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IMPRESSIVE BENEFITS OF EUCALYPTUS LEAVES

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Abstract

With a specific focus on Eucalyptus camaldulensis, this study explores the chemical makeup and therapeutic uses of various Eucalyptus species. Numerous bioactive substances, including tannins, saponins, alkaloids, flavonoids, terpenoids, glycosides, anthraquinones, and steroids, have been found in diverse plant components by thorough phytochemical investigations.. Eucalyptus camaldulensis essential oil was extracted by steam distillation, and its constituents—p-cymene, 18-cineole, beta-phellandrene, spathulenol, and cryptone—were identified by gas chromatography and mass spectrometry analysis. These compounds are associated with a multitude of therapeutic properties, including antibacterial, antioxidant, and anti-inflammatory properties. The study highlights the plant's potential for use in pharmaceutical and industrial applications, as well as its widespread use in traditional medicine to treat a variety of ailments. Additionally, the study discusses how growth methods and environmental variables can vary the chemical makeup of plants, highlighting the necessity of consistent quality control in the eucalyptus essential oil production process. This study advocates for more research into the pharmacological mechanisms and potential therapeutic benefits of Eucalyptus species, consolidating current knowledge on their medicinal-usefulness.

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Keywords: *Eucalyptus camaldulensis, Essential oil, Therapeutic uses, Antibacterial effects, Anti- inflammatory, Traditional medicine.*

Introduction

One of the two main kingdoms of living thingsis the plant kingdom. They are the only living things that can use solar energy to create their own nourishment. Food that is generated from plants cannot be replaced, despite the fact that many synthetic compounds can. Life on Earth could not exist without plants. The majority of our diet is made up of plants; in many nations, rice or wheat is the main food. Twenty plant species provide 85% of the calories consumedby humans; surprisingly, three plant species—wheat, rice, and maize—provide 60% of this energy [1]. The field of herbal medicine has grown exponentially in the last several decades. Because of its natural origin and littlenegative effects, it is becoming more and morepopular in both developed and developing nationsPlants are a valuable source of many secondary metabolites that are used as agrochemicals, food additives, flavors, colors, fragrances, and biopesticides [2–10].

Historically, plants have been vital to human life and society because they meet our basic needs for food, medicine, and shelter, but their importance goes beyond these necessities. Because they include essential nutrients like vitamins, minerals, and fiber that are required for proper biological processes, plants are essential to human health and wellness. By include a variety of plant-based foods in our diets, we can improve our general health and reduce our risk of developing chronic illnesses like diabetes, heart disease, and cancer. (Grinde, B., & Patil, G. G. 2009). Plants can prevent and treat a variety of ailments in addition to offering vital nutrients.People have been using plants for thousands ofyears to help heal and reduce the symptoms ofailments, and many conventional and contemporary medical procedures still heavilyinclude plant-based medicine (Niazi P. et al., 2023). Plants are vital to our ecosystem because they sustain the oxygen and water cycles on Earth, give other organisms food and habitat, and mitigate the effects of climate change by absorbing carbon dioxide from the atmosphere and reducing the urban heat island effect (Rawat, U. S., & Agarwal, N. K. 2015). The health of our world and our well-being depend on plants, which play a crucial role in human existence and civilization (Turner-Skoff, J. B., & Cavender, N. 2019) [11].

Eucalyptus (family Myrtaceae) is endemic to Australia, a few of its varieties are also found in nearby nations [12]. Because it can thrive in a range of soil types and temperatures, it has been

introduced to Asia, Southern Europe, and North and South Africa [13]. In addition to South America (Argentina, Chile, Paraguay, and Uruguay), Brazil, Congo, China, Indonesia, and South Africa, interspecific hybrids are cultivated on small plantations in the Philippines, Vietnam, Thailand, and Malaysia [14]. Just about 1% of the 700 or so species that exist today areemployed for industrial reasons [15]. These days, its timber is utilised to make hardwood fibre, windbreaks, shelterbelts, and fuel [16].

Classification by botany

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida Dicotyledonous

Sub class: Rosaceae
Order: Myrtales

Family: Myrtaceae

Sub family: Myrtoideae

Genus: Eucalyptus
Species: Eucalyptus globulus

Depending on the species, eucalypts volatile oils might be found in many different areas ofthe plant, but they were most prevalent in the leaves. Small glands were used to create and store eucalyptus oil, and the fresh weight of theleaves from various species

ranged from 0.1 to7% [17]. The volatile oil that was isolated from fresh eucalyptus leaves included 1,8-cineole as its main constituent. The content of 1,8-cineole has been found to range between 54 and 95%. Mature leaves consistently had higher 1,8-cineole contents, despite notable seasonal variations. Apart from 1,8-cineole, the oil also included geraniol and monoterpenes such camphene, cymene, α-pinene, β-pinene, and limonene. From the eucalyptus oil, aromadendrene, cuminaldehyde, globulol, and pinocarveol were also extracted [18, 19–23]. Lumonene,α-terpineol (which is available from the most common components found to coexist with 1,8-cineole were menth-1-en-8-yl cation, the same biogenetic precursor thought to be the source of cineole; monoterpenes (like α-pinene); sesquiterpenes (like aromadendrene); globulol and α, β and ϒ-eudesmol; and aromatic constituents (like methyl cinnamate). [24–26].

The genus Eucalyptus also contained complex mixtures of plant secondary metabolites, including hydrolyzable and condensed tannins, terpenoids, cyanogenic glycosides, flavonoids, long chain ketones, and formylated phloroglucinol compounds, in addition to oil [27]. Twenty-six compounds were extracted from Eucalyptus bicolor (Syn: Eucalyptus largiflorens) oil, with 1,8-cineole (37.5%), p-cymene (17.4%), and neoisoverbenol (9.1%) being the main ingredients [28].

A preliminary phytochemical analysis of the several sections of Eucalyptus camaldulensis revealed the presence of alkaloids, flavonoids, terpenoids, tannins, saponins, glycosides, steroids, and anthraquinones [29]. The main constituents of Eucalyptus camaldulensis essential oil were monoterpene hydrocarbons (29.0%), sesquiterpene hydrocarbons (4.3%), oxygenated monoterpenes (31.8%), and monoterpene hydrocarbons (34.9%) [30]. The essential oil from the aerial parts of Eucalyptus camaldulensis, a plant that grows wild throughout Sardinia, Italy, was extracted by steam distillation. Analysis was done using GC-ion trap mass spectrometry, FID, and gas chromatography. From 0.02 to 0.5%, the essential oil yields (v/dry weight) were observed.

A minimum of 97.7% of the total essential oils, or thirty-seven compounds, were found. P-cymene (27.8-42.7%), 1,8-cineole (4.1-39.5%), beta-phellandrene (3.9-23.8%), spathulenol (2.1-15.5%), and cryptone (3.2-10.2%) are the principal components of these compounds. Moderate quantities (1.4–4.7%) of two uncommon aldehydes, cuminal and phellandral, were found in the oils [31]. Eucalyptus is the most often used plant worldwide. It fulfills a number of functions. There are numerous advantages and disadvantages to it. This plant is used all over the world to cure a wide range of ailments because of its potential as a medicine. Its essential oils have a wide range of industrial and medicinal uses [32].

Their properties that make them useful in folk medicine include astringent, deodorant, diaphoretic, antiperiodic, antiphlogistic, antiseptic, fumigant, febrifuge, fumigant, hemostat, inhalant, insect repellent, preventive, rubefacient, sedative yet stimulant, suppurative, tonic, and vermifuge [33].
Its nine species are used for both medicinal and commercial purposes (Table 1). E. cinerea, E. cneorifolia, and E. macarthurii are also employed in fragrance and have therapeutic use.

The majority of farmers worldwide cultivate this plant primarily in areas with waterlogging in order to generate revenue for the purchase of agricultural inputs and other global expenses. The world's scarcity of poplar wood means that eucalyptus wood is mostly used in the furniture

industry. Its extremely hard and uneven wood is primarily utilised by farmers as fuel wood, while it is also used in the furniture business. Their charcoal is more well-liked worldwide and provides greater energy than poplar wood. This facility is primarily used to manage water logging. They mainly plant on soil with a high pH value. The world's attacks by white ants led to the replacement of shesham by eucalyptus. The watercourse that had been harmed by white ants was where the majority of shesham was found. White ants were introduced into farmland by canal irrigation, destroying the crops and other plants grown by the farming population. Poplar trees and sugar cane are twoof these that are highly recognised worldwide.In some places, the planting pattern no longer includes sugarcane.

Worldwide, eucalyptus wood is also utilised for electrical poles. Millions of plants are now cultivated in Pakistan as part of a treeplantation initiative. People's incomes in Pakistan have increased as a result of this programme, and Pakistani farmers are quite interested in this plantation. It significantly affects the global ecosystem system, which in turn significantly affects the reduction of global warming and climate change. It is a major global concern these days. The majority of the sun's rays now fall straight on Earth dueto environmental pollution brought on by industrial development, which has also disrupted the ozone layer. Later on, it causes irritation in both humans and animals as well as the problem of cancer. In a same vein, the ecosystem is contaminated.

The world's eucalyptus plantations are a major factor in solving the aforementioned issues. Given its significance, examining the eucalyptus plant's worldwide economic and medical value was the goal of the current study.

Table 1. Cultivated Eucalyptus species

Uses	Species	Country
Medicinal	Eucalyptus globulus Labill.	China, Portugal, Spain, India, Brazil, Chile,Bolivia, Uruguay, Paraguay
	E. smithii R. Baker	South Africa, Swaziland, Zimbabwe
	E. polybractea R. Baker (syn. E. fruticetorum F. Muell. ex Miq.)	Australia
	E. exserta F. Muell.	China
	E. radiata Sieber ex DC. (syn. E. australiana, E. radiata var. Australiana)	South Africa, Australia
	E. dives Schauer	Australia
	E. camaldulensis Dehnh. (syn. E. rostrata Schldl.)	Nepal
Perfumery	E. citriodora Hook.	China, Brazil, India
	E. staigeriana F. Muell. ex Bailey	Brazil

Source: [34]

Socio-economic advantages of Eucalyptus

To fulfill the increased demand for wood, eucalyptus is the best alternative to slow-growing species like Acacia nilotica, Dalbergia sissoo, and Morus species.. BecauseE. camaldulenisis

and E. tereticornis are moreadapted to the varied ecological circumstancesin Pakistan than other eucalyptus species, theyshould be planted more frequently than other eucalyptus species [35]. Pakistan has a relatively low percentage of forest cover— roughly 5%—and significant areas devoid of trees. The primary goals of eucalyptus plantingin Pakistan are to enhance the country's forest cover and supply fuelwood, lumber, biomass, and timber. Eucalyptus trees are often planted by farmers as a source of income [36]. For bees, birds, people, and other creatures, eucalyptus is a great supply of oil [37–38]. The staining qualities of pigments derived from eucalyptus bark range from ordinary to standard. Quercetin, a food coloring agent, is one of the primary components of eucalyptus bark [39–40].

For roosting birds and animals, eucalyptus provides thermalprotection, perching, and shelter [41]. The match business and tobacco-curing chambers use almost 200,000 eucalyptus trees annually, according to figures kept by the Pakistani government. A large number of locations in Pakistan are impacted by the excessive salt concentration in the soil and groundwater. According to studies, eucalyptus grows more quickly in saline, wet soil—more than 85%—

and is thus suggested as the best tree for these conditions [42]. In several areas of Punjab province, E. camaldulensis is planted in large quantities to reduce the acidity of salty soil since it can tolerate prolonged salinity and decrease drainage volume [43].

Eucalyptus and human health

While there is insufficient scientific evidence to support the possibility that eucalyptus contains bioactive chemicals that promote health, there are numerous ethno- pharmacological reports regarding several eucalyptus species.

On August 7, 2019, Davidson. The evergreen eucalyptus tree is often used for its therapeutic qualities. Originally from Australia, this well-known tree is now found all over the world. Its round leaves, lengthy stems, and gum-infused bark make it difficult to digest if consumed whole. On the other hand, You may brew a safe tea with eucalyptus leaves.. The leaves canalso be processed to create essential oil that canbe applied topically or inhaled. These are eucalyptus leaves' seven remarkable advantages. While full, fresh eucalyptus leavesare not edible, dried leaves can be used to maketea. Take cautious not to confuse this tea with eucalyptus oil, as consuming it could be harmful. Select a tea that bears the label "eucalyptus leaves tea" and refrain from incorporating eucalyptus essential oil into it. Antioxidants, Eucalyptus leaves are rich in flavonoids, which protect your body from oxidative stress and damage from free radicals. The primary flavonoids found in eucalyptus include quercetin, kaempferol, isorhamnetin, luteolin, and phloretin. Diets high in these substances may offer protection against dementia, heart disease, and several types of cancer. For exampleAn 18% decreased risk of fatal heart disease was associated with a diet high in flavonoids, according to a major study involving 60,289 women and 38,180 men.In general, eucalyptus tea is considered safe for adult consumption and a rich source of these antioxidants. HoweverChildren should speak with a healthcare professional before drinking this tea because they are particularly vulnerable to eucalyptus toxicity.

A common ingredient in cough and cold medications, eucalyptus is also a popular natural cold cure.

Investigate has demonstrated its ability to reduce mucus and widen your lungs' bronchi and bronchioles. Moreover, It has anti-inflammatory

properties of its own. Cineole, another name for eucalyptol, a chemical found in eucalyptus, is the main ingredient responsible for these properties. Certain studies suggest that eucalyptol helps relieve cold symptoms like headache, congestion in the nose, and frequent coughing by reducing inflammation and mucus buildup. Additionally, eucalyptol may reduce the symptoms of asthma. For twelve weeks, thirty-two patients with bronchial asthma were given either 600 mg of eucalyptol or a placebo every day. The eucalyptol group needed 36% less medicine to manage asthma symptoms than the control group, which needed 7% less.

You might try breathingeucalyptus oil via your nose to help alleviate the symptoms of a cold. Additionally, a lot of topical decongestants contain it. However, you should refrain from ingesting the oil because even minute amounts of it might be harmful. Before taking eucalyptol or altering your drug regimen, make important to speak with your healthcare practitioner [44].

Published research indicates that eucalyptus oil and extract significantly improve the viability and lower the proliferation index of a number of human cancer cell lines [45]. To investigate the pharmacological potential of eucalyptus plant extract against cancer, researchers use it to developing cancer cell lines. It has been demonstrated that a number of essential oils that are derived from different eucalyptus species can inhibit the fast growth of cancer cells and stop the disease's progression. For instance, eucalyptus extract dramatically reduced cell migration and invasion and raised the cell death rate (apoptotic index) in breast cancer cell lines [46–48]. Numerous investigations into the possible anticancer properties of eucalyptusextract have confirmed that these highlybioactive chemicals have the potential to be extremely promising treatments for a wide range of malignancies. They went on to say that while eucalyptus extracts may be useful asmedications for certain tumours, more pre-clinical research is required to determine the precise pathways [49–50].

Eucalyptus crebra has been demonstrated in a study to be a possible source of essential oil, and further research is necessary to determine its constituents' effects on pharmacological, medical, and cosmetic goods [51]. Increasing the amount of creamed eucalyptus may help. Your skin's ceramides are a particular kind of fatty acid that help keepmoisture and the skin's barrier intact. Ceramide levels are typically lower in those with dry skin, dandruff, or skin conditions includingpsoriasis and dermatitis. It's been discovered that topical eucalyptus leaf extract improves skin barrier protection, water-holding capacity, and ceramide formation in the skin. Ingredient known as macro carpal A, This appears to boost ceramide synthesis. In a research with thirty-four subjects, the use of a scalp lotion that contained synthetic ceramide and eucalyptus leaf extract significantly decreased scalp itching, redness, and scaliness.

For this reason, eucalyptus leaf extract is found in many hair and skin care products. Pain may be reduced by inhaling eucalyptus essential oil. Cineole is one of the several anti-inflammatory compounds in eucalyptus that may help reduce pain. In 52 patients who had undergone knee replacement surgery, inhaling eucalyptus oil soaked in almond oil for 30 minutes each day for three days decreased blood pressure and pain perception compared to inhaling pure eucalyptus oil.

More research is likely necessary, as evidenced by a different study that included 123 cancer patients and found no reductions inreported pain following a 3-minute inhalation of eucalyptus oil before a medical treatment.

Most people think that eucalyptus does. In one study, inhaling eucalyptus oil significantly reduced pre-operative anxiety in 62 healthy individuals. It has been discovered that eucalyptol, which is present in eucalyptus, has anti-anxiety qualities. Moreover, patients who underwent knee surgery were linked to inhaling eucalyptus oil for 30 minutes, suggesting that it has a relaxing effect.

Researchers believe it increases parasympathetic nervous system activity while decreasing sympathetic nervous system and stress response system activity. It encourages rest. The extract from eucalyptus leaves, or eucalyptol, has been shown to enhance tooth health. High concentrations of ethanol and the polyphenol macro carpal C arefound in eucalyptus leaves. These substances are linked to decreased concentrations of bacteria that can lead to gum disease and cavities. In a study including ninety-seven participants, it was discovered that chewing gum containing eucalyptus leaf extract five times a day for at least five minutes significantly reduced gum bleeding, gum inflammation, and plaque accumulation while having no effect on the control group. Eucalyptol is frequently added to mouthwash because of this. It has been discovered that chewing gum infused with eucalyptus leaf extract considerably reduces gum disease symptoms and plaque accumulation on teeth. Numerous mouthwash varieties and other oralhealth treatments contain it. Have inquiriesabout medicine? Speak with a knowledgeable, board-certified physician over the phone or online. Paediatricians and other experts are oncall around-the-clock. Eucalyptus oil naturally repels insects due to the presence of eucalyptol.

According to studies, applying this medication topically can successfully keep mosquitoes and other biting insects away for up to eight hours. The higher the eucalyptus oil's eucalyptol content, the longer and more effectively it repels. Actually, the lemon eucalyptus tree is used to make lemon eucalyptus oil, which is recognised by the Centres for Disease Control and Prevention as a potent and authorised insect repellent. Eucalyptus oilcan also be used to treat head lice. This oil was twice as successful in treating head lice as a well-known treatment in a randomised research. A recent assessment, however, indicates that further study is required. Online,eucalyptus leaves are available for use in numerous applications, such as: Put eucalyptus leaf-ground tea bags to use. aromatherapy. Add a few drops to a diffuser or steam bowl. eucalyptus essential oil. You can hang the leaves in your shower or add them to your bath for a relaxing spa-like experience. Purchase or make an insect repellent by mixing essential oil of lemon eucalyptus into it. Apply a few drops of eucalyptus oil to your chest along with a carrier oil, such as fractionated coconut oil, to ease congestion.

Eucalyptus is also an ingredient in a lot of over-the-counter items, like chewing gum, vapour rub, and mouthwash. You can use eucalyptus leaves whole, crushed, or as an oil.Eucalyptus leaf tea can be consumed, and the oil can be applied topically, as an ointment, oras a natural insect repellentBe careful not to consume the essential oil, though. While eucalyptus leaves are generally thought to be healthy, there are some serious health risks associated with consuming eucalyptus oil because of the potential for toxicity. It's also critical to remember that kids are more vulnerable to toxins. There havebeen reports of seizures, respiratory difficulties, a decreased state of consciousness,and even death. Furthermore, insufficient dataexists to establish the safety of eucalyptus oil for expectant or nursing mothers.

Because of this, these populations should avoid it. Some people develop contact dermatitis after applying eucalyptus oil to their skin. Use a carrier oil, like fractionated coconut oil or jojoba oil, to reduce the likelihood of skin irritation.

Make sure you don't have a reaction by conducting a patch test before using the oil. Lastly, there's a chance that eucalyptus oil will interfere with certain drugs, like those for diabetes, high cholesterol, acid reflux, and mental health issues. Before utilising it, make sure to speak with your healthcare physician.

Side effects and toxicity

After inadvertently consuming eucalyptus oil, a 3-year-old boy experienced significant central nervous system depression within 30 minutes. Inspection revealed that the youngster was in a deep state of unconsciousness and that his breath smelled of eucalyptus. His muscles were far less toned, his pupils were contracted, and he had no tendon reflexes. He was taking short, erratic breaths at a rate of ten per minute. The heart rate was 70 beats per minute, and the blood pressure was 75/40 mmHg. Nevertheless, following gastric lavage, he quickly recovered. His blood pressure, respiration rate, and pulse all progressively returned to normal two hoursafter being admitted. Consciousness was progressively restored after five hours, and at the end of the day, physical examination results were normal save for a slight eucalyptus breath odor [52]. 251 children had consumed an essential oil or product, and 50 children had consumed eucalyptus oil, according to callers to the Poison Information Center. The most common symptoms were cough, vomiting, and cough with vomiting. Two toddlers with seizures were rehabilitated [53].

A retrospective examination was conducted on infants and children who were admitted to Melbourne's Royal Children's Hospital between January 1, 1981, and December 31, 1992, and who had eucalyptus oil toxicity. Of the 109 children admitted, 59% exhibited clinical symptoms. Their ages ranged from 0.5 to 10.7 months (mean age: 23.5 months). Thirty-one (28%) had depression of consciousness; three fell unconscious after consuming known or estimated quantities between 5 and 10 ml, one developed hypoventilation after consuming an estimated 75 ml, and 27 experienced somnolence.

Of these, 37% experienced vomiting, 15% ataxia, and 11% pulmonary illness. Ten people had no symptoms after ingesting known amounts of eucalyptus oil (mean of 1.7 mL), eleven had minor poisoning (mean of 2.0 mL), and five had moderate poisoning (mean of 2.5 mL) and 1 experienced significant poisoning at a mean of 7.5 mL. For 12%, there was no treatment. 21% of patients received ipecac or oral activated charcoal, 57% received nasogastric charcoal, and 6% of patients had gastric lavageunder anesthesia and 4% had it without. Everypatient made a full recovery [54].

Eucalyptus's effects on the environment

Effects on the Soil

The aqueous extract of eucalyptus leaves affects the pH of soil. Because of its coarse texture and diminished allelochemical action, research has shown that sand shows the least amount of pH changes against the aqueous extract of eucalyptus leaves when compared to other soils where the pH was lowered from 5.6 to 5 [55]. Eucalyptus is known as the "Ecological Terrorist" because it reduces moisture and underground nutrient reserves, making it neither a suitable food source nor a suitable habitat for wildlife [56–57].

The idea that eucalyptus plantations could affect the local climate is one of the critiques leveled at them. This is due to their exceptionally high rate of evapo-transpiration, which may result in a decline in the water table. It is asserted that the

Not all eucalyptus plantations have a negative impact on the nutrients in the soil. The primary determinants are the species, site features, and management techniques [59–60]. Low levels of organic matter (O.M.), soil electrical conductivity (EC), phosphorus (P), potassium (K), and micronutrients (Zn, Cu, Fe, and Mn) were found in the different soil samples taken under eucalyptus trees by the Soil and Environmental Sciences Laboratory at N-W.F.P. Agricultural University Peshawar [61].

Effects on flora and fauna

Phytotoxic chemicals generated by certain plants function as a natural herbicide by stopping the growth of other plants. The eucalyptus's ability to suppress the germination of neighboring plants varies depending on the physio-chemical characteristics of the soil and its phosphorus content. According to research, gigantic foxtail extract has an allelopathic action that can inhibit neighboring plant growth by up to 35%. Its phytotoxins can change into one or more harmless substances in the soil, whereuponthey decrease the viability of neighboring plants' seeds. [62]. The Pakistan Forest Institute (PFI) in Peshawar found that whereas eucalyptus trees totally prevent the growth of wheat and sugar cane in irrigated fields, they have a detrimental effect on wheat and maize harvests in rain-fed areas [63]. The presence of phenolic acid, caffeine acid, flavonoids, chlorogenic acid, gallic acid, sesquiterpenes, P-coumaric acid, aldehydes, and ketones in eucalyptus leaves has been found in the chromatographic investigation to have highly harmful effects on the growth of neighboring plants [64].

According to the chromatographic analysis, eucalyptus leaves include phenolic acid, caffeine acid, flavonoids, chlorogenic acid, gallic acid, sesquiterpenes, P-coumaric acid, aldehydes, and ketones. The growth of nearby plants is severely harmed by these substances [64].

Numerous research have been conducted on eucalyptus foliage, or the leaves of the plant. The eucalyptus foliage contains water-solublepoisons called phenolic and terpenoid chemicals, which are released by the effects onthe other plants of dew, rain, fog, or other climatic conditions [65]. Cineole, alpha-pinene, and camphene are three volatile chemical inhibitors produced by E. globules that are released into the soil by underutilized plant sections and have an impact on other plant growth. These chemicals are soluble in water.

Inhibitors include caffeineic acids, isocholorogenic, P-coumaric, Chlorogenic, and ferulic [66]. Because eucalyptus contains volatile substances including phenolic acid,benzoic acid, and cinnamon, grass growing close to it is likewise impacted [67].

Some eucalyptus species' allelochemicals have been shown to interact with the soil's composition to create an aqueous extract that lowers the height of nearby plant species as well as their fresh root weight and fresh shoot weight (root/shoot ratio) [68].

Additionally, the possibility that varying soil physicochemical characteristics influence how distinct soil reacts to eucalyptus extract is being studied. Plants treated with eucalyptus extract produce more dry matter through vegetative processes than plants treated with water [69–70].

Effects on ground water

In many parts of the world, ground water is essential to the growth of irrigated agriculture. Pakistan is the third-biggest groundwater user globally for agricultural purposes. Farmers are better able to feed a growing population thanksto groundwater availability [71].

In addition to lowering subsurface water, eucalyptus has negative effects on nearby plants, per a study conducted by the International Union of Conservation of Nature (IUCN) Pakistan [72]. According to the China Eucalyptus Research Centre (2009), 510 L of water are needed to synthesis 1 kg of dry matter from eucalyptus, 1000 L for pine, and over 800 L for coffee, cotton, bananas, and Dalbergia, respectively [73]. Although eucalyptus is an excellent candidate species in theory for plantation forests, its forestation effect in China appears to be worse in areas where it significantly lowers ground water levels [74]. The influenceof exotic eucalyptus on surface and groundwater is drying up Pakistan. Accordingto a study, there are 64% springs in the Malakand district's hamlet of Kot and 75% in the village of Total. The water table in both villages is dropping by 0.762 meters year [75].Due to excessive eucalyptus planting and its accelerated rate of evaporation, 6.3 million hectares of Pakistani soil are now damp and devoid of vegetation. According to a study, eucalyptus outperformed all other natural plants in Pakistan in terms of evapotranspiration rate. Additionally, it demonstrates that 12% of Pakistan's ground water has been absorbed by eucalyptus [76]. According to the Parks and Horticulture Authority (PHA), areas with eucalyptus have less subsurface water. plants. They concurred that the impact of the extract is less noticeable in soil that gets water and more noticeable in soil with fine textures [77].

At a seminar on the "Pros and Cons of eucalyptus Plantation in Pakistan" to raise awareness of eucalyptus tree planting, a senior Punjab Forest department official admitted that "the blunder that was made during its plantation in past years was that eucalyptus saplings were also planted in fertile and water-scarce areas" [78].

Effects on air quality

Eucalyptus has been accused of contributing to environmental degradation in Pakistan by the Punjab Forest Department and the Environmental Protection Department. Numerous studies are focused on processing textile industry waste that contains heavy metals and dangerous compounds that pollute the environment, as well as on obtaining natural dyes from eucalyptus and using them to dye different fabrics, including cotton [79–81].

Conclusion

Lastly, the study thoroughly investigated the different impacts of eucalyptus plantations on the ecological and agricultural landscapes. The results highlight the dual characteristics of Eucalyptus species, which present both major environmental challenges and huge economic rewards through the production of essentialoils and lumber. According to research, eucalyptus has allelopathic effects that hinder the growth of native plant species and decrease biodiversity, endangering the ecological equilibrium. Furthermore, eucalyptus's water- intensive nature exacerbates problems with water scarcity, especially in dry and semi-aridareas, which can have a negative impact on nearby agriculture and water supplies.

The study also emphasizes how difficult it is to manage Eucalyptus plantings sustainably. The financial benefits are obvious, but there are environmental consequences that need to be carefully considered and managed. To lessen the negative effects, this entails choosing suitable locations for plantations, putting water management techniques into place, and looking into intercropping with different species. Furthermore, to strike a balance between the

financial gains and environmentalsustainability, continued research and adaptive management techniques are essential.

In the end, this study offers a thorough analysisof the advantages and disadvantages of eucalyptus plantations, making it an invaluable tool for stakeholders in agriculture, environmental advocacy, and policymaking. Subsequent investigations ought to concentrate on formulating inventive approaches to mitigate the ecological consequences while optimizing the financial prospects of Eucalyptus plantings. Sustainable methods must be incorporated into eucalyptus farming in order to coexist with biodiversity preservation and the sustainable use of natural resources.

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