Review Article

Pharmacological Profiling and Propagation Strategies in Sweet Basil (*Ocimum basilicum*): A Review

ABSTRACT

*Ocimum basilicum* L. (sweet basil), a member of the Lamiaceae family, is a prominent aromatic and medicinal plant extensively utilized in traditional systems of medicine, culinary practices, and the pharmaceutical and cosmetic industries. This review synthesizes current knowledge on the ethnobotany, phytochemistry, pharmacological activities, and propagation strategies of *O. basilicum*. The plant exhibits a wide array of bioactivities, including antidiabetic, antioxidant, anti-inflammatory, hepatoprotective, hypolipidemic, immunomodulatory, antimicrobial, anxiolytic, and anticancer effects. These therapeutic properties are attributed to its diverse phytochemical profile, comprising essential oils, polyphenols, and flavonoids. Experimental studies have demonstrated its efficacy in modulating oxidative stress, inflammatory pathways, enzymatic activity, and cellular signaling mechanisms. Furthermore, *O. basilicum* shows potential in environmental applications such as phytoremediation, and its extracts are being investigated for food preservation and cosmeceutical use. The review also highlights the significance of vegetative and micropropagation methods in ensuring clonal fidelity and consistent phytochemical yield, essential oil for commercial exploitation. Collectively, the findings reinforce the pharmacological versatility and industrial relevance of *O. basilicum*, supporting its further exploration as a source of bioactive compounds for therapeutic and biotechnological applications.

*Keywords: Ocimum basilicum, Phytochemicals, Traditional medicine, Functional food, Vegetative propagation*

**1. INTRODUCTION**

Plants in the genus *Ocimum* are among the most significant medicinal plants, known for producing essential oil and used in pharmaceuticals, perfumery, and traditional medicine. Consequently, *Ocimum* is often referred to as the ‘queen of herbs’, ‘the incomparable one’, and ‘the mother medicine of nature’ (Simpson and Ogorzaly, 1986). *Ocimum* species are divided into two primary groups: the Basilicum group (including *O. canum*, *O. basilicum*, *O. americanum*, and *O. kilimandscharicum*) and the Sanctum group (including *O. tenuiflorum*, *O. gratissimum*, *O. viride*, and *O. micranthum*). Among these, sweet basil (*Ocimum basilicum* L.) is a versatile herb belonging to the Basilicum group, prized for its pharmaceutical, aromatic, and culinary uses. **It is a globally significant economic crop, found in tropical regions such as Asia, Africa, Central America, and South America (Begum et al., 2002).** *O. basilicum* L. is an annual, aromatic, and erect herb that attains a height of 30–90 cm. Its root system comprises a shallow taproot with numerous lateral branches. The stem is round to quadrangular, varying in color from green to purplish, and is either glabrous or sparsely pubescent, becoming slightly woody at the base as it matures. The leaves are simple, opposite, and decussate. The venation is reticulate, and oil glands are visible as translucent dots. The flowers exhibit white, pinkish, or purplish hues. The seeds are dark brown to black, ellipsoid, and mucilaginous (Suddee et al., 2005; Zahran et al., 2020).

Basil is renowned for its abundance of bioactive compounds, which are primarily classified into three groups: essential oils, flavonoids, and phenolic acids (Yadav et al., 2024). The essential oils are chiefly responsible for basil's distinctive aroma and flavor. Key components of basil essential oil include linalool, estragole, eugenol, methyl chavicol, methyl cinnamate and 1,8-cineole, which not only contribute to the plant's sensory properties but also offer significant therapeutic advantages (Rezzoug et al., 2019; Mounira et al., 2022; Azizah et al., 2023). Flavonoids, another category of bioactive compounds in basil, are well-regarded for their potent antioxidant capabilities (Ramesh and Satakopan, 2010). The third major group of phytochemicals in basil includes phenolic acids, with rosmarinic acid and caffeic acid being the most prominent. These phenolic acids, akin to flavonoids, exhibit notable antioxidant, anti-inflammatory, and neuroprotective effects (Muralidharan and Dhananjayan, 2004). Additionally, O. basilicum contains other bioactive compounds such as tannins, saponins, and sterols (Hussain et al., 2008; Chang et al., 2009).

In many tropical countries, sweet basil is commonly grown in home gardens and as a pot plant, and is widely used as a herbal spice. Basil is utilized in both the Ayurvedic and Unani medicinal systems and is also well-known for its culinary and ornamental applications. Different parts of the sweet basil plant have been extensively employed in traditional medicine (Ch et al., 2015). Due to its rich essential oil content, it is utilized as a food flavoring agent and also, in perfumery and cosmetics. Fresh basil leaves are consumed as a vegetable or used to flavor foods and beverages, while dried basil leaves are employed to enhance the flavor of stews, sauces, salads, soups, meats, and tea. Ethnobotanically, basil is significant for its role in traditional health care systems. This article provides an overview of the various uses of *Ocimum basilicum* in pharmacology, its role as a culinary herb, and its phytonutrient content and health benefits in disease prevention and the propagation strategies.

**2. TRADITIONAL USES**

Basil is renowned for its traditional medicinal uses and is officially recognized in several countries. The plant is cultivated in commercial scale in countries, like India, Indonesia, Egypt, Mexico, and the United States. In folk medicine, basil leaves and flowers are utilized as a tonic and vermifuge, while basil tea is used to treat dysentery, nausea, and flatulence. The plant’s oil is valued for alleviating spasms, rhinitis, mental fatigue, colds, and as first aid for wasp stings and snakebites (Baytop, 1984). Additionally, basil has been employed as a remedy for boredom and convulsions (Ismail, 2006; Oliveira et al., 2009; Arthi et al., 2010). Traditionally, basil has been used to address respiratory and urinary tract inflammation, coughs, asthma, and as a carminative, stomachic, and antispasmodic (Simon et al., 1999). It is also known to alleviate headaches, improve digestion, and treat toothaches, earaches, and epistaxis when combined with camphor. An infusion of basil is effective for cephalalgia, gouty joints, fever, otitis, and snake bites (Kirtikar and Basu, 2003). Basil seed infusions are applied for gonorrhea, chronic diarrhoea, and dysentery, and the plant is also used as a deterrent for insects and snakes. Furthermore, basil is used to treat stomach issues, fever, coughs, gout, and internal conditions such as cystitis, nephritis, and internal piles (Nadkarni, 2005).

**3. USE AS CULINARY HERB**

Basil's extensive health benefits have led to its growing popularity in both traditional and modern medicine, as well as its widespread use as a culinary herb. Known for its role as a spice, basil is a key ingredient in Italian and Southeast Asian cuisines. It is commonly added to salads and sauces, with Italian pesto being one of the most famous dishes featuring basil. In North America, basil is a popular culinary herb (Simon et al., 1999). As an additive and antioxidant, basil essential oil is incorporated into beef burger products to prevent lipid oxidative degradation, without altering the food's flavor, color, or texture (Sharafati-Chaleshtori et al., 2018). Basil and its extracts are also employed for flavoring and preserving olive oils, which are favored by consumers for their vibrant color and aromatic qualities (Perez et al., 2007). The direct infusion of basil into olive oil has become a popular trend in the Mediterranean region, enhancing both sensory and nutritional attributes (Veillet et al., 2010).In Turkey, fresh basil is often paired with yogurt due to its beneficial effects, while in Portugal, basil leaves have been tested in “Serra da Estrela” cheese for their functional and preservative properties, aiming to create novel food products with natural ingredients (Carocho et al., 2016). Additionally, basil seeds are a rich source of polysaccharides and become gelatinous when soaked in water, making them a popular ingredient in Asian drinks and desserts (Razavi et al., 2009).

**4. PHARMACOLOGICAL EFFECTS**

Research on *Ocimum basilicum* L. has been conducted globally, highlighting numerous health benefits. These include its potential as antidiabetic, antimicrobial, antifungal, and antiproliferative/anticancer agents, as well as its roles in treating dyspepsia, giardiasis, inflammation, oxidative stress, viral infections, ulcers, and promoting wound healing. Additionally, studies have indicated its cardiovascular stimulation effects, impact on the central nervous system, and hypoglycemic and hypolipidemic properties, as well as inhibit platelet aggregation. This plant also possesses stomachic, antihelminthic, antipyretic, expectorant, carminative and stimulant properties (Sharifi-Rad et al., 2023; Dhama et al., 2023). Furthermore, the seeds are noted for their stimulant, diuretic, diaphoretic, and demulcent properties (Sahoo et al., 1997).

**4.1 Antidiabetic Effects**

*O. basilicum* has demonstrated effectiveness in diabetes management, attributed to its high polyphenol and flavonoid content. Zeggwagh et al. (2007) observed that the aqueous extract of *O. basilicum* has hypoglycemic effects in diabetic rats, with no significant changes in plasma insulin levels or body weight. Bihari et al. (2011) reported that methanolic extract of *Ocimum* sp*.* demonstrated antidiabetic activities which were comparable to the standard drug, glibenclamide. According to El-Beshbishy and Bahashwan (2012), the aqueous extract of *O. basilicum* inhibited α-glucosidase and α-amylase enzymes and offered beneficial effects for controlling diabetes. The basil extract displayed dose-dependent inhibition of intestinal sucrose, maltose, and porcine pancreatic α-amylase activities in mice. According to Charoensup et al. (2024) basil extract can be used for natural adjunct therapy for managing type 2 diabetes, as it improved the glycemic control and reduced total cholesterol and triglyceride levels. Essential oil from sweet basil leaves also has potential applications in managing type 2 diabetes and it exhibited inhibitory effects on key enzymes linked to type 2 diabetes (α-amylase and α-glucosidase) (Ademiluyi et al., 2015). Ezeani et al. (2017) suggested that antidiabetic effects of basil are possibly mediated through two main mechanisms of limiting glucose absorption by inhibiting carbohydrate metabolizing enzymes and by enhancing hepatic glucose mobilization. It is also stated that antidiabetic activity of basil is associated with oxidative stress reduction, insulin level enhancement, decrease in malondialdehyde (MDA) levels (Sihombing and Ferdinand, 2024) and decrease in blood glucose levels (Teofilovic et al., 2025).

**4.2 Antioxidant Activity**

The antioxidant properties of *O. basilicum* are primarily attributed to high content of phenolic compounds, flavonoids, and other phytochemicals, particularly rosmarinic acid, caffeic acid, chicoric acid, kaempferol, and eugenol (Tada et al., 1996; Jayasinghe et al., 2003; Strazzer et al., 2011; Falowo et al., 2019; Ahmed et al., 2019; Akoto et al., 2020; Gokce et al., 2021; Bravo et al., 2021; Abidoye et al., 2022). Ahmed et al. (2019) observed a strong correlation between antioxidant activity and total phenolic content in basil extracts. However, Bravo et al. (2021) noted that the total phenolic content and antioxidant capacity of basil can vary depending on species, variety, origin, and extraction methods used in the studies. According to Gulcin et al., (2007), the protective effects of basil extracts vary, based on their composition and extraction methods, with water and ethanol extracts generally exhibiting better antioxidant effects. Kanmaz et al. (2023) found that aqueous extract and essential oil of basil is rich in phenolic and flavonoid compounds, contributing to its antioxidant activity. Ahmed et al. (2019) indicated that ethanol extracts of basil showed stronger radical scavenging activity than the synthetic antioxidant BHT (Butylated hydroxytoluene). Niture et al. (2006) and Issazadeh et al. (2012) highlighted the antioxidant effects of aqueous and ethanolic extracts of *O. basilicum*, with the latter showing superior antioxidant activity compared to standard antioxidants. Meera et al. (2009), also observed ethanolic extract of leaves of sweet basil exhibited significant nitric oxide and superoxide radical scavenging activity, indicating their potent antioxidant effects. Akoto et al. (2020) compared ethanol and hexane extracts and found that hexane extract performed better in the DPPH assay, showing appreciable antioxidant activity. Kaurinovic et al. (2011) found that ethyl acetate, n-butanol, and aqueous extracts of sweet basil possess potent free radical scavenging activity. Polyphenols isolated from methanol extracts of sweet basil showed significant antioxidant activity and synergistic effects with α-tocopherol (Jayasinghe et al., 2003). Al-Ali et al. (2013) reported that extracts of*O. Basilicum* act as potent antioxidants capable of protecting against DNA damage. Dasgupta et al. (2004) and Teofilovic et al. (2021) demonstrated that extracts of fresh basil leaves increase antioxidant responses by enhancing antioxidant enzyme activities such as catalase, glutathione reductase, glutathione s-transferase and superoxide dismutase, while Yesiloglu and Sit (2012), attributed sweet basil's antioxidant activity to its inhibition of lipid peroxidation, metal chelating abilities, and radical scavenging properties. Teofilovic et al. (2025) stated that sweet basil possess a protective effect against oxidative stress as it decreased lipid peroxidation and increased the activity of antioxidant enzymes such as catalase, glutathione reductase, glutathione peroxidase, and glutathione S-transferase.

Apart from phenolic compounds, other secondary metabolites like volatile oils in sweet basil also contribute to the antioxidant capacity (Bravo et al., 2021). Shafique et al. (2011) demonstrated high antioxidant activity in essential oil from *O. basilicum*, and it showed efficacy in scavenging DPPH radicals, inhibiting linoleic acid oxidation (Hussain et al., 2008) and β-carotene oxidative bleaching (Touiss et al., 2019). Ademiluyi et al. (2015) suggested that antioxidant properties of sweet basil oil are due to its ability to inhibit lipid peroxidation. Falowo et al. (2019) found that addition of sweet basil essential oil, 2% and 4% improved colorand lipid oxidative stability in minced beef during refrigerated storage,demonstrating the possibility of using it as a natural antioxidant additive in meat. Even the residue fraction obtained after molecular distillation of basil crude oil showed the antioxidant activity in DPPH and ABTS radical scavenging assays (Li et al., 2017). The essential oil extracted from *O. basilicum* seeds also showed potent antioxidant effects due to the presence of polyphenoid rosmarinic acid (Eid et al., 2023). Furthermore, formulations containing basil extracts have shown promising effects on skin hydration, roughness, wrinkles, scaliness, and smoothness, indicating potential anti-aging benefits upon topical application due to the higher antioxidant activity (Rasul and Akhtar, 2011).

**4.3 Prevention of Vascular Damage and Heart Attack**

Elevated concentrations of plasma triglycerides, total cholesterol, and low-density lipoprotein cholesterol, coupled with decreased levels of high-density lipoprotein cholesterol, insulin resistance, and hypertension, collectively contribute to a cluster of risk factors that amplify the susceptibility to vascular diseases (Savitha and Sandeep, 2011). Amrani et al. (2009) suggested that bioactive compounds in *O. basilicum,* capable of reducing plasma lipid levels, offers potential benefits in preventing hyperlipidemia and associated cardiovascular conditions. Harnafi et al. (2009) demonstrated that high levels of polyphenols, particularly tannins and flavonoids present in sweet basil extract is responsible for its lipid-lowering properties. Studies by Gokce et al. (2021) showed that basil extract and essential oil exhibited significant hypolipidemic effects and reduced serum triglycerides and total cholesterol levels in rats fed with a high-cholesterol diet. Amrani et al. (2006) reported significant hypolipidemic effects of *O. basilicum* in animals with induced hypercholesterolemia. Charoensup et al. (2024) revealed that basil extract positively affected lipid profiles, and resulted in reduction of total cholesterol and triglyceride levels, potentially reducing the risk of cardiovascular complications. El-Nahal and Thabet (2012) and Harnafi et al. (2013) proposed three possible mechanisms by which phytochemicals in sweet basil might lower cholesterol levels, including increasing hepatic low density lipoprotein (LDL) receptor activity, suppressing cholesterol synthesis, and inhibiting key enzymes in cholesterol metabolism. According to Touiss et al. (2019) the lipid-lowering effects may be due to enhanced activity of lecithin-cholesterol acyl-transferase, stimulation of low density lipoprotein cholesterol (LDL-C) catabolism through hepatic receptors, and increased lipoprotein lipase activity. Hidayat et al. (2021) opined that the beneficial hypolipidemic effects of sweet basil are attributed to its phytochemical contents, including flavonoids, tannins, and beta-carotene. These compounds work through various mechanisms, such as inhibiting HMG-CoA reductase (3-Hydroxy-3-methylglutaryl Coenzyme A reductase) (reducing cholesterol synthesis), increasing LCAT (Lecithin Cholesterol Acyl Transferase) activity (increasing HDL), and enhancing bile acid formation and excretion. Basil seeds also have a positive effect on reducing body mass index, blood pressure, total cholesterol, and triglyceride levels in cardiovascular patients and lipid-lowering effects of basil seeds is attributed to presence of dietary fiber, unique phenolic acids and antioxidative mechanisms involving enzymes like sodium oxide dismutase, catalase, and peroxidase (Irfan et al., 2022).

Additionally, alcoholic extracts of *O. basilicum* have been shown to exert cardiotonic effects, while aqueous extracts exhibit β-adrenergic effects (Muralidharan and Dhananjayan, 2004). Fathiazad et al. (2012) found that basil extract effectively lowered malondialdehyde levels in the myocardium and serum, offering strong myocardial protection against isoproterenol-induced infarction, potentially due to its antioxidative properties. Furthermore, the aqueous extract of basil was found to decrease membrane Mg2+ ATPase activity and increase Ca2+ and Na+/K+ ATPase activities, contributing to its cardiotonic effects (Muralidharan and Dhananjayan, 2004). In addition to this, sweet basil extract has been noted for its antihypertensive and antithrombotic effects. Tohti et al. (2006) indicated its ability to inhibit platelet aggregation induced by ADP and thrombin, highlighting its potential as an antithrombotic agent *in vivo*. Umar et al. (2010) investigated the effects of *O. basilicum* in renovascular hypertensive rats and observed reductions in systolic and diastolic blood pressure, cardiac hypertrophy, as well as lower concentrations of angiotensin and endothelin. Prangthip et al. (2023) reported novel peptides derived from green basil leaves, having high angiotensin-converting enzyme (ACE) inhibition activity and antioxidant activity, hold potential antihypertensive activity. Given these multifaceted effects, basil shows promise in preventing vascular damage and related disorders.

**4.4 Anti-inflammatory Activity**

The anti-inflammatory properties of basil primarily stem due to its ability to inhibit prostaglandin biosynthesis (Godhwani et al., 1987), and its inhibition of cyclooxygenase and lipoxygenase enzymes involved in arachidonic acid metabolism (Singh et al., 1996; Złotek et al., 2015). Li et al. (2017) stated that methyl eugenol in sweet basil is the key contributor to the observed anti-inflammatory activity. Ursolic acid, isolated from *O. basilicum*, has also been identified for its anti-inflammatory effects (Silva et al., 2008). Studies utilizing crude methanolic extracts of *O. basilicum* have also demonstrated anti-inflammatory activity by inhibiting key proinflammatory cytokines and mediators (Selvakumar et al., 2007). Rakha et al. (2010) found that petroleum ether fraction and ethanolic fraction of *O. basilicum* seeds possess potent anti-inflammatory activity and significantly inhibited paw oedema in rats. Okoye et al. (2014) demonstrated that the essential oils from basil exhibited significant topical anti-inflammatory effects in animal model studies. The presence of certain compounds like eugenol, linalool, D-fenchone, 1-terpene-4-ol, thymol, alpha-caryophylene, and diterpenes/triterpenes is associated with increased anti-inflammatory activity of basil oil. The study by Rashidian et al. (2016) suggested that *O. basilicum* has a protective effect against inflammation of colon, as evidenced by a significant reduction in myeloperoxidase levels following treatment with basil essential oil at doses of 200 and 400 µL/kg. Rodrigues et al. (2017) suggested that the anti-inflammatory effects of essential oil from sweet basil are associated with modulation of the arachidonic acid pathway. Akoto et al. (2020) found that both ethanol and hexane extracts of *O. basilicum* exhibited anti-inflammatory activity comparable to that of aspirin used as the reference drug. The anti-inflammatory activity is attributed to the presence of phenols, flavonoids, glycosides, terpenoids, and steroids in *O. basilicum*. Flavonoids, in particular, are known to inhibit enzymes and mediators of the inflammation process such as c-reactive protein or adhesion molecules. Aye et al. (2019) and Wasli et al. (2021) demonstrated that both the essential oil and ethanol extracts of basil leaves possess significant anti-inflammatory properties, primarily through their ability to suppress nitric oxide production in inflammatory cells. Hence this supports the traditional medicinal use of basil and its potential for developing anti-inflammatory drugs. Overall, the diverse anti-inflammatory mechanisms of basil, including modulation of prostaglandin synthesis and enzyme inhibition, along with the presence of bioactive compounds like ursolic acid, highlight its potential therapeutic value in managing inflammatory conditions.

**4.5 Antitumor Effects/ Cytoprotective**

The anticancer properties of basil are associated with its bioactive compounds that possess antioxidant and anti-inflammatory activities (Złotek et al., 2017). According to Taie et al. (2010), the anticancer effects of basil are attributed to various compounds including monoterpene derivatives such as camphor, limonene, thymol, citral, geraniol, and linalool, phenolic compounds, and flavonoids like cinnamic acid, caffeic acid, sinapic acid, ferulic acid, and rosemarinic acid. Among this, rosemarinic acid has been noted to inhibit cell proliferation induced by platelet derived growth factor or tumor necrosis factor. Manosroi et al. (2006) tested the anti-proliferative activity of basil oil on murine leukemia (P388) cell lines, noting its potency with an IC50 value of 0.0362 mg/ml in P388 cells**.** Niture et al. (2006) investigated ethanolic and aqueous extracts of *O. basilicum*, noting their effects on O6-methylguanine-DNA methyl transferase (MGMT) activity and expression in human peripheral blood lymphocytes and cancer cell lines, suggesting increased MGMT activity as a potential chemoprevention strategy. Dasgupta et al. (2004) found that basil leaf extract exhibited anticarcinogenic potential at the peri initiational level and effectively inhibited carcinogen induced tumors in Swiss albino mice.

Al-Ali et al. (2013) investigated the anticancer activity and antioxidative potentials of methanolic extracts from *O. basilicum*, concluding that its extract possess antioxidant properties, protecting against DNA damage, and exhibiting cytotoxic activity against MCF-7 cell lines. Renzulli et al. (2004) studied the cytoprotective effects of rosmarinic acid against aflatoxin, mycotoxin, and ochratoxin induced cytotoxicity and carcinogenicity in hepatoma-derived cell line (HepG2) cells, observing dose-dependent inhibition of DNA and protein synthesis, prevention of apoptosis cell death, and inhibition of caspase-3 activation. Kathirvel and Ravi (2012) investigated the cytotoxic effects of basil essential oil against human cervical cancer cell lines (HeLa), human laryngeal epithelial carcinoma cell lines (HEp-2), and NIH 3T3 mouse embryonic fibroblasts, demonstrating potent cytotoxic effects on cancer cell lines. The anticancer activity of basil was tested in MCF7 breast cancer cell lines and it resulted in reduction of viability in breast cancerous cells by 53.78% and breast malignant cells by 47.92% (Elzaiat et al., 2024). Li et al. (2024) found that the basil extract induced cell cycle arrest and inhibited cell proliferation in Ca9-22 oral cancercells as evidenced by the downregulation of cyclin D1 and CDK4 expression, coupled with the upregulation of p21 and p53 expression and these changes were observed at both mRNA and protein levels. Taie et al. (2010) demonstrated that ethanolic extracts and essential oils of basil showed anticancer properties, with the oils demonstrating higher efficacy. Hence, use basil oil could be advantageous for the development of new chemotherapeutic agents. Aburjai et al. (2020) also observed that the essential oil showed promising anticancer effects against three cancer cell lines, MDA-MB-231 (triple-negative breast cancer), MCF7 (ER+ breast cancer), and U-87 MG (glioblastoma). The anticancer effects of sweet basil oil are due to compounds like linalool, eugenol, and eucalyptol which exhibit anticancer properties through various mechanisms such as inducing apoptosis, DNA repair, cell cycle arrest, activation of detoxification enzymes and antioxidant effects. Effect of basil tea consumption during radioactive iodine therapy (RAIT) was studied by Nomura et al. (2023). According to them, basil tea consumption could help to protect against both psychological and physical side effects in cancer patients. Basil tea significantly reduced RAIT related anxiety in patients, and helped to preserve oral mucosal conditions and improved salivary gland function. These beneficial effects were attributed to its active ingredients such as eugenol, linalool, cineol, α-terpineol, and saponins, which have various protective and therapeutic properties. Collectively, these studies underscore the potential of basil plant, in cancer treatment due to their diverse anticancer activities, including anti-proliferative, antioxidant, and chemoprotective properties.

**4.6 Immunomodulatory Activity**

Sweet basil demonstrates significant immune enhancing activity and this is closely related to its polyphenol and flavonoid content (Dashputre and Naikwade, 2010; Jeba et al., 2011; Osman et al., 2020; Gu et al., 2024). Both aqueous and ethanolic extracts from basil leaves demonstrated a significant increase in circulating antibody titer, as well as in primary and secondary haemagglutination (HA) titers. Additionally, basil led to a substantial rise in phagocytic activity in mice (Dashputre and Naikwade, 2010). Jeba et al. (2011) found that administration of aqueous extract of basil produced a dose dependent significant increase in antibody titer compared to the control group in rats, showings its immunomodulatory potential. Immunomodulatory effects of *O. basilicum* is associated with its potential to increase antibody (immunoglobulin) levels, to reduce levels of inflammatory markers such as TNF-α, IL-6, and CRP and to improve levels of lymphocytes and neutrophils (Osman et al., 2020). Eftekhar et al. (2019) stated that hydro ethanolic extract of *O. basilicum* extract demonstrated significant immunomodulatory effects in sensitized rats and these effects are likely due to various compounds in it, including flavonoids, glycosides, and aromatic compounds. Tsai et al. (2011) suggested that *O. basilicum* contributes to immunomodulation in several ways including enhanced cell proliferation of immune cells, activation of specific cell types that are essential components of the adaptive immune system, strengthening immune system and balancing immune response. The immunomodulatory effect of *O. basilicum* is complex and involves multiple mechanisms, including cytokine suppression and effects on signaling pathways like ERK2 (Extracellular signal regulated kinase 2) which is a key component of the MAP (Mitogen Activated Protein) kinase signalling pathway, which plays a crucial role in immune cell function. Altogether, researches on immune enhancing activity of sweet basil provide a strong basis for the potential development of basil-based products with immune-enhancing properties (Gu et al*.,* 2024).

**4.7 Hepatoprotective Activity**

Six triterpene acids - betulinic, oleanolic, ursolic, 3-epimaslinic, alphitolic, andeuscaphic acids - isolated from *O. basilicum* exhibited hepatoprotective activity comparable to that of oleanolic and ursolic acids (Marzouk, 2009). Additionally, the ethanolic extract of *O. basilicum* leaves demonstrated hepatoprotective effects against liver damage (Meera et al., 2009). Gokce et al. (2021) demonstrated that basil extract and essential oil exhibited protective effects on the liver and they reduced hepatic triglycerides and total cholesterol levels, with the extract being more effective. Boulaares et al. (2024) investigated the hepatoprotective effects of *O. basilicum* aqueous extract against doxorubicin induced liver damage in rats. Doxorubicin, though an effective chemotherapy drug, can cause significant hepatotoxicity and other side effects. Treatment with *O. basilicum* extract alongside doxorubicin resulted in partial reversal of the negative effects on blood cell counts, liver enzymes and reduction in oxidative stress markers and concluded that *O. basilicum* extract's antioxidant properties may protect the liver from doxorubicin induced damage and potentially other liver diseases. Sarhan et al. (2019) found that *O. basilicum* extract also decreased hepatic necrosis and inflammation in liver tissue. Teofilovic et al. (2025) found that basil extract treatment improved liver function parameters in diabetic rats and prevented increase in direct bilirubin, AST (Aspartate amino transferase), and ALT (Aspartate amino transferase) levels, indicating hepatoprotective effect (Touiss et al*.,* 2021).

The hepatoprotective effect of *O. basilicum* is attributed to its high antioxidant content, including compounds such as flavonoids, saponins, tannins, sterols, triterpenes, and rosmarinic acid. These antioxidant compounds help prevent oxidative stress and free radical damage to liver cells, which is one of the main pathways to hepatotoxicity (Renovaldi and Khalik, 2020). The hepatoprotective effect of *O. basilicum* due to its antioxidant activity and free radical scavenging properties, likely reason being its high polyphenol content, especially flavonoids (Mahboub and Arisha, 2015; Soliman et al., 2020; Touiss et al., 2021). Qahl (2025) observed that administration of basil essential oil helped to repair liver structure damaged by H2O2 in rats and the protective effects of it are attributed to its rich content of phenolic compounds and other antioxidants. The secondary metabolites of basil leaf extract, including the essential oil monoterpene geraniol and its oxidized form citral as major constituents, showed a modulatory effect on hematological abnormalities and cell cycle deregulation. Thus, the protective role of the methanolic leaf extract of *O. basilicum* against hematotoxicity has been established (Saha et al., 2012). Hence it can be concluded that the hepatoprotective effects of sweet basil extract are multifaceted, involving antioxidant action, enhancement of the liver's intrinsic antioxidant defences, improvement of liver function parameters, and preservation of liver tissue structure. All these findings suggest that sweet basil extract could potentially be a valuable natural hepatoprotective agent (Teofilovic et al., 2021).

**4.8 Neuroprotective Effect**

The methanolic extract of *O. basilicum* leaves demonstrated analgesic activity comparable to that of aspirin (Choudhury et al., 2010). Rabbani et al. (2015) investigated the anxiolytic and sedative properties of both the hydroalcoholic extract and essential oil of *O. basilicum*, finding that the essential oil exhibited more pronounced effects than the hydroalcoholic extract at the same doses, likely due to its phenolic components. Ismail (2006) observed anticonvulsant and hypnotic activities in the essential oil of *O. basilicum*, which may be attributed to its diverse terpene content. However, it does not exhibit local anesthetic effects. Additionally, Oliveira et al. (2009) found that the essential oil did not affect strychnine induced convulsions and suggested that interactions with central GABAergic receptors might be responsible for its CNS depressant and anticonvulsant properties. Furthermore, the inhalation of basil essential oil fragrance was found to be effective in reducing arousal responses in humans (Satoh and Sugawara, 2003).

**4.9 Wound Healing Activity**

In an animal model of cutaneous excision wounds, treatment with honey combined with *O. basilicum* alcoholic leaf extract accelerated wound healing process over honey alone. The effect of honey- O. basilicum leaf extract combination was comparable to that of Solcoseryl jelly, which is a well-documented wound healing gel (Salmah et al., 2005). Zangeneh et al. (2019) evaluated the wound healing properties of *O. basilicum* aqueous extract ointment in rats. This ointment significantly improved wound healing parameters, reduced wound area and enhanced wound contracture more effectively than tetracycline ointment. The authors suggest that the wound healing properties may be due to the antioxidant compounds present in *O. basilicum*, which can reduce free radicals and pus in the wound area. A new hydrogel formulation incorporating the extract of *O. basilicum* and *Trifolium pratense* was developed by Antonescu et al. (2021) for wound healing applications. The hydrogel was designed to provide controlled release of bioactive compounds and maintain a moist wound environment. It demonstrated significant wound healing potential *in vitro* using a scratch test assay on human dermal fibroblasts. At a concentration of 50 μg/mL, it showed complete recovery of the dermal fibroblast monolayer. This hydrogel also showed improved wound contraction time and complete healing after 13 days of treatment in an animal model. The wound healing efficacy of this hydrogel is due to a combination of the synergistic effects of bioactive compounds from the plant mixture and the body's immune response. Soomro and Kumar (2024) conducted *in vivo* experiments on a group of human volunteers to test the effect of herbal ointment from sweet basil and its effectiveness on common dermatological conditions such as acne, eczema, inflammation, minor cuts, and scrape wounds. It was found that that the ointment demonstrated wound healing, anti-inflammatory, and anti-bacterial activity. No adverse reactions were observed on the skin, confirming the ointment's safety for topical use. The ointment showed particular effectiveness in treating acne due to its ability to kill bacterial strains causing the condition.

**4.10 Phytoremediatory Effect**

Phytoremediation is an eco-friendly and low cost method for removing pollutants from water without chemical treatments. Researches proved that basil plants could be used for phyoremediation of soils contaminated with Pb, Cu, Cr, Zn and Cd (Sabra et al., 2016; Chand et al., 2015; Rahi̇mi̇ et al., 2020; Youssef, 2021; Fattahi et al., 2019; Zahedifar et al., 2019; Poursaeid et al., 2020). Studies on the phytoremediatory effects of *O. basilicum* have shown that it can also tolerate endosulfan contamination in soils (Ramirez-Sandoval et al., 2011). Poursaeid et al. (2020) suggested that there is a complex interplay between nutrient application and heavy metal accumulation, and the application of K fertilizers increased Cd uptake and accumulation and phytoavailability in basil, thus improving phytoremediation potential of the plant. Many researchers stated that *O. basilicum* is a promising alternative for removing dyes from water and should be adopted to reduce the environmental impact of water treatment. Al-Saffar et al. (2022) demonstrated that *O. basilicum* could remove 90% of methyl orange dye after 24 days by phytoaccumulation of dye particles in the plant's body.

Chand et al. (2015) found that sweet basil can be cultivated in heavy metal-rich tannery sludge and its plant roots function as a detoxifying agent by immobilizing and holding back elements that would be toxic to the above-ground parts. Instead, the roots retain most of the heavy metals, especially Cr. Fattahi et al*.* (2019) highlighted the potential of sweet basil grown in heavy metal contaminated soil for soil remediation and essential oil production. While sweet basil grown in contaminated soil may not be suitable for fresh consumption, it could potentially be used for phytoremediation of contaminated soils. Chand et al. (2015) proposed sweet basil as a potential candidate in phytoremediation and safe hyper accumulator since the essential oil extracted through hydro distillation does not contain heavy metals. Even though essential oil yield of basil grown in heavy metal contaminated soil was significantly affected, quality of essential oil in terms of chemical constituents was only marginally influenced. Additionally, the basil plants demonstrated potential for phytostabilization, as they were able to reduce metal mobility from soil to plants (Dinu et al., 2020). Sabra et al. (2016) also suggested that basil could be used in phytostabilization rather than phytoextraction, as it can grow in contaminated soils while limiting the transfer of contaminants to its harvestable parts.

**4.11 Antimicrobial Activity**

Basil holds significant phytomedical potential in the food, pharmaceutical, and chemical industries due to its natural antimicrobial properties. The extracts and phytochemicals derived from basil, which exhibit antimicrobial effects, can play a crucial role in therapeutic treatments. Studies suggest that basil essential oil may serve as a viable alternative to synthetic antimicrobial agents. The primary antimicrobial agents in sweet basil essential oil are thought to be monoterpenes such as linalool, eugenol, methyl chavicol, and geraniol (Salimgandomi and Shabrangi, 2016). The antimicrobial efficacy of *O. basilicum* essential oils may be largely attributed to their high linalool content. Consequently, *O. basilicum* essential oils are not only valuable as food ingredients but also have the potential to replace synthetic antimicrobial agents in the future (Gebrehiwot et al., 2015).

Numerous studies have explored the antibacterial properties of sweet basil against various bacterial strains. Researchers has examined the impact of basil essential oil on the growth of different microorganisms and results demonstrated significant antimicrobial activity of the oil against tested strains (Durga et al., 2009; Suppakul et al., 2003). Gebrehiwot et al. (2015) suggested that *O. basilicum* essential oil has a notable antimicrobial effect on both bacterial and fungal isolates, making it a promising candidate for further research. The antimicrobial assays conducted by Shafique et al*.* (2011) revealed that *O. basilicum* essential oil was effective against all tested Gram positive and Gram negative strains, showing greater potency compared to standard antibiotics used as controls. Additionally, essential oil of *O. basilicum* exhibited strong inhibitory effects against multidrug resistant clinical isolates from *Staphylococcus*, *Pseudomonas*, and *Enterococcus* (Opalchenova and Obreshkova, 2003). Hussain et al. (2008) found that basil essential oil and its principal component linalool, showed antibacterial activity against *Staphylococcus aureus*, *Escherichia coli*, *Mucor mucedo*, *Fusarium solani*, *Botryodiplodia theobromae*, *Bacillus subtilis*, *Pasteurella multocida* and pathogenic fungi such as *Aspergillus niger* and *Rhizopus solani*. Moghaddam et al. (2011) demonstrated that essential oils from basil leaves were effective against *B. cereus* and *S. aureus*, and against *E. coli* and *Pseudomonas aeruginosa*. Budka and Khan (2010) reported that essential oil from *O. basilicum*, demonstrated bactericidal properties against *Bacillus cereus* in rice-based foods. Edris and Farrag (2003) tested the vapors of sweet basil oil and its principal components linalool and eugenol, against *Sclerotinia sclerotiorum* and *Rhizopus stolonifer* and found that linalool from basil oil exhibited moderate antifungal activity. Additionally, a study analyzing the essential oil of *O. basilicum* obtained through hydrodistillation and GC-MS identified fifteen compounds constituting 74.19% of the total oil, which demonstrated significant antifungal activity against certain plant pathogenic fungi (Zhang et al*.*, 2009).

In addition to the essential oil, other sweet basil extracts, such as those obtained with methanol, ethanol, and water, have been evaluated for their antimicrobial potential. Adiguzel et al. (2005) observed that extracts of *O. basilicum* exhibit antimicrobial properties against *Candida albicans* and various bacterial pathogens under *in vitro* conditions. The antibacterial properties of essential oils and methanol extracts from the leaves and stems of *O. basilicum* were assessed for their effectiveness against food-borne pathogenic bacteria. *O. basilicum* demonstrated considerable antibacterial activity against a range of bacteria, including *Bacillus cereus*, *Bacillus subtilis*, *Bacillus megaterium*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Escherichia coli*, *Shigella boydii*, *Shigella dysenteriae*, *Vibrio parahaemolyticus*, *Vibrio mimicus* and *Salmonella typhi* (Hossain et al., 2010). Furthermore, crude aqueous and ethanolic extracts of *O. basilicum*, as well as its purified components-linalool, apigenin, and ursolic acid showed a broad spectrum of antiviral activity (Chiang et al., 2005). The crude methanolic extract from the aerial parts of *O. basilicum*, along with nine compounds, demonstrated up to 49% inhibition of *Mycobacterium tuberculosis*, supporting its traditional use in treating tuberculosis symptoms (Siddiqui et al., 2012). Jacob et al. (2016) found that aqueous extracts of sweet basil contain eight key phytochemicals- tannins, saponins, flavonoids, alkaloids, steroids, terpenoids, resins, and glycosides- which are responsible for the plant's antibacterial and antifungal properties. Presence of these phytochemicals suggest that sweet basil extracts could be valuable in therapeutic medicine, particularly for combating bacterial infections. Additionally, the antifungal properties of basil against *F. oxysporum* could help prevent wilt and reduce post-harvest losses in agricultural crops. Hence it can be concluded that *O. basilicum* has demonstrated significant antimicrobial properties.

**4.12 Acute and Sub Chronic Toxicity**

There is limited literature on the toxicity of *Ocimum* species. However, *O. basilicum*, which is extensively used medicinally, contains some potentially harmful compounds, including safrole, rutin, caffeic acid, tryptophan, and quercetin. Phenolic acids like p-coumaric acid and caffeic acid can inhibit the digestion of plant cell walls in ruminants due to their antimicrobial activity. When metabolized by rumen microbes, these acids may produce benzoic acid, 3-phenylpropionic acid, and cinnamic acid, which are then detoxified into hippuric acid. The detoxification process consumes nitrogen, potentially reducing metabolic efficiency and productivity. Although adverse effects of quercetin in *Ocimum* spp. when used for animals are not well-documented, safrole, a compound previously used to flavor sodas, was banned as a food additive in the US due to its cancer-causing effects in rats. Conversely, d-limonene in *Ocimum* oil has anticarcinogenic properties. In a safety assessment of *O. basilicum* hydroalcoholic extract in Wistar rats, the acute study revealed an LD50 greater than 5 mg/kg, and the sub-chronic study showed no adverse effects on serum parameters (Rasekh et al*.*, 2012). Nadeem et al. (2022) reported that aqueous extracts of basil at concentrations of 10 to 1000 μg/mL did not show notable toxicity, and hence could be safely used as a culinary ingredient or potential source of bioactive compounds.

**5. PROPAGATION IN SWEET BASIL AND IMPORTANCE OF VEGETATIVE PROPAGATION**

Cultivation and demand for medicinal and aromatic plants has significantly increased due to increased inclination towards herbal remedies (Yazdani et al*.*, 2004). Sweet basil is one of the most important aromatic cum medicinal plant, grown worldwide for its multifunctional properties. Sweet basil is propagated conventionally using seeds, and plants raised using seeds show a wide variability due to cross pollinated nature of the plant. Cross pollination also results in progenies that are not true to type. According to Ahmad and Khaliq (2002), inter and intra specific hybridization causes variation in the morphology and chemistry of basil species. El-Keltawi and Abdel-Rahman (2006) identified that conventional basil production *via* seed resulted in varied content of phytochemicals. All this points towards the importance of vegetative propagation in sweet basil, which is useful for obtaining high progeny uniformity and to overcome the individual variability in essential oil composition. Vegetative propagation is an important tool known for maintaining varieties of economic importance. In sweet basil, vegetative propagation is especially helpful for achieving high offspring consistency and overcoming individual heterogeneity in essential oil composition. This method also offers an easy and efficient approach for quick and practical propagation (El-Keltawi and Abdel-Rahman, 2006). Dou et al*.* (2018) reported that propagation from cuttings offered a practical alternative for the cultivation of sweet basil. El-Keltawi and Abdel-Rahman (2006) demonstrated a simple and efficient method for rapid and applicable propagation in sweet basil using rooted tip and single node cuttings. Though not common, sweet basil can be propagated by cuttings due to the ease of this method and the ability to establish mature plants quickly.

Micropropagation is another effective technique for rapid multiplication and preservation of qualities. The first successful *in vitro* regeneration system for basil (*Ocimum basilicum* L.) through primary callus was reported by Phippen and Simon (2000). Callus and shoot induction was initiated on Murashige and Skoog basal medium supplemented with thidiazuron (16.8 µM). Begum et al. (2002) standardized the protocol for *in* *vitro* regeneration of *O.* *basilicum* using shoots as explant. For rooting, *in* *vitro* grown shoots were excised from the culture flask and the highest frequency rooting was observed on MS medium containing 1.0 mg/1 NAA. The *in* *vitro* regenerated plantlets were transferred on to specially made plastic tray containing cocopeat as potting mixture and thereafter successfully established under *ex* *vitro* condition. Another efficient protocol has been developed by Siddique and Anis (2007), in which multiple shoots were developed from shoot tip explants on MS medium supplemented with 50 μM of thidiazuron (TDZ) for 8 days, followed by subculturing in MS medium devoid of TDZ. The regenerated shoots rooted best on MS medium containing 1.0 μM indole-3-butyric acid (IBA). The micropropagated shoots with well-developed roots were successfully established in pots containing garden soil and grown in greenhouse with 95% survival rate. Propagation of *O. basilicum* through *in vitro* culture of nodal segments with axillary buds from mature plants has been accomplished (Siddique and Anis, 2008). The highest rate of shoot multiplication was achieved on half-strength MS medium supplemented with 2.5 µM BA and 0.5 µM indole-3-acetic acid (IAA) combination. For rooting, MS medium supplemented with 1.0 µM indole-3-butyric acid (IBA) proved to be better. The *in vitro* raised plantlets with well developed shoots and roots were successfully established in earthen pots containing garden soil and were grown in greenhouse with 90% survival rate. Micropropagation of *O. basilicum* using cotyledonary leaves from *in vitro* geminated plants has been done by Dode et al. (2015). Cotyledons from *in vitro* germinated seeds were used as initial explants. The highest efficiency of shoot formation after 45 days occurred in the MS supplemented with 5 mgL-1 BAP and 0.2 mgL–1 NAA.

**6. CONCLUSION**

In conclusion, sweet basil is a remarkably versatile herb with a wide range of uses that extend well beyond its role in the kitchen. Its vibrant flavor and aromatic properties make it a staple in various culinary traditions, from Italian pasta dishes to Thai curries. Beyond cooking, sweet basil offers significant health benefits, including its antioxidant and anti-inflammatory properties, which contribute to overall well-being. Additionally, its essential oils are employed in natural remedies and aromatherapy for their calming effects. Its pest control potential and ornamental value further underlines its multifaceted nature. Whether enhancing a meal, supporting health, or adding beauty to a garden, sweet basil proves to be an invaluable asset, demonstrating that its benefits stretch far beyond its culinary charm.

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Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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*Fig 1: Ocimum basilicum* L.