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Use of medicinal plants through sacrificial fire to treat Tuberculosis: A review

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Abstract

Tuberculosis, a widespread pulmonary disease in the world, claims millions of lives every year. The ever-growing demand for better treatment and care, mounting costs of treatment and negligence among the patients is also a concern. In the view of modern medication and its side effects, literature suggests use of medicinal plants in the treatment of Tuberculosis. The Sacrificial fire therapy (Yajna) or the Ethnobotanical inhalation therapy is a prominent method in Ayurveda to treat pulmonary diseases. Studies have shown the sacrificial fire therapy to be effective in curing Neurological disorders too. In this process, parts of Ayurvedic medicinal plants are selected in specific proportions, sublimated, and evaporated and the components released have exhibited the potential to treat Tuberculosis. This paper explores an idea that can help against antibiotic resistance and analyses the effect on microorganisms and seems a possible option to use it as a complimentary medicine to the humankind.

Introduction

Tuberculosis is a potentially fatal lung illness. (Figure 1) The severity of the infection necessitates use of high-dose contemporary medications that may have severe side effects on the body. In the Indian Knowledge corpus, Tuberculosis (Yakshma) and its various kinds are discussed extensively in the Atharva Veda. The sacrificial fire (Agnihotra) or Yajna Agni, which is created by the prima-facie combination of energy or vitality and matter, appears to be a religious act, yet its power and effects are incredible. (Singh 2012). This has been documented in the past in many scriptures as well as scientifically successful experimental research over the last few decades.

Yajna/Agnihotra is a perennial symbol of our civilisation. The ancient Indic life was defined around the philosophy of Yajna (Nautiyal et al, 2007). Agnihotra is a simple form of homa[1] that entails setting up a fire in a tiny rectangular copper pyramid pot (Agni Kunda), directly offering cow dung cakes (gomaya) and ghee (ghritha) to the fire and chanting mantras to the fire at sunrise and dusk (Golechha et al., 1987).

[1] Sacrificial fire is referred to as homa in India.

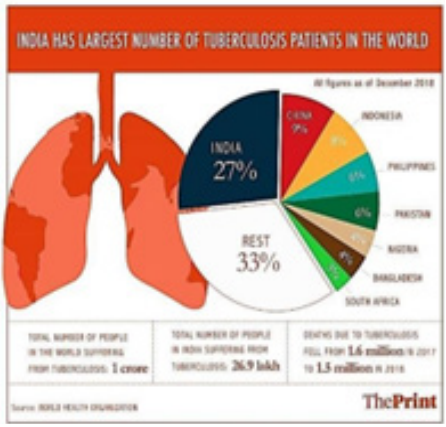


Figure 1. Graphical representation of per cent of Tuberculosis cases in countries,

(WHO report,2020)

Its origins may be traced back to the Rigveda, (Bodewitz, H. 1973) where frequent practice of this ritual is recommended for improved bodily and mental health and vigor (Golechha et al., 1987).

The process of Yajna requires the use of plant parts that are highly medicinal in nature. The burning of the wood releases phytomedicines through smoke. The Smoke produced by the burning of the medicinal components were used to treat ailments and disorders in the ancient times. (Nautiyal et al., 2007) The importance of medicinal smoke's ethnopharmacological features demonstrates the function of fire as a driving force in development of new arenas for treatments. (Nair et al., 2016) It is also said to improve the state of mind. The sacrificial fire is an Indo-European tradition, since it was also practised by the Romans, Greeks, and Iranians to offer presents to the God of fire. (Munshi et al., 2010) Domestic fires were also the site of magical practices designed to ward off sickness and unfavourable omens. The Atharva Veda contains a large number of songs and spells that readily fit within the context of domestic fire. (Munshi et al., 2010)

Therapeutic vapours created by intense heat has long been regarded to be the easiest way to administer medicine since a swift pharmacological reaction may be detected during inhalation. The fumes created by the combustion of mustard, butter, and salt were employed to eradicate microbiological illnesses in the air during the Sushruta period (800-600 BC). (Nautiyal et al., 2007 & Fraise, 2005) The smoke produced by the burning of Santalum album and/

or Peganum harmala was considered to serve as a protective barrier for the king, shielding him from all manner of evil and illness. (Nautiyal et al., 2007). Throughout the Middle Ages, smoke produced by the burning of herbs, incense and fragrant essences was frequently utilised to prevent bubonic plague caused by the bacteria Yersinia pestis. (Nautiyal et al., 2007).

About Tuberculosis

Mycobacterium tuberculosis causes tuberculosis (TB), a bacterial infection that most usually affects the lungs. Tuberculosis spreads by air from person to person. When people with lung TB cough, sneeze, or spit, they disseminate the TB germs into the air (Ntutela et al., 2009). A person has to only breathe in a few of these bacteria to catch the infection. TB most commonly affects the lungs, but it can also damage the brain, kidneys, or spine and if not treated, may lead to death. The symptoms include feelings of sickness or weakness, weight loss, fever, coughing, chest pain and blood in phlegm. The symptoms of tuberculosis in various sections of the body vary depending on the affected area. (CDC, 2011)

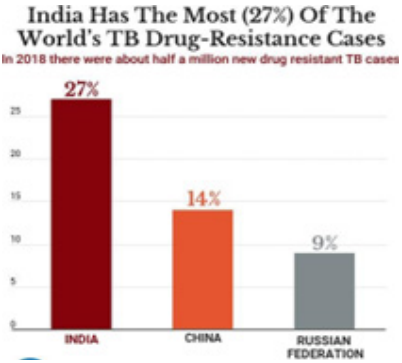


Figure 2. Graphical representation of increasing drug resistance in Tubercule bacterium

(World Health Organization report, October 2021)

In 2020, 86% of new cases occurred among 30 Nations. Two-thirds of the total case load is accounted for by India, Indonesia, China, the Philippines, Nigeria, Pakistan, Bangladesh, and South Africa, with India leading the pack. (World Health Organization report, October 2021) Multidrug- resistant tuberculosis or, MDR- TB, is still a public health concern and a security threat. Negligence or unwillingness among the patients affected by tuberculosis to take medication is the main concern for rising Drug resistance among the microorganisms (Figure 2). There is a pressing need to find and develop novel medications that will improve treatment strategies, manage infection and adverse effects and increase safety. (Ntutela et al., 2009)

Pathogenesis of Tuberculosis

Efficient tuberculosis (TB) vaccines and medicines require a better understanding of the disease's aetiology. To explore the cells, molecules, and processes in animal models, most pathogenesis research today employs sophisticated technologies. Unfortunately, none of the animal models accurately mirror the human disease. (Hunter, 2020) Mycobacterium tuberculosis (MTB) the bacterium that causes tuberculosis is a highly successful human parasite that has evolved alongside humans for thousands, if not millions, of years. (Hunter, 2020) While it can infect a wide range of animals, it is solely transmitted by humans and has no environmental reservoir. As a result, it relies on person-to-person transmission to survive. MTB has evolved to evade destruction by our adaptive and innate immune systems, as well as to cause lesions that aid in transmission (Hunter, 2020). The early stages of tuberculosis are marked by a persistent cough that can be discovered by a Tuberculin test or a blood test, whereas the later stages are marked by increased responses that can be recognized by an X-ray (Figure 3) which shows enhanced budding of the lung alveoli as a result of infection by the Mycobacterium.

A. CT scan showing tree bud of the lungs infected by Mycobacterium

B. drawing of theCT scan to represent the Mycobacterium Infection in the lungs

C. Pictorial representation of the tree bud scan

Figure 3. Tree in bud, A diagnostic tool to detect Advanced Tuberculosis.

(Hunter, 2020)

Modern medications used to treat Tuberculosis

Various medications to treat tuberculosis have been identified since the 19th century. There are two lines of medications used. Patients newly diagnosed with Mycobacterial infection are treated with the first-line therapy medicines (Table 1). These medications have been around for 50 years and are still in use. These are effective against active bacterium. When a microorganism acquires multi-drug resistance, a second-line treatment (Table 1) is used. For best outcomes, they should be administered in conjunction with first-line drugs. Every drug works in a different way. As a result, a mix of these approaches is used to provide a superior therapeutic outcome.

Table 1. List of medicines used in the treatment of Tuberculosis.

Sl no.	Name of Drug	Mode of action
First line treatment		
1	Isoniazid	Inhibit mycolic acid2 synthesis
2	Pyrazinamide	Disrupts plasma membrane and energy metabolism
3	Rifampin	Inhibits DNA-dependent RNA polymerase3
Second line treatment		
4	Ethambutol	Inhibit cell wall synthesis
5	Ethionamide	Inhibit cell wall synthesis
6	Protionamide	Inhibit cell wall synthesis
7	Capreomycin	Inhibits protein synthesis
8	Nitroimidazole	Inhibit mycolic acid synthesis
9	Para amino salicylic acid	Inhibits DNA gyrase4
10	Moxifloxacin	Inhibits DNA gyrase
11	Levofloxacin	Inhibits DNA gyrase (Hunter, 2020)
12	Cycloserine	Inhibits cell wall synthesis
13	Kanamycin	Inhibits protein synthesis
14	Amikacin	Inhibits protein synthesis
15	Streptomycin	Inhibits protein synthesis

(NIH,2016)

[2] Mycolic acid are fatty chain molecules that render impermeability to Mycobacterium cell wall.
[3] Polymerase are enzymes necessary for the replication of DNA.
[4] Gyrases are enzymes that aid in the replication of genetic material.

Tuberculosis and Vedas

As unbelievable as it may sound, there is mounting evidence that Mycobacterium tuberculosis' ancestors lived on Earth more than 2.6 million years ago, much before the hominids evolved (Agarwal, 2017). Vedas provide the first textual account of TB. The sickness is referred to as yaksma in the Rig Veda, which dates back to 1500 BC. It's known as balasa in the Atharvaveda. The Atharvaveda is where the first description of scrofula (a type of tuberculosis) is found.

Yajurveda advises those affected by the ailment to relocate to higher altitudes away from the village. This could imply that traditional Indian doctors (vaidyas) thought the ailment was contagious. Sushruta Samhita, which was written circa 600 BC (Agarwal,2017) suggests that cow milk, varied meats, and rest be used to cure the illness.

A Yajna for treating this condition is mentioned in the Grihya sutras (rules of Vedic domestic ceremonies). Inhaling herbal smoke is suggested in Ayurveda for treating respiratory (vata and kafa) illnesses in humans, thus it's only natural that smoke or fumigation would be recommended in Vrikshayurveda for certain disorders. Vrikshayurveda describes in its 53 verses, various plants used for fumigation. It also enlists 32 different plant (Table 2) materials that were supposed to be inhaled to treat illness of various body parts of humans. (Nene YL,2014) The wood of some of the medicinal plants (Phalgu druma) (Annexure 2) is used for kindling sacred fire of Vedic rites. Therefore, such plants are called "Yajnanga" (the inherent part of yajna)

Table 2. Various medicinal plants used in sacrificial fire and the active components released

Botanical name	Common name	Components released and their Action
Aconitum heterophyllum	Aconite/ Ativisha	Several flavonoids and alkaloids; antimicrobial
Allium sativum	Lasuna, rasona	Organosulphur compound, Allicin works against bacteria, fungi, nematodes, and viruses; insect repellent
Azadirachta indica	Neem	triterpenoids such as nimbinine, nimbine,nimbidine; Neem oil contains limonoids insecticidal and antibacterial
Balanitis aegyptiaca	Ingudi	Glycosides, Saponins, fatty acids; anthelmintic and antimicrobial
Brassica nigra	Rajika	Isothiocyanates; antimicrobial
Citrullus colocynthis	Indrabeeja	Flavonoids, tannins, terpenoids. antimicrobial

Commiphora wightii	Guggula	Glycosides, Alkaloids, terpenoids, steroids, oleo gum resin and flavonoids,; antibacterial
Costus speciosus	Canda, kebuka	Diosgenin, benzoquinones; antimicrobial
Curcuma domestica	Haridra	Curcuminoidsand Diferuloylmethane(curcumin); antifungal, antibacterial and antiviral
Cyperus rotundus	Musta	Oil contains 16 compounds [oxo-isolongi folene, α- gurjunene,(z)-valerenyl acetate, α-salinene, etc.]; antifungal and antibacterial
Datura metel	Datura, unmatta	Steroidal with ametelin;antibacterial and antifungal
Embelia ribes	Bidanga, vidanga	Benzoquinone derivative embelin; anthelmintic, antibacterial, and antifungal
Ferula assafoetida	Asafetida/ Hingu	Oleoresin gum; antimicrobial
Ficus microcarpa	Kubera, plaksah	Phenolic compounds in aerial roots; antibacterial and latex antifungal
Jasminum sambac	Mallika	glycoside, Alkaloids, saponins, flavonoid, triterpenes, tannin, salicylic acids and resin, antifungal, antibacterial, and anthelmintic
Luffa acutangula	Kosataki	Glycosides, Terpenoids, flavonoids, and steroids; antibacterial and antifungal
Nigella sativa	Kalajaji, upakunchika	Thymoquinone; antibacterial
Opuntia spp.	Nagaphana	Alkaloids
Piper longum	Pippali	Resin, terpenoid, alkaloids – piper longuminine, piperine; antibacterial and anthelmintic
Piper nigrum	Maricha	Volatile oils; antibacterial

Pongamia pinnata	Karanja	Flavonoids; antibacterial
Pterocarpus marsupium	Asana	Phenols, terpenoids, alkaloids, glycosides, flavonoids and antibacterial, antiviral and antifungal
Sansevieria roxburghiana	Sarpi	glycosides, flavonoids, alkaloid, phenols, Saponins, etc.; antibacterial and antifungal
Semecarpus anacardium	Bhallataka	Phenolic, Biflavonoids compounds, antimicrobial
Sesamum indicum	Tilah	Antioxidants and phenols (sesamin, sesamol, sesamolin) antibacterial
Terminalia Arjuna	Arjuna	Tannins, Arjunolic acid, glycosides; antimicrobial
Vataria indica	Sarjah	Phenols and flavonoids. antibacterial
Vigna mungo	Masha	Mucilage; suspending and binding agent
Vitex negundo	Nirgundi	Alkaloids (nishindin and Hydrocotylene)

(Nene, 2014)

Yaksma (consumption / tuberculosis) in the scriptures

Tuberculosis is a general internal disease that affects both people and cattle, according to the Atharva Veda (AV) (VIII.7.15; XII.2.1) It is defined by its ability to invade and possess every portion of the body (IX.8.7,9, VI.85.1). It sources limb breakdown, fever in the limbs, pain in the heart, and pain throughout the body (IX.8.5, V.30.8.9; 13-19,21,22). (Prasad., 2002)

The scholars in large number in Vedic literature opine that Yaksma referred to a group of disorders with primarily consumption-related symptoms. In the Atharva Veda, yaksma is the broad term for an illness. Yaksma was merely a demon or external force in the minds of the Vedic people that produced disease when it entered the body (Munshi, et al., 2010). From the perspective of the ancient Indian, the likenesses between the descriptions of Yaksma and those of consumption, or more broadly, any disease that causes a general state of body disintegration, cannot be overlooked. (Prasad, 2002)

Many Yaksmas are mentioned in the Atharva Veda hymns or charms, and they are categorised as speaking like a child and an adult, implying that their sufferers were both youngsters and adults (IX.8.10-12; XIX.36.3 2002, Prasad). The "Ajnatayaksma" and the "Rajayaksma" (Royal Yaksma or Yaksma of Kings or King of the Diseases) are two such diseases (III.11.1; VI.127.3; XII.5.22;XI.3.39).

The Yaksmas are claimed to have their genesis in the bride's family (XIV.2.10) as well follow the bridal procession and more specifically, Yakshma is stated to be produced by sin (XIV.2.10) (VIII.7.3). The Atharva Veda mentions that Yakshma can afflict the stomach, lungs, navel, and heart (IX.8.12) (Prasad, 2002).

The Vedic word "Jayanya" means "to break ribs," "to settle in the lungs," "to shelter in the back," and "to spring from excessive sexual intercourse" (VII.76.3). According to the Vedas, the origin of consumption that develops as a result of excessive cohabitation flies like a bird and enters a human's body. There are two types of it: chronic and transitory (VII.76.4). (Prasad, 2002)

Tuberculosis in the ancient literature

Tuberculosis has existed in India for several thousand years. There has been extensive mention of them in the scriptures. (Kanabus, 2019)

Tuberculosis in India around 1500 BCE:

In India, tuberculosis is a long-standing illness. Consumption (Tuberculosis) is described in Indian literature dating back to roughly 1500 BCE, with the disease being linked to extreme fatigue, anxieties, hunger, pregnancy, and chest wounds.

(Kanabus, 2019)

Tuberculosis in India around 500 BCE:

The Ayurveda system of general Indian medical practice is derived from a variety of Sanskrit documents dating back to roughly 500 BCE. A group of disorders known as Sosha can be found in at least one of these (Kanabus, 2019). These are diseases marked by wasting, as well as other symptoms including "coughing and blood-spitting." The Moon-God, the ruler of the Brahmanas, is also supposed to have been the first to succumb to this disease, which is now known as Rajayakshma, or king's disease (Kanabus, 2019).

Tuberculosis in India around 900 CE:

The Rogaviniscaya, also known as the Madhavanidana, is a subsequent major compilation on Indian medicine and the Madhukosa is one of several commentaries on it. The exact dates of the Madhavanidana and the Madhukosa are unknown, but both are thought to have been composed between 800 and 1000 CE. (Kanabus, 2019) The Madhukosa mentions an illness known as yaksman, or rajayaksman (kingly consumption) in a number of different writings, as well as how it has been identified by many as what is now known as Tuberculosis in the twenty-first century. The Madhukosa, on the other hand, claims that the ancient disease had a considerably broader scope than tuberculosis, and that the writings clearly show that it encompassed a variety of symptoms from physical tiredness to cachexia or physical waste. (Kanabus., 2019)

Types of Tuberculosis mentioned in the Vedas

"Aksibhyam te nasikabhayam karnabhayam chubukata adhi Yakshma
sirsanyam mastiskata jihvayam vi vrihami"

(Atharvaveda 2.33.1)

The above verses indicate Tuberculosis above the neck. Out of your two eyes (akshibhyam), nostrils (nasikabhyam), ears (karnabhyam), chins (chubukata adhi), brain (mastikata), tongue (jihvayam) is the wasting disease (vrihami) (TB) seated in the head (sirsanyam).

"Grivabhyah usnihabhyah kiksabhyah anukyata Yaksham
doshanamsabyaha bahubhyam vi vrihami te"

(Rigveda 10.163.2)

The above verses indicate the Tuberculosis on neck (grivabhyah), shoulder (ansabhyam), arms (bahubhyam), arteries (usnihabhyah), bones (anukyata), joints.

"Antrebhyah gudabhyo vanisthoh udarahdadi Yaksmam kuksiyam
plasehnobyaha vivrihami te"

(Atharvaveda 2.33.4)

The above verses indicate the tuberculosis on Gastro-intestinal system. Tuberculosis of intestine (antrebhyah), guts (gudabhyo), bowels (vanisthoh), abdomen (udarah), flanks (kuksiyam), mesentery (palseh), naval(nabhya)

"Urubhyam te ashtivadhabyam parsinabhyam prapadabhyam Yakshmam
bhasadat sronibhyam bhasadat bhansasah vi vrihamite"

(Atharvaveda 2.33.5)

The above verses talk about the Tuberculosis on thigh (urubhyam), knee (asthibhyam), heals (parsinabhyam), waist (sronibhyam), feet (prapadabhyam) and anus (bhansasah)

"Asthibhyah majjabhyah snavabhyah dhamanibhyah Yakshmam
panibhyam angulibhyah nakhebhyah vi vrihami te"

(Atharvaveda 2.33.6)

The above verses indicate Tuberculosis of bones (asthibhyah), bone-marrow (majjabhyah), fingers (angulibhyah), blood vessels (dhamanibhyah), hands (panibhyam)

"Ange ange lomni lomni yaste paravani parvani
Yakhmam tvacasyam te vayam casyam vibarhen visvanca vi vivrihami"

(Atharvaveda 2.33.7)

Tuberculosis occurring in the body, every limb (ange ange), joints (paravani paravani), hair (lomni lomni) will be plucked off by the scattering rays of Sun (kasyapasya).

Agni and Agnihotra in Vedas:

Agni (The Fire God) is the most popular god in the Rigveda, as evidenced by the quantity of hymns written in his honor. All Vedic sacrificial offerings are invariably made to Agni and, through him, to other Gods. (Jayaram, 2019) As a result, Agni is the major beneficiary or carrier of all Vedic sacrifices. The Vedic people feared and revered him as the most powerful and visible kind of energy, both useful and destructive at the same time. A hymn to Agni begins almost in every mandala or section of the Rigveda. The Vedic hymns lavishly glorify him, frequently referring to him as the highest god and creator. (Jayaram, 2019)

"Agnir devo dwijathinam...."

In a discussion, Dr Sanath Kumar, a Sanskrit pandit and a Vedic practitioner mentioned how Agni, Fire God holds highest position and is immensely filled with light, emits heat, and always rises upwards, which

made the Vedic people think, this allows him to easily approach the other gods. Thus, he is most sought. The sacrificial fire is elaborately mentioned in the Purvamimamsa sutra. The vedhi or the sacrificial fire pot construction is implemented with a specific geometry as mentioned in the Shulbasutra.
There are three parts to the Agnihotra Vedhi, (Figure 4.)

1. Gharapathya Agni to the West- here the fire is started and is moved into the next chamber
2. Dakshina Agni to the South – here the purpose of the fire is to burn away any obstructions that could otherwise hinder the ritual from being completed.
3. Madhya vedhi - here the actual sacrificial offerings to the God of Fire (Agni) should happen.

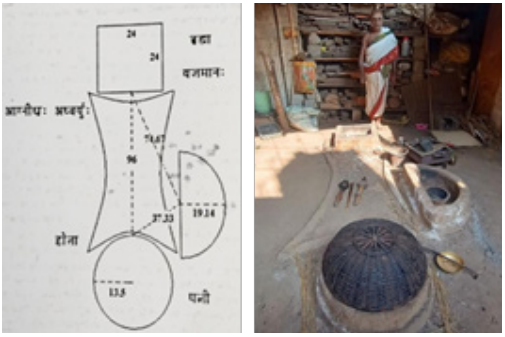


Figure 4. The Sacrificial fire Vedhi
A- As described in the Shulbhasutra (Ashwathnaraya na, 2009)
B- in Dr. Sanath Kumar's Yajna Shala

(Author collected from Mattur, Karnataka)

Recommendations in the Vedas :

Vedas (for example Yajurveda 18/1 to 18/23) recommend performing of Sacrificial fire (Yajna) (Table 3) twice a day, in the morning and evening, to achieve disease treatment, spiritual refinement, , mind and environment purification, and mental peace. (Prasad., 2002)

[5]Vedhi is the Sacrificial fire dais where the rituals are performed.

Table 3. Mention of Yajna in the Vedas for curing various diseases and ailments

Tuberculosis (TB)	AV6- 3 /11 / 1-2	Defines the use of sacrificial fire and Air (herbal smoke) to cure patients with active or latent tuberculosis, as well as late-stage TB.
	AV- 3/11/3	Yagya fume is described as a way to avoid TB recurrence.
	AV- 3 /11 /4	Defines how, 'Yagya' Fire, Sun, and Jupiter's vital energy (parjanya), can cure tuberculosis and offer 100 years of lifespan.
	AV- 7/80/3-4	Yagya is used to treat deep penetrated or primary-infected tuberculosis.
Worm infections	AV- 5/23	Worm diversities are described
	AV- 1/8/1-4	The power of 'Yagya' fumes to kill worms even in the most inaccessible regions
	AV- 5/29/4	The use of 'Yagya' fume to kill worms by interfering with their numerous functions.
	AV- 5/29/6-9	It also guarantees that 'Yagya' would completely free the patient from illness, worms and their eggs must be eradicated.
Diseases without specific description	AV- 6/55/3	Disease prevention
	AV- 7/55/6	Longevity by Yagya
	AV- 7/89/1	Strength by Yagya
	RV7- 1/12/7	Destruction of diseases .
	AV- 19/58/1	Long-term herb burning with ghee promotes vitality and longevity.
	RV-3/10/3	Strength through herbal sacrifice
Goiter	AV- 6/83/1-4	Details the use of Yagya fumes, as well as Sun and Moon rays, to cure sickness.
Mania	AV- 6/111/2	Yagya fume is described as a treatment for madness caused by sin and patients with uncontrollable speech.

Fever	AV- 1 /12 /2	Herbal sacrifice is described as a way to combat fever and weakness caused by it.
	AV- 1/12/3	Describes Fever and related symptoms like as headache and cough caused by Vata, Pitta, or Shleshma will be relieved by the sun in conjunction with sacrificial fire .
	AV- 5/22/1-2	Describes how to properly use 'Yagya' components like the Vedi, Sun, Somras,, and Kusha. Fever and related weakness can be alleviated with the use of Samidha and other herbs.
	AV- 5/22/10/13	Yagya is used to treat various forms of fevers, including cold, hot, long short, seasonal, and so on.
Pregnancy	AV-20/16/11-13	Yagya is described as a method for removing pregnancy-related complications and issues.
	RV-10/162/1-2	Yagya is a technique for making an embryo free of invasive organisms including worms.
	RV- 10/162/3	Yagya can treat conditions like impotency, abortion during fetus development, unstable embryo, delivery risks and new born health issues according to this description.
	AV-7/80/3-4, 7/81/1	Yagya is used to treat deep-penetrated or primary- infected tuberculosis.

(Verma, 2018)

[6]AV – Atharva Veda
[7] RV – Rig Veda

Methodology

A comprehensive review of ancient literature as well as modern references was conducted in order to gain sufficient insights into the operating code of Agnihotra yajna in the current scientific investigation and the effects of medicinal plants used in the Yajna was studied. Ayurvedic doctors were approached for potential leads and insights. Vedic (Rig and Atharva Veda) and ayurvedic literature was elaborately researched. Reviews of various experiments previously designed in the same area were carefully studied. Some information was obtained by consulting specialists with sound knowledge of ancient scripts.

The Yajna therapy is performed by lighting a fire in a copper pyramid (Agni kunda). Unbroken Rice, dried cow dung, pure cow ghee, various parts of medicinal plants (hawan samagri or Samindhu) (Figure 5) are used for the ritual. The Copper Kunda should be of pure copper, a heavy metal according to metallurgy. Pure copper has oligodynamic action (exerts lethal effect on the bacterium). The dimension of the copper pyramid should be 14.5x14.5 cm at top, 5.25x5.25 cm in bottom and 6cm height. (Bhat, 2011). A significant amount of oxygen is necessary for complete combustion. The pyramidal design of the copper vessel ensures this. (Abhang, 2017)

Figure 5. . Illustrates various hawan samagri used in the Agnihotra process (Snapdeal.com)

Vedic texts says "Triyambakam yajamahe sugandhim Pushti vardhanam": The chant talks about the aroma (sugandhim) that enhances the immunity or disease fighting power (Pushti). Thus, the offerings to the Agnikunda release aromatic compounds which has the potential to treat diseases and disorders.

At sunrise and sunset, the Copper pyramid is taken. Dry cow dung cakes are smeared with ghee and placed within the pyramid in a way that allows for airflow. The fire is ignited and allowed to grow into a stable flame. Then the offering of rice, wood of various plants, ghee is done systematically by reciting the Vedic hymns. The wood used in the Yajna must be dry, dust-free, insect-free, and worm-free (Annexure 1). Wood should be cut into small pieces and the wood strips are positioned in the copper pyramid to generate gradual, continuous combustion with a controlled air supply. (Raghuvanshi, 2004)

Following hymns are to be chanted while performing the Agnihotra, this increases the concentration power,

At Sunrise,

"Sooryaya swaha sooryaya idam na mama Prajapataye swaha prajapataye idam na mama"

At Sunset,

"Agnaye swaha agnaye idam na mama
Prajapataye swaha prajapataye idam na mama"

The Agnihotra pyramid's structure is said to create a temperature gradient, with the bottom of the copper pot reaching 300°-400°C and the area directly over the flame reaching 1200°-1300°C. The temperature gradient limit may be 600°-700°C when the flame becomes less intense, and 200°-300°C when the flame gets even less intense. Because this is where the most active and intense fumigation occurs, and air supply is limited, it is known as the "potential fumigation zone" (PFZ)(Fig.6). This is the area where the medicinal plants employed in the yajna release their powerful immunity boosting/disease fighting ingredients. The bulk of hydrocarbons in the PFZ region are partially oxidized and aids in the formation of various products because the autogenous ignition temperatures of most hydrocarbons are in the range of 500°-600°C (Satyaprakash, 2014)

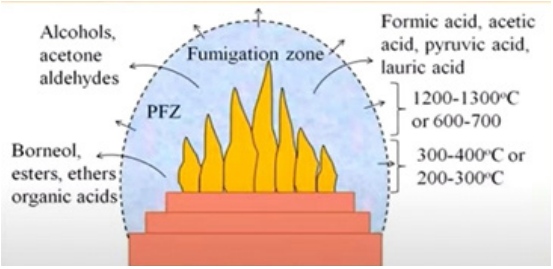


Figure 6. Illustrates the Potential fumigation zone (PFZ) and the components released after combustion of medicinal plants

(Satyaprakash, 2014)

Results

The medicinal value of a sacrificial fire is known to be determined by the substances deployed in the process of homa (Satyaprakash, 2014). Depending upon the resulting Phyto medicines emanating, theoretically, the efficiency of sacrificial fire can be dramatically boosted by including suitable natural ingredients, and an old Vedic literature, Jaiminiya Brahmana 1:19, makes this provision. (Bodewitz, 1973). As has been noted, fumigating compounds play a critical role in reaping the benefits of sacrificial fire (Satyaprakash, 2014). The boiling point and vapor pressure of the volatile substances/compounds involved determine the fumigation process (Satyaprakash, 2014 & Ajwa, 2002). The following are the products that are released during the Agnihotra yajna.

In the PFZ, from the lowest of the pyramid (colder regions), aromatic compounds with a high boiling point and other oils vaporize and are discharged into the atmosphere. The principal chemicals liberated are esters, borneol, and organic acids. Instead of being burned, most medicinal plant preparations go through vapour phase transformation, sublimation spreads, and decay with temperature gradients and volatile chemicals and gases generated by yajnya burning (Satyaprakash, 2014). Agnihotra's burning substance has a very low calorific value. The temperature of the base fire is also low, resulting in a controlled production of nitrogen oxides. A significant amount of oxygen is required for complete burning, which is ensured by the pyramidal shape of a copper pot. Carbon dioxide and other volatile organic compounds are produced during combustion of Agnihotra fire. (Abhang, 2017)

Yajna is usually performed during sunrise. Solar rays at sunrise falls on the sides of copper pyramid, generates electrons. These electrons in turn aids in the redox reaction of the compounds which acts as antimicrobial agents. (Singh, 2012) Raw unbroken rice is essential as it enhances energy around and releases ethylene oxide, propylene oxide, formaldehyde, vita propyl lactone on combustion. (Raghuvanshi, 2009) Cow dung upon combustion releases menthol, ammonia, phenol, indole, formalin. Studiesshow that in olden days, tuberculosis patients were kept in Cow shed, as they believed the components from Cow dung had the potential to cure the disease. Burning of cow dung also releases hydrogen sulphide, nitric oxide. (Raghuvanshi, 2009)

Pure ghee used in the yajna burns the cellulose content of the wood and in turn releases acetone, aldehydes. These substances have a certain amount of lethal effect on the bacterium and its genetic material. Some volatile organic chemicals are released when wood cellulose is burned like Eugenol, terpinol. (Arya, 2019) Heat energy generated during Yajna fire achieves desired physiochemical, biological, and spiritual benefits. (Raghuvanshi M, 2009) Transformation of energies may be due to materials (Samindhu-Annexure 1) used in the Yajna; the carbon dioxide released from the sacrificial fire is converted to

formaldehyde ($CO_2 + H_2O_{(vapour)} \rightarrow HCHO + O_2$) to certain extent. Formaldehyde is a powerful antimicrobial agent. (Singh, 2012) Propiolactone alters the carboxyl group of the microbial DNA. Eugenol disrupts cellular membrane. Essential oils released weaken the cell wall. Each component, essential oil, volatile substance released has a unique mode of action on the microorganism, owing to its destruction.

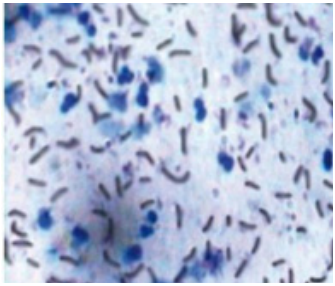
Experiments to prove the potential of Sacrificial fire

A study on the use of Medicinal plants (Havan samagri) to cure various ailments was conducted at the Ayurveda and Holistic Health department, Dev Sanskriti Vishwavidyalaya, Gayatrikunj-Shantikunj, Haridwar, from 2015 to 2019. (Annexure 3). More than 350 people have benefited from the use of medicinal plants and sacrificial fire therapy. (Shrivatsava et al., 2019)

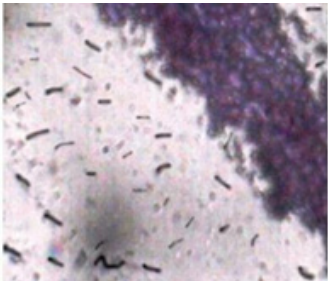
Golecha et al., (1987) has proved that performing yajna everyday can influence a person to quit alcoholism and shift to a healthy lifestyle.

Rastogi et al., (2020) published a study on the effects of yajna on FBS and PPBS levels in diabetic patients. A total of 11 people were recruited for the study, and they were instructed to participate in the Agnihotra process daily. Fasting Blood Sugar (FBS) and Post-prandial blood sugar (PPBS) levels were collected before and after. The readings (Annexure 4) were clearly lower after attending Agnihotra sessions, demonstrating that the gases from the sacrificial fire have therapeutic effect in healing illnesses.

Raghuvanshi et al., (2009) have conducted an experiment on the effect of Yajna fumes on the growth of Mycobacterium tuberculosis. Sputum samples from a Tuberculosis patient was taken and was spread on selective media for the growth of M.tuberculosis. The control plate was kept undisturbed. The test plate was subjected to Yajna fumes and then incubated. After incubation, it was observed that there was 75% reduction in the growth of the bacterium (Figure 7) on the test plate exposed to Agnihotra fumes compared to the control. (Raghuvanshi,et al, 2009)



Microscopic view of Acid-Fast Bacilli - Control



Microscopic view of Acid-Fast Bacilli treated with the fumes of Sacrificial fire

Figure 6. Growth of M. tuberculosis, Raghuvanshi, et al, 2009

Table 4. Experimental studies involving sacrificial fire carried out by various authors to cure various disorders

Sl. No.	Authorname	Title of the paper	Year of publishing	Experiment Conducted & location	Key findings
1	Raghuvanshi et al.,2009	In- vitro review of anethnobotanical inhalation therapy (yagya-therapy) against the pulmonary tuberculosis	2009	Acid fast Bacilli (AFB) (M. tuberculosis) was plated on the medium. The samples were collected from patients tested withTuberculosis.	The control plate had more growth of AFB whereas, the plate exposed to Yajna Fumes had 75% Reduction in the growth of the bacterium.
2	Dr.Ulrich Beck, 2020	Coronavirus-How can Agnihotra help?	2020	Lady diagnosed with pre-stroke effects in her electrocardiogram. Lima, Peru	Electrocardiogram showed reduced risk of pre-stroke after conducting agnihotra continuously
3	Goleccha et al, 1987	Agnihotra – as an useful adjunct in the recovery of a resistant demotivated smack addict	1987	25-year-old boy addicted to drugs could not give up on his practices Delhi, India	Behavioral changes studies and rating system was used. Indicative and positive hanges were observed
4	Shrivatsava et al.,2019	Management of the Symptoms Associated with z Obsessive-Compulsive Disorder (OCD) and Polycystic Ovarian Disease (PCOD) through an Integrated Approach including Yagya Therapy	2019	40-year-old female suffering from OCD and PCOD for many years, Dev Sanskrit Vishwavidyalaya, Haridwar, Uttarakhand	Visual changes with respect to OCD was seen and the PCOD problem was resolved.

5	Mishra Alka et al., 2019	Management of the Epileptic Seizures Through an Integrated Approach Including Yagya Therapy	2019	45-year-old patient experiencing seizures every 5-6 days for past few years. Dev Sanskriti Vishwavidyalaya Haridwar, Uttarakhand	There was no recurrence of seizures after performing Agnihotra.
6	Ramadass et al., 2021	Agnihotra- as an inexpensive method to treat HIV / AIDS- A pilot Study	2021	10 children infected with HIV were taken for the study. Mysore, India	Significant decrease in Viral load and increase in CD4 cells was observed after 2 years (2015-2016)
7	Shrivatsava et al.,2020	Application of an integrated approach including Yagya therapy for the management of acute pulmonary edema with mild cardiomegaly	2020	33-year-old women complaining of multiple disorders. Dev Sanskriti Vishwavidyalaya Haridwar, Uttarakhand	Feed back from the patient showed significant development in the health and reduced complications in the health.
8	Rastogi etal., 2020	Statistical Analysis on efficacy of yagya therapy for type-2 Diabetic mellitus Patients through various parameters	2020	People with type 2 Diabetes mellitus were taken for the study Yagyopathy Research Center (YRC), Jaipur,	There was significant improvement in the body weight, PPBs, and HbA1c levels

9	Rastogi et al., 2020	Yajna and mantra Therapy applications on Diabetic and other diseases subjects: computational intelligence based experimental approach	2018	11 people with Diabetes mellitus was considered for the study. Chetan Kendra, Noida,India	Significant reduction in FBS, PPBS was observed. Overall health improved among the subjects
				Patient complaining of severe body pain and sleeping trouble Chetan Kendra, Noida, India	After a 7-day yajna course, the patient was found to have 80% reduction in pain and sleep cycle balanced
				Patient with history of severe heart failure, acute breathlessness Chetan Kendra, Noida, India	Improvement in the overall health, and breathing

Active Phytochemicals from Sacrificial fire and their action on the microorganism

Flavonoids:

While tuberculosis still affects over a third of the world's population, flavonoids may provide an intriguing and affordable alternative therapy due to their direct antimycobacterial and immunomodulatory properties. (Cao et al., 2019) Flavonoids are a group of polyphenolic secondary metabolites that inhibit Mycobacterium growth and increase cell death and membrane damage (Pawar et al., 2020). The mode of action includes inhibition of nucleic acid synthesis, inhibition of cytoplasmic membrane function, inhibition of energy metabolism, inhibition of attachment and biofilm formation, inhibition of the porin on the cell membrane, alteration of membrane permeability and attenuation of pathogenicity (Xie et al., 2015).

Terpenoids:

Terpenoids are one of the most diverse classes of naturally occurring molecules in terms of structure. There have been a few mechanisms postulated for their antibacterial property. The rupturing of the cell membrane and alterations

in the ion channels (Na+, K+, Ca2+, or Cl) in the cell membrane, for example, could enhance permeability and result in the release of important intracellular constituents as well as inhibition of target enzymes. (Cushnie et al., 2014).

Phenols:

The mode of action of phenolic compounds on bacterial cells include damage to the bacterial membrane, inhibition of virulence factors such as enzymes and toxins and suppression of bacterial biofilm formation (Majdanik et al., 2018). The metabolite appears to be more inhibitory as the structure becomes more oxidized. (Cowan, 1999).

Alkaloids:

Alkaloids are a wide and structurally diverse collection of chemicals that have been used as scaffolding for antibacterial medications (Cushnie et al., 2014) Alkaloids are recognized to have a variety of pharmacological properties in both traditional and modern medicine. Caffeine, cocaine, and nicotine are examples of alkaloids that have become part of human society as recreational or abusive drugs. Some alkaloids are known to be highly poisonous, causing human poisoning and blocking nucleic acid synthesis (Cushnie et al., 2014). Bacterial respiratory inhibition and enzyme inhibition are mode of action of the Alkaloids.

Tannins:

Tannins are polyphenolic chemicals found in plants that bind to proteins, amino acids, and alkaloids, causing them to precipitate. They are antibacterial biomolecules that are well-known. Tannin is a substance that is both natural and effective. Tannin can penetrate through the cell wall and into the interior membrane, interfering with the cell's metabolism and destroying it. Tannin biological activity could be linked to oxidation and polymerization patterns (Coppo and Marchese, 2014). Tannins work as antimicrobials by forming complexes with proteins that are both covalent and non-covalent. They are also capable of forming polysaccharide complexes. Direct inactivation of bacteria has also been demonstrated. (Cowan, 1999).

Saponins:

Saponins are detergent-like compounds that have antibacterial and cancer-fighting properties. Saponins' ability to permeabilize cell membranes by complexing with cholesterol is linked to their therapeutic potential against eukaryotic cells. (Arabski et al., 2012).

Quinones:

Quinones have two ketone substitutions on their aromatic ring. Quinones' capacity to contribute free radicals is what gives them antibacterial action. They can also inactivate proteins by forming irreversible compounds with their amino acids. Quinones attack the surface adhesions, cell wall polypeptides, and membrane enzymes because of their unique characteristics. Quinones can also sequester substrates that bacteria require. (Cowan, 1999).

Summary

Medicinal plants are the local heritage with the global importance. Nature provides a plentiful supply of plants used to treat human sickness. Herbs have had a wide-ranging impact on human health as a primogenital and primary framework of traditional medical systems. (Ntutela et al., 2009) Agnihotra is being practiced by an increasing number of people from diverse religions and cultures, both in the East and in the West (Golechha, 1987).

Global acceptance and use of herbal medicines and allied items is increasing at an exponential rate. An appropriate information foundation relevant to diagnostic and therapy decision-making is also critical. Moreover, due to the simultaneous implementation of several natural medicinal plant products in the sacrificial fire, a large number of constituents are released concomitantly. This reinforces the possibility that the inhibition of the Mycobacterium is linked to multiple mechanisms, including immunomodulation, which suppress the growth of the bacterium or reduce its possibilities of resistance.

In light of all the above facts, Sacrificial fire or yajna can be considered as a complementary medicine (Bansal P., 2016) The two families who survived the Bhopal gas tragedy were said to practice Agnihotra every day, which was thought to be the antidote to the gas leak's devastation (Keralam, 2012).

Based on all the above explanations, this therapy might be promising alternative to the high dose modern medication. However, Clinical trials can further corroborate if there are any negative effects of these medicinal plant-based compounds as per modern clinical trial methodology. Distressingly, research in the field with respect to the use of ancient knowledge for cure of Tuberculosis is scanty or limited to be used as an adjunct. There is dire necessity for the research to be carried on providing scientific evidence to the ethnobotanical inhalations which is just believed to be sacred among many.

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Annexure 1. List of common medicinal plants used in the sacrificial fire

Name of Plant	Botanical Name	Common Name
Somavalli	Sarcostemma brevistigma	Somalata, Soma, Akujemudu and Somamum,
Mango	Mangifera indica	Amramu, Maangai, Amba
Pipal	Ficus religiosa	Pipli, Pipar, Aswatha,
Sandalwood	Santalum album	Bhadrasri,Chandan, Anindita, Anukkam
Saffron	Crocus sativus	Kesar Kashmiram
Brahmi	Bacopa monnieri	Sambranichettu, Jalnaveri, Jalanimba,
Guggul	Commiphora wightii	Devadhupa , Indian Bedellum
Rice	Oryza sp.	Tandul,Chaval, Dhan, Akki,Bhatta
Lemon grass	Cymbopogon sp.	Nimmagaddi, OlechaGandhatrina, Lilicha
Holy Basil	Ocimum tenuiflorum	Tulsi, Manjari
Sacred fig	Ficus religiosa	Bodhi tree, Pipala tree, Ashvattha tree
Shami	Prosopis cineraria	Khejri, Chhonkara, Jammi
Cluster fig	Ficus racemose,	Audumbara

Annexure 2. Medicinal Plants, their classification, and phytochemical properties

(Khare, 2007)

a. Sarcostemma brevistigma

(flickr.com)

- Synonym - S. acidum Voigt.
- Family- Asclepiadaceae.
- Habitat- Dry places in West Bengal, Bihar andPeninsular India.
- English name- Moon Plant, Soma Plant. Ayurvedic name- Somavalli, Somalataa, Somakshiri, Saumyaa, Dwijpriyaa. (Substitute: Ephedra gerardiana.) Siddha/Tamil Somamum, KodiKalli.

- Malic acid, reducing sugar, succinic acid, surcosa, traces of an alkaloid, tannin, alpha- and beta-amyrins a phytosterol, , lupeol, beta-sitosterol and lupeol acetate are among the compounds found in the plant.

b. Mangifera indica

(alamy.com)

- Family - Anacardiaceae.
- Habitat- Uttar Pradesh.,Punjab, Maharashtra,
- West Bengal , Andhra Pradesh, and Tamil Nadu.
- English name- Mango.
- Ayurvedic name- Rasaal, Amb, Sahakaar, Aamra, Atisaurabha, Pikavallabha,Madhudoot, Maakanda

- Phenolic substances (protocatechuic acid, gallocatechin), xanthones (homomangiferin), various sterols and triterpenoids are all found in the bark. All parts gave phenolic acids (gallic acid, ellagic acid, ethyl gallate); flavonoids (catechin) and xanthones (mangiferin).

c. Santalum album

(paudhshala.com)

- Family - Santalaceae.
- Habitat - Dry regions Dry portions of Peninsular India, particularly in Karnataka and Tamil Nadu, from the Vindhya mountains southwards.
- English name- White Sandalwood.
- Ayurvedic name- Hima,Chandana, Shrikhanda, , Gandhsaara, Shvetachandana, Malayaja, Ekaangi, Bhadra-Shree

- Ursen-butyl-palmitate is a triterpene found in the bark. Alpha- and beta-santalol are the main components of heartwood essential oil
- Sesquiterpene hydrocarbons such as alpha-, beta-, epibeta-santalene, beta-farnesene and alpha- and betacurcumene are also present. Di-hydro-agar furan can also be found in the essential oil.

d. Crocus sativus

(paudhshala.com)

- Family- Iridaceae.
- Habitat- Cultivated up to 2000 meters in Kashmir and in Uttar Pradesh's Chaubattia.
- English name- Crocus, Saffron.
- Ayurvedic name- Rudhira, Kumkuma, Kaashmira, Rakta, Vaalhika, Kaashmiraka, Agnishikhaa Vadrika, , Ghrusrrn, Kshataja. Keshara (usually Keshara indicates Naagakeshara, Mesua ferrea Linn.)

- The volatile oil in saffron is made up of terpene alcohols, terpenes, and esters. Crocin, crocetin, picrocrocin, , carotenoids, thiamine, and riboflavin are also found in the herb.

e. Bacopa monnieri

(paudhshala.com)

- Synonym- Herpestis monnieria (Linn.) H. B. & K. Moniera cuneifolia Michx.
- Family- Scrophulariaceae.
- Habitat- damp marshy areas of Indian plains.
- English name- Thyme-leaved Gratiolae-
- Ayurvedic name- Darduradalaa, Kapotavankaa, Nirbraahmi, Aindri, Bhaarati, Matsyaakshaka, Shaaluraparni, Braahmi, Mandukaparni (also equated with Centella asiatica Linn., synonym Hydrocotyle asiaticaLinn. Umbelliferae, Apiaceae).

- The herb contains the alkaloids brahmine, herpestine, it also contains the saponins, monnierin, hersaponin, bacosides A and B

f. Oryza sativum

(en.wikipedia.org)

- Family- Gramineae; Poaceae.
- Habitat- Cultivated all over India as a food crop.
- English name- Rice.
- Ayurvedic name- Shaali, Vrihidhaanya, Tandula, Nivara

g. Cymbopogon sp.

(en.wikipedia.org)

- Family- Poaceae.
- Habitat- Warmer parts of India, from Punjab to Bengal and in South India.
- English name- Camel-Hay.
- Ayurvedic name- Rohisha (var.)
- It has a number of methyl ketones, as well as limonene, camphene, and a group of oxygenated sesquiterpenes, the most important of which is elemol.

h. Ocimum tenuliflorum

(en.wikipedia.org)

- Family- Labiatae; Lamiaceae.
- Habitat- In India, it is grown in homes, gardens, and temples.
- English name- Holy Basil, Sacred Basil.
- Ayurvedic name- Tulasi, Surasaa, Surasa, Bhuutaghni, Suravalli, Sulabhaa, Manjarikaa, Bahumanjari, Deva- dundubhi, Apet- raakshasi, Shuulaghni, Graamya, Sulabhaa
- Eugenol, carvacrol, nerol, and eugenolmethylether are the main components of the essential oil. Ursolic acid, apigenin, luteolin, apigenin-O-glucuronide, luteolin-O- glucuronide, orientin, and molludistin have all been found in the leaves.

i. Ficus religiosa

(en.wikipedia.org)

- Family- Moraceae.
- Habitat- Sub-Himalayan regions, West Bengal, Central and South India; planted as an avenue tree throughout India.
- English name- Peepal, Bot-tree.
- Ayurvedic name- Ashvattha, Bodhidru, Bodhivrkisha, Sebya, Chalapatra, Gajabhaksha, Kshiradruma, Peeppal.
- Beta-sitosteryl-Dglucoside is found in the bark. The stem bark contains vitamin K, n- octacosanol, methyl oleanolate, lanosterol, stigmasterol, and lupen-one.

j. Ficus racemose

(en.wikipedia.org)

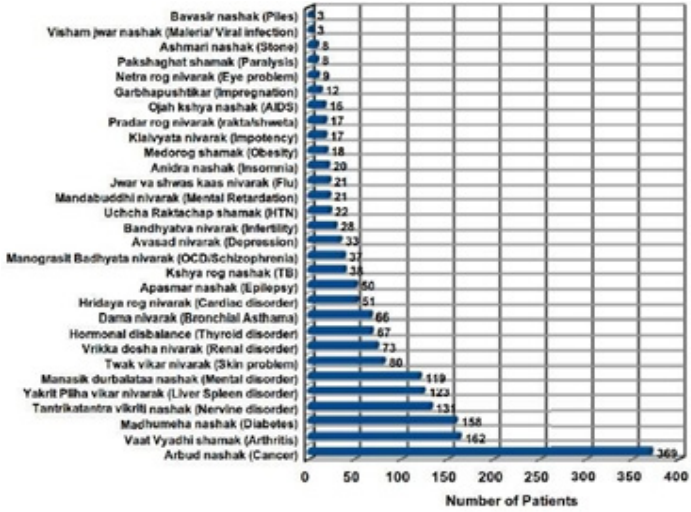
- Synonym- F. glomerata Roxb.
- Family- Moraceae.
- Habitat - India as a whole. It grows wild in the woods and on the ridges. Often found near underground water streams.
- English name- Cluster Fig, Country Fig.
- Ayurvedic name- Udumbara, Sadaaphala, Hema-daudhaka, Jantuphala, Yagyaanga.
- Gluacol is found in the leaves and berries. Beta-sitosterol, lupeol acetate, friedelin, higher hydrocarbons, and other phytosterols are also found in the fruit.

k. Prosopsis cineraria

(nestree.com)

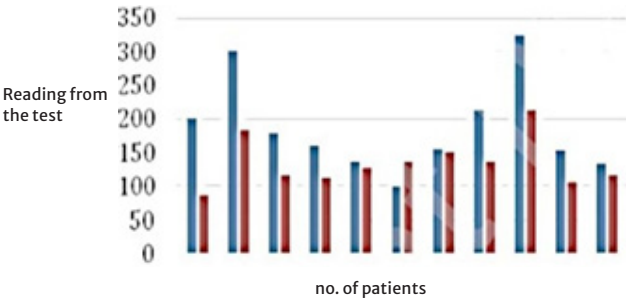
- Family- Mimosaceae
- Habitat- Dry and acrid regions of India.
- Ayurvedic name- Shami, Tungaa, Keshahantri, Shankuphalaa.
- Patulibin, a cytotoxic principle, has been isolated from this plant.

Annexure 3. Graphical representation samagri or medicinal plants parts in curing various diseases and ailments



(Shrivastava et al., 2019)

Annexure 4. Graphical representation of the FBS and PPBS reading before (blue) and after (red) sacrificial fire therapy



(Rastogi et al., 2020)

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