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Ethnobotanical Comparison of *Ocimum sanctum* L. and *Croton bonplandianus* Baill.: Insights into their Traditional and Medicinal Uses

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Abstract
Ocimum sanctum L. also referred to as Tulsi, and *Croton bonplandianus* Baill., commonly referred to as Ban Tulsi or Jungle Tulsi, are two powerful medicinal herbs deeply rooted in traditional medicine, especially within the Indian subcontinent. This comprehensive review delves into the ethnobotanical properties and pharmacological activities of these remarkable plants. Tulsi, often hailed as the "Queen of Herbs," has long been revered for its versatile therapeutic characteristics. It is traditionally utilized to address a wide array of health issues, including chronic fever, dysentery, haemorrhage, vomiting, eye disorders, respiratory infections, diabetes, and gastric and hepatic disorders. Furthermore, Tulsi exhibits antifertility, anti-inflammatory, radiation protection, antibacterial, antioxidant, anticancer, as well as antifungal characteristics, making it a truly multifaceted medicinal herb. On the other hand, Jungle Tulsi is sought after for its efficacy in treating skin diseases, hypertension, wounds, diabetes, cancer, constipation, abdominal dropsy, and various infectious disorders. Like Tulsi, Jungle Tulsi also showcases a broad variety of pharmacological activities, that includes antifungal, hepatoprotective, wound healing, antimicrobial, antioxidant, and anti-inflammatory properties. Given pressing challenge of multidrug-resistant microbial strains, the exploration of novel plant-based antimicrobial agents is more crucial than ever. Tulsi and Jungle Tulsi emerge as promising sources due to their broad-spectrum pharmacological activities. However, further research, including clinical trials and mechanistic studies, is essential to fully unravel the therapeutic potential of these herbs and to develop standardized, safe, and effective herbal formulations.
Keywords: Ethnobotany, Pharmacology, Euphorbiaceae, Lamiaceae, Traditional Medicine.

1. Introduction
Throughout history, plants have been a primary source of human medicine as well as sustenance. Approximately 4 billion individuals, or 80% of the population of the world, already utilize herbal remedies as a component of their daily medical regimen[1]. Various cultures use locally grown plants to cure common ailments, and these herbal medicines have proven to be remarkably effective over centuries[2]. Certain natural remedies have been shown to work better than traditional allopathic medications. Herbal medicine is the practice of treating human and, occasionally, animal illnesses by using medicinal herbs in different forms, such as extracts, decoctions, or powders. Many people are turning to traditional treatment practices that use the therapeutic properties of herbal medicines for relief due to the drawbacks and adverse effects of some allopathic medications[3].
Holy basil, also referred to as Tulsi in Hindi and Sanskrit, has been a prominent member of the family Lamiaceae and is identified scientifically as *Ocimum sanctum* L. The therapeutic qualities of tulsi have been utilized in Ayurvedic medicine for over 3,000 years to treat a range of illnesses.

Tulsi leaf extracts have been used to cure fever, bronchitis, and other ailments, according to Indian medical books. This extensively grown plant is regarded as a vital household plant in India and has been very prestigious in Hinduism. Hindu mythology goes into great lengths to examine the importance, uses, and traits of tulsi[4]. Tulsi is an aromatic shrub that grows to a height of 3 to 5 feet and is often grown in gardens. Its strong flavor and aroma make it extremely valuable to humans. Traditional Ayurvedic medicine often uses Tulsi leaves to cure a range of illnesses, for example, intestinal disorders, common colds, heart problems, headaches, stomach problems, kidney stones, and more. It is especially effective at treating fevers and has been shown to prevent mosquito reproduction and treat intestinal diseases. The adaptable Tulsi plant has many uses, and its leaves are regularly used for their health-restoring qualities and as a sensory stimulant, greatly improving memory acuity[5]. Tulsi is also known to help with respiratory conditions. An excellent remedy for influenza, asthma, as well as bronchitis is a concoction of Tulsi leaves, ginger, and honey. Owing to its many medicinal benefits, tulsi is regarded as a crucial element for improving well-being. Extensive research and empirical investigations have demonstrated the safety of consuming tulsi in a variety of forms, indicating that this small herb is a considerable source of medical benefits. These therapeutic qualities are acknowledged and supported by recent scientific research. The herb tulsi provides protection against a number of health hazards, particularly those brought on by contemporary lifestyle choices. It is considered the best herb in India and is essential to many Ayurvedic treatments due to its both curative and preventative qualities[3].

The most common species in the *Croton* genus, *Croton bonplandianus* (Euphorbiaceae), goes by a few names. Northern Argentina, Paraguay, and Southern Bolivia are the native habitats of *C. bonplandianus*. It has been frequently referred to as Ban Tulsi (jungle tulsi) because of the way its leaves along with flower cymes resemble those of Tulasi (*Ocimum sanctum*). The plant can be found growing in yards, wastelands, riverbanks, and along roadsides. As a tiny annual herb, *C. bonplandianus* can grow up to 24 inches wide as well as 28 inches tall. The lanceolate leaves, which are 3-5 cm long and alternately arranged, have serrated edges[6]. Because of inadequate light exposure, *C. bonplandianus 's* leaves are coriaceous, smaller, and less pigmented; in contrast, they display more vivid coloration in bright light. The greenish fruits have verrucose surfaces and are oblong capsules, 5 mm in length. The tiny, peach-colored flowers have 12 racemes and tiny, globose flower buds that are placed in upright spikes. They also have five petals, five sepals, and a large number of long stamens that protrude. From September through November, *C. bonplandianus* is in blossom[7]. Traditional medicine has made considerable use of the plant *Croton bonplandianus* L. to treat a diversity of illnesses, encompassing jaundice, infectious diseases, abdominal dropsy, acute constipation, hypercholesterolemia, external wounds, hypertension, and dysentery. Several in vitro & in vivo research have confirmed, *C. bonplandianus* is a crucial source of traditional medicine for treating a variety of illnesses[8].

The current investigation intends to elucidate ethnobotany as well as pharmacology of *O. sanctum* and *C. bonplandianus* to identify research gaps and delineate areas requiring further investigation.

2. Methodology

The pharmacological, phytochemical, and ethnomedicinal applications of *O. sanctum* and *C. bonplandianus* were reviewed. The pertinent information was gathered from online resources such as Google Scholar, Web Science, PubMed, Research4Life, Springer, and Science Direct using keywords like *O. sanctum*, *C. bonplandianus* and its synonyms, ethnomedicinal usage, phytochemicals, and pharmacological properties. The title, abstract, and entire study were reviewed to filter the information that was gathered. An agreement between the authors allowed the information to be included. This review does not include personal communications, unpublished results, or extraneous information. This review contains 55 references, with most of the research publications coming from India.

3. Historical perspective

Ocimum species, such as basils, are commonly referred to be "king of the herbs." The common term "basil" probably originates from Greek words "basileus" and "basilikon," which both mean "king" and "royal." The Rig Veda, a classic Indian text, was the first to reference *O. sanctum*, which was initially used around 1500 BC. In accordance with Ayurvedic tradition, *Ocimum sanctum* has been tonic for many features of life and may assist with a lot of modern health problems. Likewise, *O. sanctum* also referred to as

"Thulasi" or else "Thulasi Ilai," has been greatly valued for its therapeutic properties in the Siddha school of medicine[9]. As an adaptogen, it supports the body's response to stress and has antibacterial, antioxidant, and immunomodulatory properties. The plant, known as "kaphrao" or "bai kraprow," has been utilized as an offering in Buddhist ceremonies and has spiritual, cultural, and historic importance in Thai culture. Additionally, it is offered at temples or incorporated into rituals performed at home. Then, in the Unani medical system, it is called "Tukhm Rehan," and it is known to have antibacterial qualities, ease respiratory discomforts, and support digestive health[10]. Additionally, traditional Chinese medicine uses it to treat digestive system issues like diarrhea and stomach aches as well as infections. *O. sanctum* has been utilized in conventional African medicine for treating whooping cough as well as various fevers. Its leaf decoction has been also utilized to treat coughs in West Africa[11]. For perhaps 5,000 years, tulsi has been considered one of India's most fabled therapeutic herbs. Millions of people use and revere Tulsi's generous healing nature every day for everything from acute critical imbalances to general well-being. In Sanskrit, tulsi signifies "one that is incomparable"-one that does not accept or allow for similarity. The English pronunciation is "tool-see." The Charak Samhita, the earliest ancient Sanskrit Ayurvedic text, which was composed in 400 CE as well as maybe as early as 6000 BC, refers to the lengthy history of Tulsi's medicinal applications. The Rigveda, commonly known as the Book of Eternal Knowledge, which is thought to have been written around 5000 BC, also refers to Tulsi. The entire value of *O. sanctum* is demonstrated by its journey through various texts and medicinal techniques. Consequently, the fact that it has been used in many cultures and medical systems shows its worldwide appeal[12].

In the 18th century, Carl Linnaeus was the first to describe the genus *Croton*. Numerous *Croton* species, including *C. bonplandianus*, have been classified and better understood over time thanks to the efforts of botanists like George Don and others. With reference to its natural habitats in areas like Central and South America, the plant has been positioned within the larger framework of tropical flora. *Croton* species have long been used medicinally by indigenous peoples to cure a variety of conditions, such as digestive and skin disorders. Like other *Croton* species, *C. bonplandianus* might have had traditional medical applications. Interest in the *Croton* genus increased over the 19th and 20th centuries as botanical exploration increased. The species' distinctive qualities were investigated by botanists and horticulturists, who helped to popularise its cultivation in attractive gardening. Because of its colourful leaves and capacity to flourish in tropical and subtropical climes, *C. bonplandianus* became a popular ornamental plant in the late 20th century. Gardeners valued its versatility and little maintenance. The taxonomic classification, traditional use, and horticultural role of *C. bonplandianus* are all part of its historical development. Its development reflects more general plant science concerns, such as ecology, conservation, and the value of traditional knowledge[13].

4. Distribution of *O. sanctum* and *C. bonplandianus*

All six inhabited continents have tropical and warm temperate regions where *O. sanctum* is endemic, with Africa hosting the largest number of species. It is also widely distributed in West Africa, Malaysia, Australia, and a few Arab nations. It has recently been proposed that this species originated in North-Central India based on extensive phytogeographical research using chloroplast genome sequences. This therapeutic herb is grown all over India, from the Andaman and Nicobar Islands to the Himalayas, which are near about 1800 meters above sea level. Both as an escaped weed and as a cultivated plant, it is widely distributed. It has been cultivated for its essential oil along with for religious and therapeutic purposes[14].

The native range of *C. bonplandianus* extends from Uruguay to South Bolivia. It grows mostly in the seasonally dry tropical biome and is classified as a shrub or subshrub. It is indigenous to Brazil South, Bolivia, Paraguay, Uruguay, Brazil West-Central, and Argentina Northeast and Northwest. India, Borneo, Bangladesh, Comoros, Gulf States, Cambodia, Laos, East Himalaya, Maryland, Kenya, Malaya, Myanmar, Nepal, Pakistan, Mauritius, Reunion, Nicobar Island, Sri Lanka, Taiwan, Thailand, Rodrigues, Sulawesi, and West Himalayas are among the countries where it has been introduced[15]. It typically grows as a weed along riverbanks, roadsides, and wastelands. It draws a lot of insects and pollinators and has a highly healthy population. It provides ecological functions and is a significant host plant for jewel bugs[16].


A


B

Figure 1. Pictures showing A. *Croton bonplandianum* B. *Ocimum sanctum* growing in wild

5. Phytochemistry

Tulsi's chemical composition has been quite complicated as well as containing a variety of nutrients along with additional physiologically active compounds, levels of which can vary greatly among strains as well as even among plants in similar regions. Moreover, the amount of several of these components has been greatly impacted through various harvesting, processing, growing, as well as storage circumstances, many of which have been currently unknown. As utilized historically, the herb's pharmacological and nutritional properties are derived from the synergistic interactions among numerous active phytochemicals. Consequently, individual components or else extracts cannot completely replicate Tulsi's effects. Tulsi's intrinsic botanical and biochemical complexity has prevented modern science from standardizing it up to this point[3].

The genus *Croton* has a wide variety of biomolecules. The genus' secondary metabolites are primarily composed of diterpenoids, which may include the skeletal categories such as cembranoid, clerodane, neo clerodane, Hali mane, kaurane, secokaurane, labdane, phorbol, and trachylobane. It has been found that several *Croton* species contain pentacyclic or steroidal terpenoids. Volatile oils comprising mono- and sesquiterpenes, as well as compounds derived from shikimate, are prevalent in the species. The genus' importance from a medical perspective is greatly increased by reports that some species are suppliers of many alkaloids. Numerous studies have focused on phenolic chemicals, primarily flavonoids, lignoids, and proanthocyanidins. Because they contain proanthocyanidins and/or alkaloids, certain *Croton* species exhibit crimson sap[17].

Table 1: Selected compounds identified from various parts of *O. sanctum* (OS)[3] and *C. bioplandianum* (CB)[17] and their classes.

Class	Compund names in OS	Distribution in OS Plant	Functions	Compound names in CB	Distribution in CB plant	Functions
Terpenoids	Urosolic acid	Leaves	Antioxidant	Clerodanes	Leaves	Anti-inflammatory
	Carvacrol	Leaves	Neuroprotective	Cembranoids	Leaves	Anticancer
	Linalool	Leaves	Antimicrobial	Urosolic acid	Root	Antioxidant
	Limatrol	Leaves	Anti-inflammatory	Kauranes	Leaves	Antiparasitic
	Methyl carvicol	Leaves	Antimicrobial	Taraxerol	Stem and Leaves	Cardioprotective
	Bornyl acetate	Stem	Hypotensive effect	Phorbol esters	Leaves	Antiallergic
	β-elemene	Stem	Anticancer effect	Trachylobanes	Leaves	Antitumor
	Neral	Leaves	Antineoplastic	Sarcopetalanes	Stem	Muscle contraction
				Sonderianin	Leaves	Anxiolytic
				Oleonolic acid	Root	Antiasthma tic
				Vomifoliol	Stem and Leaves	Immunosuppressive
Phenols	Rosmarinic acid	Stem	Antioxidant			
	Cirsimaritin	Stem	Antiproliferative			
Flavanoids	Orientin	Leaves	Heart protection	Catechin	Leaves	Antioxidant
	Vicenin	Leaves	Antitumor	Gallocatechin	Leaves	Antiviral

	Luteolin	Leaves	Renoprotection	Rutin	Leaves	Anticancer
	Apigenin	Leaves	Antiamyloidogenic			
	Apigenin-7-o-glucuronide	Leaves	Anticomplement			
	Luteolin-7-o-glucuronide	Leaves	Antidepressant			
	Molludistin	Leaves	Antibacterial			
	Isothymonin	Stem	Antifungal			
	Isothymusin	Stem	Antioxidant			
	Cirsilineol	Stem	Antithrombotic			
Alkaloids				Crotsparinine	Leaves	Antioxidant
				Crotsparine	Leaves	Antimicrobial
				Crotoflorine	Leaves	Antimalarial
				Sparsiflorine	Leaves	Antibacterial
				Proporphine	Leaves	Antioxidant
				Isoquinoline ionone	Leaves	Antifungal
				Glaziovine	Stem and Leaves	Antiulcer
Essential oil	Eugenol		Analgesic			
	Euginal		Food preservative			
	Caryophyllene		Gastroprotective			
	1,8-cineole	Leaves	Antimicrobial			
	1,8-bisabolene		Antibacterial			
	Methyl eugenol		Anaesthetic			
	β-caryophyllene oxide		Analgesic			
Sterol	Stigmasterol	Stem	Antidiabetic	Stigmasterol	Stem	Antitumor
	β-sitosterol	Leaves	Antiinflammatory	Campesterol	Stem	Antiinflammation
				Sitosterol	Whole Plant	Lower cholesterol
				Sitosterol-D-glucoside	Leaves	Antifungal
Other compounds				16-Hexadecanoyl hydrazide	Leaves	Antidepressant
				Phytol	Leaves	Antimicrobial
				bis (7-methyl octyl) ester	Stem	Food packaging
				2-benzenedicarboxylic acid	Stem	Used to make Saccharin
				12-orthotrideconeoly-phorbol-13-acetate	Seeds	Antineoplastic

6. Ethnobotanical uses of *O. sanctum* and *C. bonplandianum*

O. sanctum contains a variety of bioactive substances and may have therapeutic uses. Ethnobotanical research that documents Indigenous knowledge is crucial for both the sustainable utilization of biological resources along their conservation. Tulasi is worshipped as a goddess in Hinduism, and all parts of the plant leaves, stem, flower, root, seeds, and oil—are regarded as sacred. It is even believed that the nearby soil, which has just been demonstrated to contain helpful endophytic fungi, is a part of the divine. Because of this, a Hindi home would not be complete without a tulsi plant, usually kept in a decorative earthen pot in the courtyard. Tulsi is utilized for both utilitarian as well as ceremonial purposes[3]. For instance, the unique clove-like scent of tulsi, which comes from its high eugenol content, helps to repel flies, mosquitoes, and other dangerous insects while also connecting the householder to the holy. Rituals in the morning and evening, along with additional spiritual as well as cleansing activities that may include drinking tulsi tea or swallowing leaves, enhance the utilization of Tulsi in everyday life.

In Hinduism as well as certain Greek Orthodox churches, tulsi is employed ceremonially to produce

"holy water," which also sanctifies dwelling. Tulsi's historic Ayurvedic usage, according to plant cultures, may be due to the inherent qualities of the plant's essential oils, which include eugenol and other acids with anti-inflammatory and antioxidant qualities[4]. It had been discovered that the plant originated in South America and Asia. *C. bonplandianus* has been employed for the treatment of skin conditions for example ringworm infection, respiratory problems, and bodily inflammation due to its antibacterial properties[23]. Bark as well as roots of *C. bonplandianus*'s chemical composition is cholagogue and purgative. Stems and leaves of Ban Tulsi are used to cure genital sores, diarrhea, and to stop bleeding from cuts and other bodily ailments. The seeds of this plant are used to cure internal abscesses, liver problems, severe constipation, and abdominal dropsy[24].

Its juice is used to treat headaches. In Malden's rural areas, *C. bonplandianus* has been commonly grown as well as utilized as fuel and detergent. Fuel can be made from its stems and branches. After that, ash is gathered and stored for 5 or 6 days in a container. The remaining residue has been utilized as a detergent to clean cotton clothes after dissolving in warm water. Ethnic tribes in rural West Bengal, India, use *C. bonplandianus*'s roots along with leaves to alleviate extreme heat and snake venom. According to the literature, the leaf extract is utilized to cure a diversity of conditions, encompassing venereal disease, cancer, ulcers, and more[25]. Numerous human problems can be cured by the entire plant and its various parts; these are listed in tabular form below:

Table 2: Common Ethnobotanical uses *O. sanctum* and *C. bonplandianus*

S. No.	Plant part	Medicinal uses	References
1.	Leaves	To cure: Flu, Headaches, Emetic syndrome, Colic pain, Common colds, Migraine headache, Inflammation, Wound, Earache, Fatigue, Diabetes, Bronchial asthma, Snakebite, Arthritis, Skin diseases, Ulcers, Convulsions, Gastric diseases, Chronic fever, Eye infection, Malaria fever, Immunological disorders, Sore throat, Insomnia, Digestive disorders, Night blindness, Infections of mouth, Diarrhoea, Dysentery, Cold, cough, Insect bite, heart disease As an antianxiety, anticancer, antidepressant, antifertility, antifatigue, antiasthmatic, antithyroid, antihelminthic To stop vomiting and the negative impact of radiation.	[3, 18, 19]
2.	Fruits	For flavoring foods for example poultry and fish, honey, tea and liquor, vegetables, jelly Utilized in various dishes, including salads	[20]
3.	Seeds	As an antiulcer, antihypertensive, larvicidal, anticancer, antiarthritic, and analgesic	[4]
4.	Whole plant	For the treatment of stress, scorpion-sting, inflammation, snake bite, and diabetes Function as antiseptic, antiallergic, cardioprotective, and memory enhancer	[21, 22]

7. Pharmacological activity of *O. sanctum* and *C. bonplandianus*

Flavonoids, polyphenols, & essential oils are among numerous bioactive substances found in these plant parts that contribute to their pharmacological effects.

7.1. Antioxidant activity

Many researchers have reported *O. sanctum* L. antioxidant properties. Flavonoids' antioxidant qualities and their connection to membrane defense have been highlighted. Together with phenolic components that include isothymusin, cirsimaritin, cirsilineol, apigenin, along with rosmarinic acid that shows great antioxidant activity, *O. sanctum* L. extract of fresh leaves along with stems comprised notable levels of eugenol, a crucial part of volatile oil. Flavonoids orientin as well as vicenin showed antioxidant action in vivo by significantly lowering radiation-encouraged lipid peroxidation in mice's liver[26]. In male albino rabbits, *O. sanctum* L. aqueous extract reduces erythrocyte lipid peroxidation activity caused by hypercholesterolaemia in a dose-dependent way. Additionally, oral feeding significantly protects the aorta and leaver tissue from peroxidative damage brought on by hypercholesterolemia. Another investigation found that *O. sanctum* L. aqueous extract substantially boosts the activity of antioxidant enzymes that include superoxide dismutase as well as catalase levels in an extract-treated group in comparison with the control group[27].

Conversely, *C. bonplandianus* ethanolic extracts demonstrated DPPH and hydroxyl radical scavenging capabilities. *C. bonplandianus* leaf hydro-ethanolic extract has shown strong free radical scavenging ability. Its *C. bonplandianus* leaf chloroform fraction demonstrated a nitric oxide scavenging assay, lowering power capacity and free radical scavenging property[48, 49]. Furthermore, the n-hexane and ethyl acetate fractions of *C. bonplandianus* leaves had less antioxidant activity than the chloroform fraction. Excellent free radical scavenging activity has been exhibited by ethanolic leaf extract of *C. bonplandianus* (IC_{50}=170.3µg/mL); nevertheless, total antioxidant content had been determined to be 214±0.20µg/mL. Dried *C. bonplandianus* leaves ethanolic extract demonstrated a scavenging effect against free radicals and nitric oxide[50].

7.2. Antidiabetic activity

Diabetes mellitus is the most prevalent endocrine condition as well as has been referred to as the silent killer. Due to deficiencies in either insulin action or secretion, it is associated with a spectrum of metabolic disorders that are typified by persistent hyperglycemia and anomalies in the metabolism of carbohydrates, lipids, proteins, as well as acids. It is a medical condition in which glucose, or blood sugar, increases[46]. *O. sanctum* L.'s ethanolic extract substantially lowers glycosylated hemoglobin, blood glucose, as well as urea in streptozotocin-induced diabetic rats while concurrently raising glycogen, hemoglobin, and protein[28]. Insulin and peptide levels along with glucose tolerance increased because of these extracts. In another research, Vats[29] investigated impact of *O. sanctum* L. on 3 key enzymes that participate in the metabolism of carbohydrates: PFK (phosphofructokinase), hk (hexokinase), gk (glucokinase), as well as glycogen amount in insulin-dependent (skeletal muscle along with liver), insulin-independent (kidneys along with brain) tissues in rats given a 30-day dose of streptozotocin (STZ, 65mg/kg) to induce diabetes. When 200 mg/kg of *O. sanctum* L. extracts are administered for 30 days, approximately 9.06 & 24.4 percent declines in plasma glucose levels occur on days 15 as well as 30, correspondingly. *O. sanctum* substantially declines renal weight but not liver weight when measured as a body weight percentage. PFK, gk, as well as hk activity distributed in control of diabetic, had been largely restored by *O. sanctum* L. It had been discovered that giving an *O. sanctum* L. leaves alcoholic extract orally notably reduced blood sugar levels[3]. The antidiabetic properties of *C. bonplandianus* are not typically documented in its plant extracts.

7.3. Nootropic activity

Nootropic drugs improve memory, focus, and processing speed, among other aspects of cognitive function. Numerous substances found in *O. sanctum*, including carvacrol, rosmarinic acid, and eugenol, have been demonstrated to possess nootropic properties. *O. sanctum* has the potential to enhance cognitive abilities. By lessening chronic stress's detrimental impact on the brain, its adaptogenic properties, which promote the adaptation of stress as well as the reduction of anxiety, may subsequently assist in improved cognitive function[30]. In mice, Joshi and Parle[21] evaluated the extract from *O. sanctum's* potential as a nootropic as well as anti-amnesic. The mice were given an aqueous extract of the entire plant of *O. sanctum* L., which prevented the amnesic effects of scopolamine (0.04mg/kg), and diazepam (1mg/kg), along with age-induced memory degradation. Exteroceptive behavioural models were the passive avoidance paradigm and the elevated plus maze. In mice, *O. sanctum* L. extract substantially lowered transfer latency as well as enhanced step-down latency in comparison to the scopolamine, control (piracetam-treated), and elderly groups. Therefore, *O. sanctum* L. preparation might be valuable in the treatment of cognitive diseases like Alzheimer's and dementia. A 400mg/kg intraperitoneal (ip) *O. sanctum* root extract's methanolic extract lengthens the mouse's swimming time in a despair swim test paradigm, indicating *O. sanctum* L. possess anti-stress and/or central nervous system stimulant properties[31]. The plant extracts of *C. bonplandianus* have not been commonly reported to possess nootropic activities in current literature.

7.4. Gastroprotective activity

Standardized methanolic extract of *O. sanctum* leaves (OSE) exhibited a dose-dependent ulcer preventative effectiveness against stomach ulcers produced by cold-restraint stress when taken orally 2 times daily for 5 days at dosages ranging from 50-200 mg/kg. According to Goel[32], the optimal effective dose of OSE (100 mg/kg) demonstrated considerable ulcer protection against gastric ulcers caused by ethanol as well as pyloric ligation, but it had been inefficient against ulcers caused by aspirin. Additionally, OSE (100 mg/kg) enhances the longevity of mucosal cells, cellular mucus, and mucin secretion, while suppressing the production of lipid peroxidation and the unpleasant acid pepsin. Rats with pyloric ligation

and aspirin treatment were used to test *O. sanctum*'s antiulcerogenic properties. Seven days prior to therapy, the extract boosted mucus secretion and decreased ulcer index, free, and total acidity when administered acutely and chronically. Because *O. sanctum* extract can increase mucus secretion and decrease acid secretion, it can be said to have anti-ulcerogenic properties against experimental ulcers[33]. Gastroprotective properties are not frequently present in the different parts of the *C. bonplandianus*.

7.5. Antimicrobial activity

The greater quantity of linoleic acid in *O. sanctum* fixed oil may have contributed to its antibacterial qualities, mentioning Singh et al.'s investigation. The oil exhibits strong antibacterial activity against *Pseudomonas aeruginosa*, *Bacillus pumius*, *Staphylococcus aureus*, with *S. aureus* being the most susceptible. Likewise, it was discovered that *O. sanctum* was effective against strains of *Neisseria gonorrhoea* that were resistant. In contrast to the alcoholic extract, Geeta et al. discovered that the aqueous extract of *O. sanctum* (60 mg/kg) displays extensive zones of inhibition against *Proteus* spp., *Escherichia. coli*, *Candida albicans*, *Klebsiella* spp., as well as *Staphylococcus. aureus* when evaluated utilizing agar diffusion approach. Alcoholic extract exhibited a greater *Vibrio cholerae* zone[34].

To investigate the antibacterial properties of *C. bonplandianus* leaves, fruits, latex extracts, and fresh latex, 500mg of every extract was combined with 5ml of sterile 10 percent DMSO (dimethyl sulfoxide) to make 10% w/v test solutions of the plant's leaves, fruits, and latex. To assess fresh latex, extracts from the same source were used to determine that 25, 50, 75, and 100 had 2.5, 7.5, and 10 mg of antibacterial activity, respectively. At various concentrations (2.5, 5, 7.5, & 10mg), *C. bonplandianus* whole plant and latex extracts were added to each well of Mueller Hinton Agar (MHA) plates that had already been infected with the relevant bacterial cultures. At 37 ºC plates had been incubated for a whole day. Streptomycin (10 µ g) served as the positive control group in this investigation, while 10% DMSO served as the solvent. A zone reader was used to measure the diameter of the inhibition zone (in millimeters) surrounding the well following incubation[42]. The best results were achieved at 7.5mg/75 µl when the antibacterial activity of several solvent-extracted extracts of *C. bonplandianus* leaf were examined against bacterial isolates. When contrasted with other bacterial isolates, aqueous leaf extract demonstrated a minimum zone of inhibition of 10±1mm against *P. aeruginosa* as well as the maximum zone of inhibition of 15±2 mm against *S. aureus*[43]. Several bacterial isolates were treated with ethanolic leaf extract; the results showed that *E. acrogens* and *E. coli* had the highest zone of inhibition, that is 22±2 mm, while *E. faecalis* had the lowest zone of inhibition, that is 16±2 mm. The leaf acetone extract's smallest zone of inhibition was 10±1 mm, while its largest zone of inhibition against *E. acrogens* and *E. coli* was 19±2mm. The leaf extract in chloroform showed inhibition of 19±2 mm against *E. coli* and *S. aureus*, but the leaf extract in benzene showed inhibition of 20±2 mm against *S. aureus*[44]. As per the National Committee for Clinical Laboratory Standards (1997), agar disc diffusion technique was utilized to examine the invitro antibacterial activity of aqueous extracts (say) of *C. bonplandianus* against 3 strains of Gram-positive along with 4 strains of Gram-negative bacteria. Potent antibacterial action against a variety of harmful bacteria has been demonstrated by several antibiotics made from plant extract. *C. bonplandianus* possesses antimicrobial and genotoxic properties. In the anaphase and telophase stages, the root tip cells *Allium* exhibited a 24.17% aberration due to the leaf aqueous extract. However, 22.08% and 21.55% aberration were produced by methanolic and acetone extracts, respectively. *C. bonplandianus* leaf & fruit's methanolic extract have been more efficient against microbes for example *Pseudomonous aeruginosa, Bacillus subtilis, E. coli, Klebsiella pneumonia*, along with *S. aureus*. Most efficient against *B. subtilis*, *P. aeruginosa*, *E. coli*, *Proteus vulgaris*, *B. megaterium*, as well as *S. aureus* had been *C. bonplandianus* leaf extracts prepared in chloroform and benzene[25, 45].

7.6. Anti-inflammatory activity

O. sactum's methanolic extract (500 mg/kg) as well as aqueous suspension demonstrated analgesic, antipyretic, & anti-inflammatory activities in rats with acute (carrageenan-induced pedal edema) along with chronic inflammations. The fixed oil and linolenic acid have potent anti-inflammatory activities against PGE2, leukotriene, and arachidonic acid-induced paw edema in rats because they may block cyclooxygenase as well as lipoxygenase pathways of arachidonic acid metabolism[35].

An estimation of the *C. bonplandianum* leaf ethanolic extract was conducted on human blood vessel membranes. About 83.2% was prevented from hypotonicity-induced human blood vessel membrane lysis by ethanolic extract (200 mg/mL). An assessment was conducted on the anti-inflammatory features of *C. bonplandianum* hydro-alcoholic leaf extract. Rat model of pow edema produced by carrageenan After four hours of treatment, a hydro-alcoholic *C. bonplandianum* leaf extract notably reduced rat paw edema caused by carrageenan[53].

7.7. Anticancer activity

Numerous researchers have demonstrated and cited anticancer properties of *O. sanctum* Alcoholic extract (AlE) from *O. sactum* leaves modulates carcinogen-metabolizing enzymes that include cytochrome b5, cytochrome P 450, aryl hydrocarbon hydroxylase, GST (glutathione S-transferase), that have been essential for the detoxification of carcinogens as well as mutagens. Benzo(a)pyrine-induced neoplasia of mouse forestomach along with 3'-methyl-4-dimethylaminoazobenzene-induced hepatomas in the rats were substantially reduced by OS[36]. It has been demonstrated that the AlE in OS leaves inhibits chemically produced cutaneous papilloma in mice. Fresh Tulsi leaf paste taken orally might be capable of stopping the initial stages of buccal pouch carcinogenesis caused by DMBA. OS leaf extract inhibits the carcinogen's metabolic activity, hence blocking or suppressing the events linked to chemical carcinogenesis. The anticancer properties of *O. sanctum* have been identified in Swiss albino mice with EAC (Ehrlich ascites carcinoma) & S 180 tumors. The incidence and volume of tumors caused by 20-methaylcholathrene were considerably decreased by supplementing with the oil at the maximally tolerable dose of 100 µl/kg body weight. Mice given seed oil treatment showed an improved rate of survival and a delay in the occurrence of tumors. The chemo-preventive effectiveness of 80mg/kg vitamin E had been equivalent to that of 100µl/kg seed oil. Seed oil's antioxidant properties have been partially linked to its possible chemo-preventive effects[37].

The Euphorbiaceae family includes the green shrub *C. bonplandianus*, which is native to Southeast Asia. Croton oil's main active ingredient, 12-O-tetradecanoylphorbol-13-acetate, has been used as a cancer promoter region because it causes irritation and inflammation when applied topically to mice's skin that has previously been exposed to 7,12-dimethylbenz(a)anthracene or other aromatic polycyclic substances (typical dose: 5–16 nmol, twice a week). TPA has been shown to limit growth, induce apoptosis, or stimulate development in human malignant cells isolated from individuals with melanoma, lung, breast, or prostate tumours. This data comes from a thorough tumor investigation. Prostate cancer cells known as LNCaP treated with the right amounts of TPA (1-1.6NM) have shown inhibition of growth. Nevertheless, the same cells that were given TPA at dosages that were significantly higher showed signs of apoptosis. TPA and ATRA together have been shown to restrict the growth of cultured prostate cancer LNCaP cells, whilst TPA or ATRA therapy was found to inhibit the growth of existing LNCaP tumors in immunodeficient animals. All of the treated animals experienced some tumor regression when TPA along with ATRA was given to these mice with tumors, though some of the treated mice experienced tumor regressions[13].

7.8. Anti-fertility

O. sanctum leaf benzene extract has a reversible antifertility action because it reduces sperm motility, forward velocity, and total sperm count when taken at a dose of 250 mg/kg body weight for 48 days. While the percentage of abnormal sperm in the caudal epididymal fluid rose, the fructose content of seminal vesicles as well as the caudal plasma of epididymis declined. All these readings reverted to normal 2 weeks after the medicine had been withdrawn[38]. Currently, there is no documented evidence or research indicating that *C. bonplandianus* exhibits any properties that inhibit fertility.

7.9. Immunomodulatory effect

The rich phytochemical composition of *O. sanctum*, which includes polyphenols, essential oils and flavonoids has been demonstrated to possess immune-enhancing qualities and is linked to its capacity to regulate the immunological response. Albino rats' humoral immune response had been altered through a steam-distilled extract from fresh OS leaves. This might be explained by a number of processes, including the creation of antibodies, the release of hypersensitive reaction mediators and the target organs' tissues' reactions to these mediators[26]. The immunomodulatory effects of *O. sanctum* seed oil, which appear to impact humoral and cell-mediated immune response, might be mediated by GABAergic pathways. The leaves of *O. sanctum* stimulate the humoral immunogenic response, as demonstrated by the cellular immunologic response, demonstrated by lymphocytosis and the formation of E-rosette, and by a rise in antibody titer in sheep erythrocyte agglutination and Widal tests[34]. In the course of the comparison between the two plant species, it was observed that the immunomodulatory effects exhibited by *C. bonplandianus* were significantly less pronounced than those of its counterpart. This finding suggests that *C. bonplandianus* may not be as effective in modulating immune responses, highlighting the need for further investigation into its potential therapeutic applications and mechanisms of action.

7.10. Central Nervous System (CNS) depressant activity

Pentobarbital (40 mg/kg, ip)-induced mice's loss of reflex was prolonged by *O. sanctum's* AlE, which also reduced the duration and intensity of electroshock and convulsions caused by pentylenetetetrazole. In "open field" trials, it also reduced ambulation and fighting time caused by apomorphine. OS extract enhanced swimming time at high doses, indicating CNS stimulant or else antistress effect. The impact had been equivalented to that of desipramine, an antidepressant drug. It has been demonstrated that rats administered OS fixed oil (2–3ml/kg, ip) sleep longer when given pentobarbitone. The increase in pentobarbitone-induced sleep duration may be caused by fixed oil's suppression of pentobarbitone's hepatic metabolism and renal clearance[39]. The findings suggest that *C. bonplandianus* may have a constrained ability to influence reflex actions. This highlights the necessity for more in-depth research to gain a clearer understanding of its possible therapeutic benefits and the underlying mechanisms that drive its effects. Such investigations could be essential in revealing the full scope of its potential applications in medical science.

7.11. Antiarthritic activity

Rats with formaldehyde-induced arthritis were used to test *O. sanctum* fixed oil's antiarthritic properties. The fixed oil substantially declined the diameter of an irritated paw. Rats' arthritic conditions significantly enhanced after receiving the fixed oil intraperitoneally every day for ten days. Aspirin at a dose of 100mg/kg had antiarthritic impact that had been alike to that of 3ml/kg, ip41. Inflammatory as well as carrageenan mediators, for example, histamine, serotonin, PGE2, & bradykinin, were suppressed by the fixed oil. Naturally, any inflammatory reaction involving these mediators may be inhibited by the oil. The outcome indicates that the inflammation models, which include adjuvant and turpentine oil-induced joint edema in rats, may have beneficial antiarthritic properties[40]. At present, there is a notable absence of documented evidence or scientific research that supports the claim that *C. bonplandianus* possesses any properties capable of influencing or controlling anti-arthritic activity.

7.12. Adaptogenic activity/antistress activity

The adaptogenic action of plants might be due to *O. sanctum's* immunostimulant potential. The OS whole plant's AlE enhanced swimming mice's physical endurance (survival time) inhibited stress-induced ulcers in rats, as well as stopped mice's milk-induced leucocytosis. These findings suggest that *O. sanctum* increases animals' non-specific resistance to a range of stress-induced biological changes[41]. Currently, there is a significant lack of documented evidence or scientific studies that substantiate the assertion that *C. bonplandianus* has such properties that can affect or regulate adaptogenic activity. This absence of research leaves a gap in our understanding of the potential benefits of this plant and highlights the need for further investigation into its characteristics and effects.

7.13. Wound healing activity

In everyday life, wounds are typical clinical entities that may vary in size from small to large. Five steps can be distinguished in the wound healing process: collagenation (cellular phase), contraction (wound contraction), collagen deposition (collogenation), epithelialization (epithelialization), as well as scar remodeling (cicatrixization). Wound contraction is the process by which the wound area shrinks, while wound healing is the process by which damaged tissue is returned as nearly to its normal state as feasible. In accordance with Ramachandran[46], the alcoholic leaf extract of *C. bonplandianus* substantially raises the pace of wound concentration. They concluded that herbal extract ointments containing leaf extracts from *C. bonplandianus* substantially boost the rate of wound concentration[55]. At present, there is a considerable deficiency of documented evidence and scientific research that verifies the notion that *O. sanctum*, commonly referred to as holy basil, has any significant properties that can influence or improve the process of wound healing. This lack of rigorous studies and data not only leaves a conspicuous void in our comprehension of the potential therapeutic benefits offered by this remarkable plant but also emphasizes the urgent need for comprehensive research to explore its characteristics, mechanisms, and effects related to wound regeneration and healing processes.

8. Conclusion

The ancient practice of phytomedicine represents the earliest known form of medicine, relying on the healing properties of plants. Among these plant-based remedies, *O. sanctum*, commonly known as Tulsi, and *C. bonplandianus* stand out for their extensive use in ethnomedical practices across the globe, where they are employed to treat an array of ailments. Rooted in the rich biodiversity of India, Ayurvedic medicine uniquely draws upon a diverse spectrum of medicinal and culinary plants that few other medical systems can claim. Tulsi, in particular, is lauded not only for its specific therapeutic applications but also for its remarkable adaptogenic qualities. These properties confer significant

preventive and curative benefits, particularly against the stress-related degenerative diseases prevalent in modern industrialized societies. Ongoing clinical research is anticipated to further uncover and validate Tulsi's numerous health-promoting attributes. Recent studies have revealed a wealth of diverse phytochemicals in various parts of *C. bonplandianus*, including its fruit, leaves, and latex. Altogether, a total of twenty-one key phytochemicals has been identified, underscoring the plant's medicinal potential. The extensive literature surrounding traditional and ethnomedical practices highlights both the remarkable efficacy and safety of these plants in addressing a wide range of health issues. However, a deeper exploration is essential to better differentiate, describe, and clarify the intricate chemical profiles of the bioactive compounds that endow *O. sanctum* and *C. bonplandianus* with their therapeutic effects. By employing advanced reverse pharmacological techniques, researchers can extract potent and safe medicinal compounds from these plants, paving the way for the development of innovative natural drugs.

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Author contributions
SS – Research concept and design, PB – Collection and assembly of data, Data analysis and interpretation, Writing the article, SS, PB– Critical revision and final approval of the article.

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