8.0.0e7,16]triacontan, 1(22),7(16)-diepoxy-	1.26	44.717
15	. Alpha. -bisabolol oxide	1.06	48.465
16	Trans-Geranylgeraniol	1.06	49.070

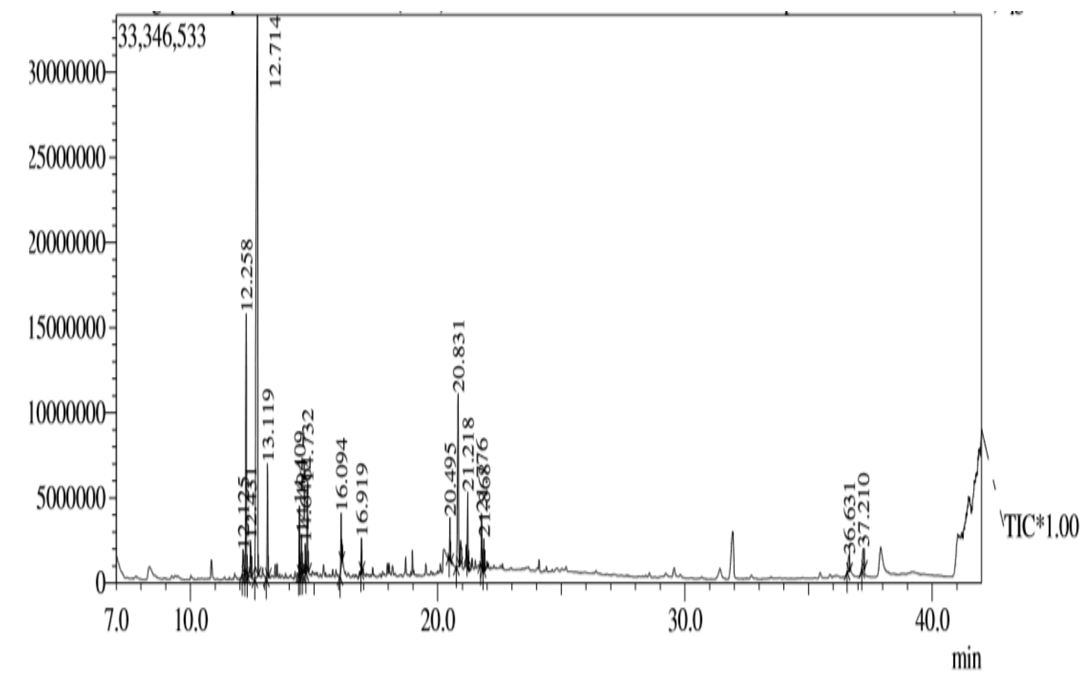


Fig 34. Chromatogram Sample of gum-oleoresin in Acetone

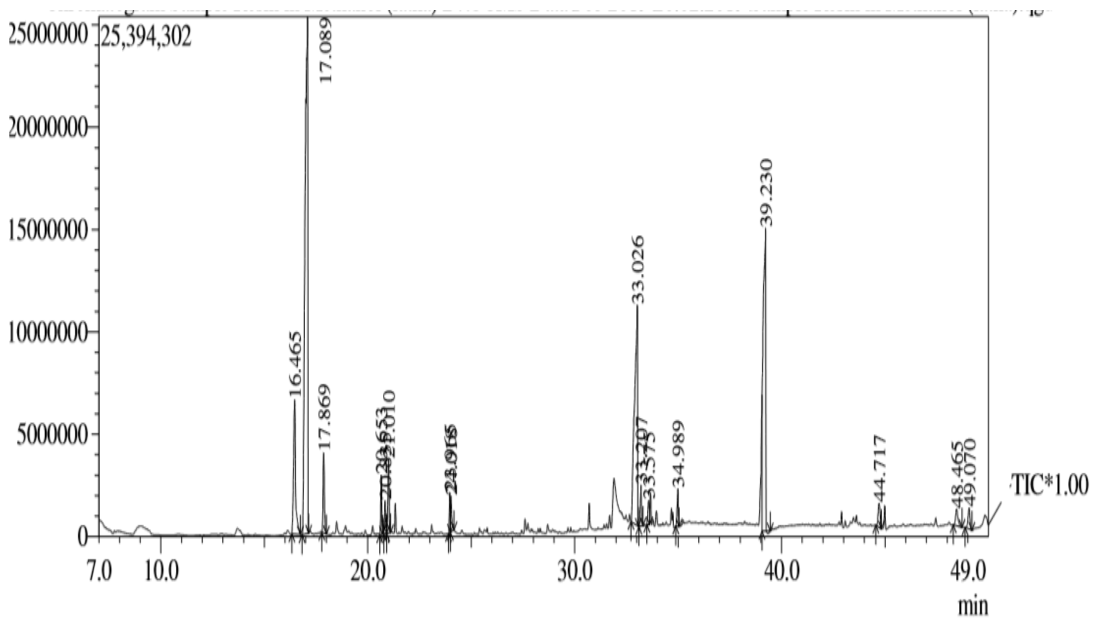


Fig 35. Chromatogram Sample of gum-oleoresin in Methanol

DISCUSSION

Gum-oleoresin yield from *Ailanthus triphysa* trees grown in Arboretum, near KAU School, College of Forestry, Kerala Agricultural University under two different girth classes (70-110 cm, 111-150 cm) and with three different ethephon treatments and physico-chemical properties are discussed here under following headings.

5.1 EFFECT OF DIFFERENT CONCENTRATION OF ETHEPHON ON GUM-OLEORESIN PRODUCTION

Ethephon is a synthetic compound of ethylene, phosphate and chloride ions. When applied to plants, ethephon primarily metabolizes into ethylene gas inside plant tissues. Ethylene is generally biosynthesized in plants in response to environmental stress, especially drought. Increased rates of ethylene biosynthesis induced by stress trigger various developmental responses in plants (Hall and Smith, 1995). Gum exudation may be considered as one such developmental response to dehydration stress (Anderson, 1995). 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 (Bhatt, 1987). Every year, the application of ethephon resulted in successive reduction in gum yields as well as seed yields, while alternate-year application ensured a stable gum production but also entailed successive reduction in seed yields (Harsh *et al*., 2013). It has been suggested that aquaporin could be a physiological mechanism that induces latex production increase by ethylene stimulation, because aquaporin activity is regulated at post-translational level in response to hormonal treatments (An *et al*., 2016).

Gum-oleoresin production at monthly intervals showed a significant variation with respect to different concentration of ethephon treatments. It was observed that treatment T4 (3.9% E) gives more yield compared to other concentration of ethephon treatments T1 (CM), T2 (2.34%), T3 (3.12%) and T4 (3.9%) is found to be statistically significant from other treatments.

The same findings were observed by many researchers in different species. Bhatt (1987) reported that the improved gum tapping method in *Anogeissus latifolia* by using ethephon treatment in trunk by injecting through a syringe into holes made by increment borer. Gummosis is enhanced by ethephon application and 466-fold increase in gum yield was recorded in plants treated with 1600 mg of active ethephon substance. similar experiment reported by Kanzaria *et al*. (2015) in *Acacia senegal* investigated that gum inducing chemical ethephon 100 ppm /5ml is injected by drill method 5mm diameter and 4mm deep transverse hole. The maximum production was observed in ethephon treated trees.

Effect of ethephon on *Acacia senegal* gum production conducted by Bhatt and Ram (1990) reported that no gum was produced by control trees and the most gum exudation was 806-950 g/tree obtained in the 960 mg treatment. Kuruwanshi *et al.* (2017) reported the same findings in *Sterculia urens*. The quantity of gum was significantly highest in T4 @3.9 % ethephon (239.02 g and 259.15 g) followed by T4 @3.12 % ethephon (137.51 g and 172.36 g) and T2 @2.34 % ethephon (66.80 g and 87.67 g). However, in T1 (control, distilled water 4ml) no exudation was observed.

These finding are in line with Bau and Menon (1989), Prasad *et al*. (2012) and Tiwari and Ram (2010) who also observed that use of ethephon as a gum inducer enhance gum production, has proved to be effective for gum tapping. Nair (2003) also observed that introduction of new tapping methods using ethephon have increased exudation of gums yield.

5.2 EFFECT OF GIRTH CLASS ON GUM-OLEORESIN YIELD

Gum-oleoresin production at monthly intervals showed variation with regards to tree dimensions. It was observed that girth class G2 (111cm-150 cm) showed more yield compared to G1 (70-110) but the difference was not significant. Monthly wise data revealed that out of twelve months only in six months (June, July, August, November, December and April) showed the significance difference between the girth classes. This is may be because there was not much variation between tree diameter classes that are being selected for the study. Hakeem *et al*. (2007) reported that age and location of cashew trees have no significant effect on the production of gum.

Das *et al*. (2014) reported that gum production was positively correlated with tree girth and same findings reported by Choudury (2018) that gum-oleoresin yield of *Ailanthus triphysa* in monthly intervals was found to be significantly different due to different girth classes and it was mostly found that the highest amount of gum-oleoresin was obtained from >150cm girth class (59.34 g) whereas (50.33 g) in 75-150cm girth class and least in <75cm girth class (12.3 g).

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. Same findings observed by Sharma and Dutt (2016) in six diameter class (D1 to D6) of *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 (Mohapatra *et al*., 2016).

5.3 PHYSICAL PROPERTIES OF GUM-OLEORESIN

The exudates 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 studies regarding its physiological characterization, it has become difficult to optimize the utilization of this indigenous natural resource. The study revealed the physical properties such as solubility, pH, viscosity, moisture level, color parameters, ash content and heavy metals.

5.3.1 Solubility

The solubility of gum-oleoresin was found higher in xylene (89.04%), n-butyl alcohol (87.51%), Ethanol (79.59%), Acetone (62.83%), Chloroform (62.58%).). In case of water as solvent, it is observed that the sample swells up by absorbing water but not soluble in water. As per FAO (1995) gums are either water-soluble or absorb water and swell up to form a gel or jelly when placed in water so *Ailanthus* contains little portion of gum. The swelling behavior of gum karaya is caused by the presence of acetyl groups in its structure (Le Cerf *et al*., 1990). The presence of protein fractions, along with the monosaccharide structure of gums, may also probably affect their water solubility (Torio *et al*., 2006).

Gum-oleoresin was not completely soluble in organic solvents. Gums are formed from the disintegration of internal plant tissues, mostly from the decomposition of cellulose in a process called gummosis. Gums contain high amounts of sugar and are closely allied to the pectins. They are colloidal and soluble in water, either dissolving entirely or swelling Resins are formed as oxidation products of various essential oils and are very complex and varied in chemical composition, where resin is usually secreted in definite cavities or passages. Resinous substances may occur alone or in combination with essential oils or gums. Resins, unlike gums, are insoluble in water, but they dissolve in ether, alcohol and other solvents.

Aslam *et al*. (2006) reported that *Khaya grandifolia* has only limited solubility in water but dissolves in sodium carbonate with removal of calcium ions. Gennero (2000) reported that swelling of a linear polymer without dissolution is an indication that it is cross linked. The cross-links tie the macromolecular chains together by primary covalent bonds thereby transforming each particle into a single giant molecule. The swelling ability of polymers enables it to absorb water and reduce the fluidity of diarrhoeal stool one of the major uses of gums. Cross-linked polymers are also suitable for use as disintegrants because they form hydro gels, they can be used for controlled release dosage forms.

5.3.2 pH value

pH of the samples was found to be strongly acidic. The acidity of the oxidized plant gum was due to the presence of salts (Ca, Mg, K, Na and Fe) of acidic polysaccharides, the activity of which is due to uronic acids in their structure (Dweikat *et al.,* 2007). The pH is an important parameter in determining its suitability in formulations since the stability and physiological activity of most preparations depend on the pH (Goycoolea *et al.,* 1997). Anderson *et al.* (1968) investigated that the pH value of *Acacia senegal to* be 4.4 and it is slightly acidic because of the presence of fewfree carboxyl groups of its constituent acidic residue, *viz.* D-glucuronic acid and its4-O-methyl derivative.

5.3.3 Viscosity

Molecular association in fluids greatly influences their rheological behaviors. Increase in viscosity with concentration may be probably due to increasing number of high molecular weight polymeric chain of the gum per unit volume and increased interaction between these chains in aqueous solution or dispersion. However, higher relative viscosity of the gum solution suggests the presence of high molecular weight in the gum chemical constitution which was introduced during oxidation (Adeyanju *et al.,* 2017). Weiping (2000) reported that stability of viscosity depends on time of harvest, climate during harvest, storage conditions including temperature/humidity.

In the present study Viscosity was observed to be 2340 cps (3 rpm/min, spindle no 62) and 695 cps (6rpm/min, spindle no 62). Idris (1989) concluded that the age of *Acacia senegal* tree affected the viscosity of gum solution. Anderson *et al*. (1968) determines the ages 10- 15 years of trees to be produced gums with higher viscosity, while the oldest and youngest trees studied gave gum of low viscosity. Montenegro *et al*. (2012) stated that solutions containing less than 10% of gum have a low viscosity. Generally, to obtain higher viscosity with gum the concentration needs to be up to 40- 50% (Siddig, 2003). Ameh *et al*. (2010) stated that the increase in viscosity of the gum is a result of raising the pH and the reduction in viscosity is due to increasing temperature.

5.3.4 Moisture level

The moisture content can help to suggest the stability in storage of gum. Suitable moisture will lead to the activation of enzymes and the proliferation of microorganisms, thereby affecting the shelf life of food (Barbosa, 2003). Moisture content determines the hardness of the gum. Any excess of water in medicinal plant materials will encourage microbial growth. Moisture content facilitates the solubility of hydrophilic carbohydrates and hydrophobic proteins in gum (Montenegro *et al*., 2012).

Depending on the temperature, the moisture of a mixture could lead to the activation of enzymes and the potential proliferation of micro-organisms which might affect the shelf life of the mixture (Zaku *et al*., 2009). Present study revealed that moisture content in gum-oleoresin found to be 5.17%. Gundidza *et al*. (2011) reported that moisture content obtained from *Commiphora africana* was 10.6 ±0.04%, the low level of moisture in this gum resin appeared to be desirable since it will attract little bacterial or fungal growth in the formulation.

Therefore, it is important to investigate the moisture content of potential pharmaceutical materials since its economic importance for industrial application will depend on the optimization of production processes such as drying, packaging and storage.

5.3.5 Color parameters

Color varies from pale yellow to dark reddish brown. The 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 (Choudhury, 2018). Nadkarni (1976) reported that *A. triphysa* contains wax like, reddish brown, water soluble having bitter principle, known as ailantic acid. However, light yellow colored deposits were frequently found inside the vessels and the gum-oleoresin exudate was of same colour.

Fennema (1996) reported that the colour of gum arabic is depending on the climate. Baldwin *et al*. (1998) reported that the Babool gum occurs in the form of rounded or ovoid tears and the colour varies from pale-yellow to brown or almost black according to the age of the tree and the conditions of collection. Deshmukh *et al*. (2012) in *Anogeissus latifolia* is light yellow to brown colour powder available in a various grade. Umekar and Yeole (2014) reported that colour of copal gum resin was observed cream yellowish. It has been widely employed in food, pharmaceuticals, paper and other industries due to its excellent emulsification and thickening property (Deshmukh *et al.*, 2012).

5.3.6 Ash content

Total ash content is used to determine the critical levels of foreign matter, acid insoluble matter, salts of calcium, potassium and magnesium (Mocak *et al*., 1998). The cationic compositions of ash content are used to determine the specific levels of heavy metals in quality of gum arabic (FAO, 1996).

Ash content is an important in some preparations (Ozcan *et al*., 2007). When gums are incinerated, they leave inorganic ash which in some cases varies within fairly wide limits. In many cases the total ash figure is within a characteristic narrow range and can be a useful characterization tool (Adikwu *et al*., 2001). In present study the Ash content was found to be 1.66%. The ash usually consists mainly of carbonates, phosphates, silicates and silica (Aziznia *et al*., 2008). Ash content has been reported to be an important property and could be considered as purity in parameter in gums (Glicksman, 1969).

5.3.7 Mineral metals

The result showed that Potassium (K) have the highest value followed by Magnesium (Mg), Calcium (Ca) and Iron (Ir). It may be due to the high concentration of these elements in the soil parent material (Makin *et al*., 1975). These elements indicate the nutritive value of gum (Ahmed *et al*., 2009). The presence of metals in addition to carbohydrate and protein has made gum of high potential for the use in food industry and Pharmaceuticals. Arsenic, lead, zinc and copper contents is very important in determining the level of toxicity, they must not exceed certain level (Mahmoud, 2000)

Gums from mature trees were generally found to have higher levels of protein, phenols, moisture and minerals than those from young trees and this may be due to the storage of starch and the production of cellulose, hemicellulose and proteins in the mature trees (Rayburn, 1993). Cashew gum was found to have very high levels of calcium, sodium, and potassium, which are the essential minerals required by the body to meet metabolic needs (Welch and Graham, 2003).

5.5. CHEMICAL COMPOSITION OF GUM-OLEORESIN

Total 18 compounds were identified from Acetone extract of gum-oleoresin analysed in GC-MS, the major constituent of the chemical compound is beta.-caryophyllen, it has the distinction of being the first known dietary cannabinoid, a common component of food that has GRAS (Generally Recognized as Safe) status and is approved by the FDA for food use. It has now been shown to be directly beneficial for colitis (Bento *et al*., 2011), osteoarthritis (Mendes *et al*., 2015), diabetes (Basha and Sankaranarayanan, 2014), anxiety and depression (Bahi *et al*., 2014) followed by Tetradecaneis an alkane hydrocarbon containing 14 carbon atoms. It is majorly used for the organic synthesis, and used as a kind of organic solvent. Its binary mixtures with hexadecane can be used as phase change materials (PCMs) for cool storage in district cooling systems for refrigeration and air-conditionin, 1-octadecene constitute least contribution. The most abundant component identified in methanol extracts was are caryophyllene followed by 1,2-benzenedicarboxylic acid are widely employed in many personal care products, cosmetics as well as plastics, paper coating, paints, and adhesives. The least abundant constituent was found to be 0.89% 3-hexadecene others 0.92 % androst-1-en-3-one, 4,4-dimethyl-, (5. alpha.) 0.96% tetradecanal. The above identified compounds in *Ailanthus* gum-oleoresin were not reported so far. GC-MS analysis is the first step towards understanding the nature of active principles in the plant extracts and will be helpful for further detailed study. However, isolation of individual phytochemical constituent and subjecting it to biological activity will definitely give fruitful results (Selvamangai and Bhaskar, 2012)

Similar study was found in different species by various researchers. Manickam *et al.* (2016) analyzed GC-MS of naturally occurring gum exudates of *Azadirachtaindica* and observed twelve compounds. The predominant compounds were fatty acids like Ethyl hexadecanoate is recommended to be antioxidant, hypocholesterolemic, nematicide, pesticide and sesquesters spleen function and shows anti- inflammatory effect.

Salem *et al.* (2014) extracted essential oils from *Pinusroxburghii*tocheck theantibacterial and antioxidantactivities. The major chemical constituents of wood essential oil were caryophyllene (16.75%), thunbergol (16.29%), 3-carene (14.95%), cembrene (12.08%), α-thujene (10.81%), and terpinolen (7.17%). In bark they were α-pinene (31.29%) and 3-carene (28.05%) and in needles α-pinene (39%) and 3-carene.

Rawat *et al*. (2006) identified two new xanthone as 1,5-dihydroxy- 3,6,7-trimethoxy-8 dimethylallyloxy-xanthone and 1-hydroxy-3,6-dimethoxy-2-β-D glucopyranoxanthone which have been isolated from the methanolic extract of the bark of *Pinusroxburghii.* These compoundsare reported to have wound healing, cytotoxic, antibacterial, antifungal and spasmolytic actions.

5.5 EFFECT OF BARK THICKNESS ON GUM-OLEORESIN YIELD

Based on the correlation studies, it indicated 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, trees have more thickness of bark. Responses to stem damage might be another reason which involves interactions of anatomical, phylogenetic, physiological, and ecological factors.

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. Choudury (2018) studied the effect of bark thickness on gum-oleoresin yield in *Ailanthus triphysa* showed that bark thickness and girth class of tree are positively correlated with the gum-oleoresin production, greater the girth class greater the bark thickness and greater the production.

5.6 EFFECT OF CLIMATIC PARAMETER ON GUM-OLEORESIN YIELD

The rate of gum exudation was found to be more in post-monsoon season followed by rainy season and least in summer season (Fig.27 and Fig.28). It indicated that the seasonal changes had 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 have major role in gum-oleoresin production as it had 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 was at 10% significance level and it is negatively correlated. Ballal *et al*. (2005) have also reported that highest yield per tree in all types of stands is obtained in early tapping. 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 (Dione and Vessal, 1998). *Ailanthus triphysa* flowering in India and Nepal is between February and March, fruiting follows in April-May (Orwa *et al*., 2009: Chandrasekar, 1996), 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 found high in wood parenchyma during post-monsoon and monsoon season where in no phenological events take place.

SUMMARY

The present study entitled “Physio-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on gum-oleoresin yield” was carried out at Arboretum, near KAU School, college of forestry, Vellanikkara during the year 2018-2019. The main objective of the study was to assess the effect of different concentration of ethephon on gum-oleoresin production and to study effect of diameter classes on production of gum-oleoresin and also to know the physical and chemical characteristics of oleoresin from *Ailanthus triphysa* such as Solubility, pH, Viscosity, Moisture level, Color parameters, Ash content and Analysis of chemical composition and minerals of gum-oleoresin. The results obtained from the study are summarized in this chapter.

- Compilation of one-year data revealed that the difference in gum-oleoresin yield due to different girth classes was found to be significant during the month of June, July, August, November, December, April and different girth classes was found to be non-significant during the month of May, September, October, January, February and March.
- Significant difference in gum-oleoresin yield due to different concentration of ethephon treatment in all the months except in the month of July could be observed. T4 (3.9%) ethephon treatment gave better yields compared to other treatments. T1 (control) had shown very less yield.
- The exudation of gum-oleoresin was found to be more in post monsoon period followed by monsoon and least during summer. Interaction between different ethephon treatments and seasons was found to be not significant.
- Total yield observed for the one-year data from two girth classes is G1 (415.04gm) < G2 (592.10gm) and yield from different concentration of ethephon is T1 (control) is 226.16gm < T2 (2.34%) is 512.74gm > T3 (3.12%) is 457.38gm < T4 (3.9%) is 817.99gm.

- Physical parameter comprises pH, moisture content and ash content were 5.5, 5.17% and 1.66%, respectively. Viscosity observed is 2340 cps (3 rpm/min, spindle no 62) and 695 cps (6rpm/min, spindle no 62). Color of the gum-oleoresin observed to pale yellow to dark reddish brown. Solubility observed maximum in xylene (89.04%) > n-butyl alcohol (87.51%) > ethanol (79.59%) > Acetone (62.83%) > Chloroform (62.58%) and it's not soluble in water but it absorbs and swell when kept in water. Heavy metals were resulted as Potassium (K) > Magnesium (Mg) > Calcium (Ca) a > Iron (Ir).
- Total 18 compounds were identified in acetone extracted gum-oleoresin sample; the major constituent of the chemical compound is beta. -caryophyllen (peak 4; 51.82 %) followed by Tetradecane (peak 2; 10.45%) and 1, 3, 3-trimethyl-2-(2-methylcyclopropyl)-1-cyclohexene (peak 13; 9.70 %). 1-octadecene constitute to least contribution (0.91%). In methanol extracted sample, 16 compounds were identified and most abundant compound is caryophyllene (peak 2; 37.80 %) followed by 1,2-benzenedicarboxylic acid (peak 13; 20.63 %) and bicyclo [4.3.0] nonan-2-one, 8-isopropylidene-(peak 9; 17.57 %). The least abundant constituent was found to be 0.89 % 3-hexadecene others 0.92 % androst-1-en-3-one, 4,4-dimethyl-, (5. alpha.) 0.96 % tetradecanal.
- The temperature was found to be effected negatively on gum-oleoresin production.

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APPENDIX

ANOVA TABLE FOR ANALYSIS ON MONTHLY INTERVAL BASIS

MAY

Source	Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Girth	219.55	1	219.55	1.50	0.24
Treatment	2666.95	3	888.98	6.10	0.00
Replication	71.96	2	35.98	0.24	0.78
Girth * treatment	40.06	3	13.35	0.09	0.96
Error	2039.94	14	145.71		
Total	5038.47	23			

JUNE

Source	Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Girth	1040.16	1	1040.16	5.68	0.03
Treatment	2668.16	3	889.38	4.85	0.01
Replication	342.33	2	171.16	0.93	0.41
Girth * Treatment	660.83	3	220.27	1.20	0.34
Error	2562.33	14	183.02		
Total	7273.83	23			

JULY

Source	Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Girth	1441.50	1	1441.50	7.72	0.01
Treatment	974.83	3	324.94	1.74	0.20
Replication	400.00	2	200.00	1.07	0.36
Girth * Treatment	308.83	3	102.94	0.55	0.65
Error	2613.33	14	186.66		
Total	5738.50	23			

AUGUST

Source	Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Girth	1850.29	1	1850.29	5.36	0.03
Treatment	5489.56	3	1829.85	5.30	0.01
Replication	964.26	2	482.13	1.39	0.27
Girth * Treatment	1159.13	3	386.37	1.12	0.37
Error	4826.55	14	344.75		
Total	14289.82	23			

SEPTEMBER

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	3538.56	1	3538.56	1.40	0.25
Treatment	26828.65	3	8942.88	3.53	0.04
Girth * treatment	2674.20	3	891.40	0.35	0.78
Rep	1202.26	2	601.13	0.23	0.79
Error	35397.95	14	2528.42		
Total	69641.64	23			

OCTOBER

Source	sum of Squares	Df	Mean Square	F	Sig.
Girth	5912.93	1	5912.93	3.72	0.07
Treatment	16569.70	3	5523.23	3.47	0.04
Replication	1212.48	2	606.24	0.38	0.69
Girth * Treatment	2596.10	3	865.36	0.54	0.66
Error	22255.28	14	1589.66		
Total	48546.50	23			

NOVEMBER

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	3918.09	1	3918.09	6.18	0.02
Treatment	9358.68	3	3119.56	4.92	0.01
Replication	1300.90	2	650.45	1.02	0.38
Girth * treatment	2833.89	3	944.63	1.49	0.26
Error	8872.01	14	633.71		
Total	26283.59	23			

DECEMBER

Source	Sum of Squares	Df	Mean Square	F	Sig.
GIRTH	1573.02	1	1573.02	6.48	0.02
TRT	3068.93	3	1022.97	4.21	0.02
REP	29.21	2	14.60	0.06	0.94
GIRTH * TRT	662.60	3	220.87	0.91	0.46
Error	3397.99	14	242.71		
Total	8731.77	23			

JANUARY

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	2233.01	1	2233.01	1.21	0.29
Treatment	38775.18	3	12925.06	7.00	0.00
Replication	398.76	2	199.38	0.10	0.89
Girth * Treatment	757.23	3	252.41	0.13	0.93
Error	25820.94	14	1844.35		
Total	67985.13	23			

FEBRUARY

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	32.24	1	32.24	0.06	0.80
Treatment	10642.06	3	3547.35	6.70	0.00
Replication	375.18	2	187.59	0.35	0.70
Girth * Treatment	458.30	3	152.76	0.28	0.83
Error	7411.51	14	529.39		
Total	18919.32	23			

MARCH

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	1.36	1	1.36	0.00	0.95
Treatment	8574.09	3	2858.03	6.69	0.00
Replication	147.44	2	73.72	0.17	0.84
Girth * Treatment	237.68	3	79.23	0.18	0.90
Error	5980.57	14	427.18		
Total	14941.17	23			

APRIL

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	166.90	1	166.90	16.15	0.001
Treatment	1501.64	3	500.54	48.44	0.000
Replication	37.81	2	18.90	1.83	0.197
Girth * Treatment	76.08	3	25.36	2.45	0.106
Error	144.66	14	10.33		
Total	1927.10	23			

ANOVA TABLE OF DIFFERENT SEASONS (MONSOON, POSTMONSOON, SUMMER)

MONSOON SEASON

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	1864.02	1	1864.02	4.107	0.062
Treatment	6045.75	3	2015.25	4.440	0.022
Replication	564.39	2	282.19	0.622	0.551
Girth * Treatment	370.90	3	123.63	0.272	0.844
Error	6353.90	14	453.85		
Total	15198.97	23			

POST MONSOON SEASON

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	3203.97	1	3203.97	3.768	0.07
Treatment	13711.91	3	4570.63	5.375	0.01
Replication	525.12	2	262.56	0.309	0.73
Girth * Treatment	839.88	3	279.96	0.329	0.80
Error	11904.34	14	850.31		
Total	30185.23	23			

SUMMER SEASON

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	74.66	1	74.66	0.44	0.516
Treatment	5019.01	3	1673.00	9.96	0.001
Replication	58.98	2	29.49	0.17	0.841
Girth*Treatment	83.96	3	27.98	0.16	0.917
Error	2349.81	14	167.84		
Total	7586.43	23			

ANOVA TABLE FOR EFFECT OF DIFFERENT SEASON, GIRTH AND ETHEPHON TREATMENT ON GUM-OLEORESIN YIELD (gm)

Source	Sum of Squares	df	Mean Square	F	Sig.
SEASON	9556.78	2	4778.39	10.54	0.00
TREATMENT	26777.40	7	3825.34	8.44	0.00
REPLICATION	919.53	2	459.76	1.01	0.37
SEASON * TREATMENT	4436.67	14	316.90	0.70	0.76
Error	20837.02	46	452.97		
Total	62527.42	71			

ANOVA TABLE FOR WHOLE STUDY PERIOD (MAY 2018- APRIL 2019)

Source	Sum of Squares	Df	Mean Square	F	Sig.
Girth	74.66	1	74.66	0.44	0.51
Treatment	5019.01	3	1673.00	9.96	0.00
Replication	58.98	2	29.49	0.17	0.84
Girth * Treatment	83.96	3	27.98	0.16	0.91
Error	2349.81	14	167.84		
Total	7586.43	23			

ABSTRACT

Gum and resins are natural bio-polymers having number of applications in pharmaceutical and food industries. Most of them are regarded as bio-degradable and safe because of their bio-compatibility, low cost, non-toxic, processing, environmental friendly and local availability. It is viable income source for thousands of forest dwellers. So the present study entitled “Physico-chemical characterization of gum-oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on gum-oleoresin yield” was carried out at Arboretum, College of Forestry, Vellanikkara during the year 2018-2019. The main objective of the study was to assess the effect of different concentration of ethephon on gum-oleoresin production in *Ailanthus triphysa* and also study the effect of diameter classes on production. The physical properties such as Solubility, pH, Viscosity, Moisture level, Color parameters, Ash content and chemical compounds were also determined as part of the study.

A total of twenty-four trees were selected for conducting the study in which two girth classes (70-110cm, 111-150cm), four chemical treatments, each with three replications were taken. Data analysis was done on monthly intervals, showed significant difference in girth class on resin production in the months of June, July, August, November, December and April and in other months it found non-significant. It was observed that girth class G2 (111cm-150 cm) showed more yield compared to G1 (70-110).

It was statistically found significant difference in gum-oleoresin yield due to different concentration of ethephon treatments. T4 (3.9%) ethephon treatment gave more yield (817.99gm) compared to other treatments, where T1 (control) gave very less yield (226.16gm). The exudation of gum-oleoresin was found to be more in post monsoon (55.06gm) followed by monsoon (43.78gm) and least during summer (27.01gm). Interaction between different ethephon treatment and season was found to be non-significant.

The physical and chemical properties of gum-oleoresin were studied and it indicated the gum-oleoresin was found to be strongly acidic, highly soluble in xylene and least in chloroform and in case of water, it absorbs water and swell. Moisture content was 5.17%, pH observed was 5.5, Colour of the gum-oleoresin observed was pale yellow to dark reddish brown and Viscosity observed was 2340 cps and 695 cps. Heavy metals like K > Mg > (Ca) > (Ir) were detected. Chemical compounds were identified by using GC-MS. Total 18 compounds were identified from Acetone extract of gum-oleoresin in GC-MS, the major constituents of the chemical compound were beta.-caryophyllen followed by Tetradecane and 1,3,3-trimethyl-2-(2-methylcyclopropyl)-1-cyclohexene and 1-octadecene constitute least contribution, where as in methanol extracts, 16 compounds were identified, most abundant compound was Caryophyllene followed by 1,2-benzenedicarboxylic acid and bicyclo, the least abundant constituent was found to be 3-hexadecene.

The correlation studies of bark thickness on production of gum-oleoresin were found to be significant with correlation coefficient 0.42. The climatic parameters like rainfall, relative humidity, temperature was found to be non-significant on production of gum-oleoresin.