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An Extensive Survey of the Phytochemistry and Therapeutic Potency of *Ocimum sanctum* (Queen of Herbs)

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ABSTRACT
Ocimum sanctum, known as Queen of Herbs, is an important member of the family Lamiaceae due to its use in herbal medication centuries back, especially, in India and other parts of the sub-continent. It is still a subject of immense importance in modern medical research and it is due to the chemical constituents present in it like flavonoids, terpenoids, alkaloids, saponins, vitamins, minerals, proteins, carbohydrates and many others. It has shown a wide range of therapeutic potencies like antimicrobial, anticataleptic, antitoxic, immunomodulatory, analgesic, antidiabetic and cardioprotective activities. The aim of the present review is to present an extensive survey on the phytochemistry and pharmacological applications of the herb.

Keywords: *Ocimum sanctum*, Queen of Herbs, phytochemistry, pharmacological applications.

1. INTRODUCTION
Medicinal plants have considerable importance as source of medicines in both rural and urban lives. Traditional medical practitioners use these plants in their day to day practice[1]. The phytochemicals found in plants are preventive against a number of diseases like diabetes, nervous disorders including nervous degenerative disorders and cancer[2-4]. From ancient times till today, these plants are being investigated for their phytochemistry and medicinal potency.
Ocimum sanctum is different from pesto form of the basil, that is, *Ocimum basilicum*. It is the purest and most sublime plant. It is found in tropical part of Asia and has been grown in India for more than 3,000 years. In India, *O. sanctum* is considered as the most sacred plant by Hindus as it is used for religious purposes in addition to its medicinal value[5]. It symbolizes Laksmi Devi, according to their religion, who is considered as the most important lady. Tulsi means "The incomparable one" and is regarded as "the queen of herbs". It is known as religiously and spiritually pious. Tulsi, also known as Holy Basil, has got immense Ayurvedic medicinal importance especially in the Eastern areas.

2. BOTANICAL DESCRIPTION
O. sanctum is an erect, medium sized perennial herb which is woody below. Leaves are 2.5-6.0 cm long, being oblong and narrow at both ends. Petiole is thin and about 1.5-3 cm long. Floral leaves are sessile. Flowers are small and are arranged on small stalks in 15-20 cm long bracteate racemes. Colour varies from white, pink to purplish. Calyx is campanulate, membranous and enlarged. Corolla is extended beyond calyx. A group of four nutlets are enclosed in it. They are round, smooth and pale reddish-brown in colour. Nutlets are sub-globose and elliptic. Odour is aromatic and taste is pungent. Root is thin, soft, hairy and branched being blackish-brown externally and pale violet internally.Stem is herbaceous, hairy, woody, branched and sub quadrangular. It is purplish-brown to black externally and cream coloured internally. Odour of the stem is slightly aromatic. Seeds are oval to round and mucilaginous. They are odorless and taste is slightly pungent[6].

The soils best fit for cultivation of the herb are saline, rich loam to poor laterite and alkaline to slightly acidic. At altitudes of 900m (tropical and sub-tropical regions) best cultivating climate is available for the herb. For good vegetative growth, well-drained soil is best. Reasonable rainfall, humid conditions and long days with high temperature are fit for its proper growth and good oil production. Low oil production results in case of partially shaded habitat.

***Ocimum sanctum* plant with flowers**

3. ETHNO MEDICINAL APPLICATIONS
Leaves of *O. sanctum* are expectorant. Juice of leaves is used as stimulant, stomachic, diaphoretic, antiperiodic, used in gastric disorders and hepatic infections. It is also used in earache, catarrh, bronchitis and bronchial asthma. Dried

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leaves of the herb are used as snuff. In malarial fever, root decoction proves to be beneficial. Seeds of *O. sanctum* are demulcent and effective in urinary disorder. The plant as a whole is a remedy for snake and mosquito bites. It is also used for the treatment of arthritis, diarrhea, skin diseases, eye infections and chronic fever. The leaves of the herb contain a bright yellow volatile oil which is effective against insects and bacteria. It inhibits the in vitro growth of *M. tuberculosis* and *M. pyogenes* var. *aureus*. When externally applied, it helps in curing ringworms and other skin diseases. Juice or paste of leaves taken twice a day on an empty stomach increases the resistance of the body and reduces the chances of inviting swine flu. This potential of *O. sanctum* has been discovered recently. It helps in fighting against Japanese Encephalitis[7]. The herb is also used to treat hemorrhage and dyspepsia It is also known to have antimicrobial, antifungal, antifertility, anticancer, antidiabetic, hepatoprotective, cardioprotective, antiemetic, analgesic, antispasmodic and adaptogenic potential[1].

3.1 *Taxonomical Classification*

Kingdom:	Plantae
Phylum:	Magnoliophyta
Class:	Magnoliopsida
Order:	Lamiales
Family:	Lamiacaea
Genus:	Ocimum
Species:	sanctum

3.2 *Vernacular Names*

Sanskrit :	Surasā, Krsnatulas i, Bana Tulas i
Assamese	Tulasi
Bengali :	Tulasi
English :	Holy Basil
Gujrati :	Tulasi, Tulsi
Hindi :	Tulasi
Kannada :	Tulasi, ShreeTulasi, VishnuTulasi
Kashmiri :	--
Malayalam	Tulasi, Tulasa
Marathi :	Tulas
Oriya :	--
Punjabi :	Tulasi
Tamil :	Tulasi, Thulasi, ThiruTheezai
Telugu :	Tulasi
Urdu :	Raihan, Tulsi[6]

3.3 *Parts Used*

Leaves, seeds, whole plant, oil

3.4 *Production lead time*

Four weeks.

4. PHYTOCHEMICAL STUDIES

Whether the plant colour is green or purple, all *O. sanctum* plants have the same chemotype. High amounts of eugenol or methyl eugenol or sesquiterpenes are found in *O. sanctum* belonging to different habitats. Eugenol is the major constituent of essential oil (27–83%) along with methyl eugenol (3– 24%), methyl chavicol (10–15%) and sesquiterpene hydrocarbons. Fifty one components, representing 94.2% of the whole oil, were detected in *O. sanctum* (green) essential oil. The composition of the oil is eugenol / sesquiterpene-type: eugenol (41.7%), sesquiterpene hydrocarbons (39.2%) and total sesquiterpene components (45.9%). α-caryophyllene and α-elemene were the main sesquiterpene hydrocarbons. In one study, a solvent system for HPTLC analysis of quercetine in aqueous and alcoholic extract of *O. sanctum* showed the amount to be 0.74 mg/ml[8]. In leaf of *O. sanctum*, volatile oil, phenols, alkaloids, tannins, saponins, flavonoids, protein and carbohydrate were recorded to be 0.8, 1.02, 3.9, 0.42, 0.24, 1.10, 3.3 and 4.5 mg/100g, respectively. In stem and root, the quantities were found to be 0.7, 0.72, 1.9, 0.14, 0.22, 1.08, 2.82, 2 and 0.4, 0.99, 1.1, 0.10, 0.20, 0.96, 1.20 and 2.1 mg/100g, respectively. Thiamin (Vitamin Bl), riboflavin (vitamin B12) and niacin were estimated to be 0.48, 0.24 and 0.27 mg/100g, respectively, whereas, magnesium, calcium, potassium, phosphorus, sodium, iron, zinc and manganese concentrations were 0.48 to 0.18, 3.598 to 195.02,4.98 to 396.94, 196.05 to 100.54, 81.34 to 26.94, 16.18 to 0.22, 0.10 to 0.08 and 0.18 to 0.12 mg/100g, respectively[9]. In crystal springs *O. sanctum* Local, Stoneville *O. sanctum* Local, Beaumonte *O. sanctum* Local and Verona *O. sanctum* Local the concentrations of phytochemicals were: α-humulene (5.53 ± 0.662, 2.88 ± 0.281, 3.89 ± 1.11and 4.38 ± 0.710, respectively) eucalyptol (23.4 ± 0.770, 7.45 ± 3.00, 6.72 ± 1.09 and 13.6 ± 1.30, respectively) humulene epoxide II (1.63 ± 0.135,2.49 ± 0.0886, 2.44 ± 0.328 and 2.21 ± 0.204, respectively) methyl chavicol (25.1 ± 3.12, 11.9 ± 1.37,7.02 ± 0.814 and 17.3 ± 0.703, respectively) and (–)-trans-caryophyllene (1.35 ± 0.146, 0.884 ± 0.206, 1.04 ± 0.348 and 2.37 ± 1.61, respectively)[10]. The phytochemical estimation of *O. sanctum* showed the presence of alkaloids, tannins, flavonoids, amino acids, steroids, carbohydrate, reducing sugar, triglycerides, phospholipids, cholesterol, LDL – cholesterol, VLDL – cholesterol and HDL – cholesterol[11]. The qualitative analysis of leaf extract of *O. sanctum* detected tannins, saponin, flavonoids, steroid, terpenoids and cardiac glycerides. GC-MS analysis of hydroalcoholic extract showed the presence of ten compounds: caryophyllene (26.53%), eugenol (43.88%), cyclopropylidene-(1.02%), 1, 2, 4-triethenyl (15.31%), 1, 1-dimethoxy-(2.04%), N, N, a, 4-tetramethyl-(2.04%), benzene methanamine, cyclohexane, cyclopentane, octadecane[12]. Eugenol (80.94%) was extracted from the leaves of *O. sanctum* by kinetic method in 90 min with the agitation speed being 1000 rpm[13]. Ursolic acid, apigenin, luteolin, oleanolic acid, rosmarinic acid, carvacrol, linalool and β-caryophyllene have been identified in *O. sanctum*[14]. Alkaloids, glycosides, gums mucilage, proteins, amino acids, tannins, phenolic compound, triterpenoids, steroids, sterols, saponins, flavones and flavonoids were found to be present in *O. sanctum* located in South Eastern Odhisa[15].

In Thailand, α-thujene, camphene, sabinene, β-pinene, limonene, linalool, borneol, α-copaene, β-elemene, β-caryophyllene, α-humulene, γ-murolene, α-bulnesene, eugenol and methyl eugenol were detected by GC-MS analysis of the hydro distillate of aerial parts of *O. sanctum*[16]. In one study, alkaloids, flavonoids, tannin, saponins and cyanogenic glycosides in stem and leaves of *O. sanctum* were estimated to be 7.50, 6.30, 0.45, 0.76, 32.18 mg/100g and 11.80, 11.50, 3.55, 0.28, 25.66 mg/100g, respectively. Nutritional analysis showed protein, lipids, fiber, carbohydrates, moisture content and ash in stem and leaves to be 9.25%, 2.75%, 18.30%, 68.05%, 88.30%, 20.15% and 12.30%, 3.0%, 7.0%, 77.70%, 83.55%, 18.35%, respectively[17].

5. PHARMACOLOGICAL STUDIES

Vast research has been done regarding the therapeutic potential of *O. sanctum*. Some of the work is mentioned below.

5.1 *Anti aflatoxin Potential*

Reduction of aflatoxin B1 (AFB1) in stored rice by extracts of *S. aromaticum*, *C. longa*, *A. sativum* and *O. sanctum* was investigated. *S. aromaticum* (5 g/kg) showed complete inhibition of AFB1 production. *C. longa*, *A. sativum* and *O. sanctum* also inhibited aflatoxin B1 production (72.2–85.7%) at the same concentration[18].

5.2 *Anti amnesia Potential*

Antiamnesic effect of the aqueous extract of *O. sanctum* was investigated on time induced amnesia and sodium nitrite-induced amnesia in mice. Prior to experiment, for a period of three days, the extract was administered to mice at 100 and 300 mg/kg dosage intraperitoneally. The effect of the extract was noticed by object discrimination task and elevated plus maze task. The standard drug used was Piracetam. When given before and after training trial,*O. sanctum* was found to have a potential memory enhancing character[19].

5.3 *Analgesic Potential*

The ethanol extract of the leaves of *O. sanctum* was used to test the analgesic potential of the herb. In the hot-plate test, at the doses of 250 and 500 mg/kg body weight, the extract showed a significant ($p<0.05$) dose dependent increase in reaction time in mice. Significant ($p<0.05$) anti-inflammatory effect was also observed by inhibition of paw volume by 43.33% at the dose of 500 mg/kg body weight at the fourth hour of study. The ethanol extract of *O. sanctum* proved to have dose-dependent analgesic and anti-inflammatory activity[20].

5.4 *Anthelmintic Potential*

The hydro alcoholic extracts of *W. sominifera* and *O. sanctum* were investigated for anthelmintic potential against earthworms. For both the plants, dose of 40 mg/mL possesses more wormicidal activity. For *O. sanctum* and *W. sominifera*, the paralysis time was 2.5±0.6 and 2.8±0.8 and the death time was 6.5±0.7and 7.1±0.9, respectively. *O. sanctum* proved to be a better anthelmintic cure[21].

5.5 *Immunomodulatory Potential*

Immunomodulatory potential of the aqueous extract of *O. sanctum* leaves in wistar rats was investigated by studying the humoral antibody titre (HA), total leukocyte count (TLC) and differential leukocyte count (DLC). Levamisole was the standard drug used.The data obtained proved the antianaphylactic activity of *O. sanctum*[22]. Comparison of immunomodulatory activity of alcoholic and aqueous extracts of *O. sanctum* was undertaken by giving doses of 50, 100 and 200 mg/kg/day for 14 days to Swiss albino rats. Humoral (haemagglutination antibody titer model) and cellular immunity (delayed type hypersensitivity reaction models) were used for testing the potential. Alcoholic extract had more potential in producing immune stimulation than the aqueous extract[23]. Immunomodulatory effect of aqueous extract of *O. sanctum* in rat was investigated by its administration orally at 100 and 200 mg/kg/day for 45 days. Increasing antibody production in dose-dependent manner was observed along with increased RBC, WBC and haemoglobin production, thus, proving immunomodulatory and haematological activity of the herb[24]. Amelioration of endosulfan induced immunotoxicity by *O. sanctum* was studied in male wistar rats by mixing in ground nut oil in the concentrations of 6, 3 and 1.5 mg/kg body weight. The mice were divided in groups. To some groups, in addition to endosulfan, *O. sanctum* was given. Immunity improved in the *O. sanctum* treated groups[25].

5.6 *Cardio protective Potential*

Cardio protective activity of aqueous extract of *O. sanctum* was tested in male albino rabbits. Adult male rabbits were given 0.5mg/kg cholesterol with or without plant extract for 45 days. Normal control, cholesterol control and *O. sanctum* groups (10mg, 25mg, and 50mg/kg body weight/day) were made. Biochemical evaluation of serum lipid was done for 4 months then tissues were analyzed for cholesterol. *O. sanctum* lowered the blood and tissue cholesterol levels, thus, proving to have anticholesterol property[26]. Treatment with *C. mukul* and *O. sanctum* showed decrease in serum triglyceride, cholesterol and MDA. These indigenous drugs had significant positive effect on hypercholesterolemic rabbit model[27]. Male albino rats were subjected to restraint stress 3h/day for 6 days. Aqueous extract of *O. sanctum* was given (100 mg/kg for 6 consecutive days) following stress. In cerebrum, cerebellum and

brain stem, MDA, nucleic acids and proteins were estimated. Restraint stress increased the rate of lipid peroxidation and decreased nucleic acids and proteins. Aqueous extract of *O. sanctum* prevented the stress related changes, hence, proving the protective role of the herb[28].

5.7 *Wound Healing Potential*

To test wound healing potential of *O. sanctum* streptozotocin induced type 2 diabetic rats were given 2 gm fresh leaves of the herb for 30 days. Serum glucose and lipids were estimated by using diagnostic kits. Incision and excision models for observation of wound healing potential were generated. *O. sanctum* had pro-healing effect. DHR-S rats treated with *O. sanctum* leaves, took less number of days for healing as compared to DHR and CR group[29]. In one study, comparison of the oral and topical application of *O. sanctum* for wound healing potential was done. Excision and incision methods were used for study in albino rats. Four groups of rats were made for oral test, control and topical test with six rats per group. Oral and topical treatment showed better results as compared to control[30]. In wistar albino rats, wound healing potential of cold aqueous extract of *O. sanctum* leaves along with its effects on tumor necrosis factor –α was assessed. Topical application of *O. sanctum* extract in petroleum jelly resulted in faster healing as compared to the application of petroleum jelly alone. Significant healing was noticed in animals, which in addition to topical application of 10% *O. sanctum* extract, were given 250 mg/kg b. w of aqueous *O. sanctum* extract for 20 days. TNF-α level was found to be increased by *O. sanctum* treatment, thus, promoting wound healing potency[31].

5.8 *Anti diabetic Potential*

Anti-diabetic potential of *O. sanctum* was found by experimenting on male rats. After induction of diabetes by alloxan, fall in blood glucose, blood urea, serum cholesterol and serum triglyceride was noticed by treating the diabetic respondents sub-cutaneously with *O. sanctum* leaf extract, thus, proving anti hyperglycemic action of the herb[32]. From PAU, Ludhiana, ninety male diabetic patients (40-60 years) who were non-insulin dependent were selected to study the effect of *O. sanctum*and *A. indica* leaves on them. After a month control period, the patients were divided into group 1, 2 and 3 (30 each). In capsule form, group 1 was given *O. sanctum* leaf powder, group 2 *A. indica* leaf powder and group 3 was given mixture of both powders. Four capsules constituting 2 gm powder were given in lunch and dinner for 3 months period. Diabetic symptoms lessened in all the three groups, but, the maximum improvement was seen in group 3 patients. Hence, combination of the leaves proved to be beneficial for diabetes[33]. The effect of aqueous extract of *A. indica*, *A. sativum*, *A. cepa*, *A. indica*, *M. sapientum*, *M. indica*, *M. koenigii*, *O. sanctum*, *P. amarus* and *T. cordifolia* on type 2 diabetic patients was investigated. Four hundred out of 828 patients were selected for the study. Ten experimental and ten control groups were made (20 diabetics/group). After 2 months study, *M. indica*, *M. koenigii*, *O. santum*, *P. amarus*, *A. cepa*and *A. indica* proved to be anti-diabetic and hypolipidemic. *O. sanctum* decreased total cholesterol (142±14 to 137±15 mg/dl, $p<0.03$), LDL (91±14 to 85±19 mg/dl, $p<0.03$) level and enhanced HDL (25±3 to 27±4 mg/dl, $p<0.03$) level[34].

5.9 *Hepatoprotective Potential*

The hepatoprotective potential of aqueous extract of *O. sanctum* in lead induced toxicity in wistar albino rats was studied. Six groups comprising of six rats each were made. Oral administration of the herb for a period of 21 days was made. After analysis of antioxidant status of the animals, lipid per oxidation (LPO) and hepatic serum markers (AST, ALT, ALP, GGT), increase in the serum marker enzyme level and serum bilirubin content, lowered levels of serum protein and tissue glycogen was noticed due to lead toxicity. In hepatic tissues lipid peroxides accumulation was observed. Restoration to normal level of all the parameters was seen when treated with the aqueous extract of *O. sanctum*, depictive of the hepatoprotective nature of *O. sanctum* in lead induced toxicity[35]. In another study, hepatorenal protective potential of aqueous filtrate of dried leaf powder of *O. sanctum* (100, 75 and 50 mg/kg./oral) in distilled water was tested. In second experiment, lethal dose (1gm/kg./i.p) of acetaminophen was tried at its maximum dose (1.5gm/kg/oral). Leaves of *O. sanctum* reduced hepatorenal toxicity of acetaminophen in mice[36].

5.10 *Anti toxic Potential*

The protective potential of the herb was tested in 35 white leghorn chicks (4 weeks old males). Five groups i.e. 1 (control), 2 (Pb 50 ppm), 3 (lead 100 ppm), 4 (Pb 50 ppm + *O. sanctum* 100 ppm) and 5 (Pb 100 ppm + *O. sanctum* 100 ppm) were made (7 chicks/group). After 12 weeks,a significant ($p < 0.01$) decrease in total erythrocyte count, hemoglobin and TLC was noted in the chicks fed on 50 ppm and 100 ppm lead as compared to control but increased in groups fed with lead and *O. sanctum*, thus, proving that the herb under study neutralized the toxicity and is protective in nature[37]. Genotoxicity in adult male wistar albino rats was induced by lead acetate for 12 weeks. Lead increased micronuclei in polychromatophilic erythrocytes of bone marrow. Rats were divided into six groups including control group and the other five groups were fed with low and high doses of lead and *O. sanctum*. The group, which was treated with high dosage of *O. sanctum* in addition to lead, exhibited reduction in lead induced genotoxicity by reducing number of micronuclei in bone marrow cells[38]. The ethanolic extracts of *B. pinnatum*, *S. aromaticum* and *O. sanctum* were used to make polyherbal formulation. Intraperitoneally gentamicin (100 mg/kg/d) was given for 8 days which resulted in nephrotoxicity in wistar rats. Alcoholic *B. pinnatum* (200 mg/kg) and

polyherbal formulation (200 mg/kg) reduced gentamicin induced nephrotoxicity[39]. Antigenotoxic and anticlastogenic effect of *O. sanctum* leaf distillate on human polymorphonuclear leukocytes and human peripheral lymphocytes was studied. Three doses of distillate (50 µL/mL, 100 µL/mL, and 200 µL/mL) were given. The positive controls used for inducing genotoxicity and clastogenicity were: MMC (0.29 µmol/L), Potassium dichromate (Cr^{+6}) 600 µmol/L, Benzo[a]pyrene (30 µmol/L). The damage to DNA, chromosomal aberration and micronucleus formation was protected with distillate of *O. sanctum* leaves (50 µL/mL, 100 µL/mL, and 200 µL/mL). LC-MS showed eugenol, luteolin and apigenin and they had the protective effect against genotoxicants[40].

5.11 *Anti microbial Potential*

Ethanol extracts of *O. sanctum*, *O. majorana*, *C. zeylanicum* and *X. armatum* were tested for antibacterial activity against *B. subtilis, B. cereus, B. thuringiensis, S. aureus,Pseudomonas* spp, *Proteus* spp, *S. typhi, E. coli, S. dysentriae, K. pneumoniae* by agar well diffusion method. The plant extracts showed more activity for gram-positive bacteria than gram-negative bacteria[41]. Synergistic effect of acetone extract of *O. sanctum* and antibiotics (Penicillin, Gentamicin, Cephalexin, Ciprofloxacin and Tetracycline) was tested against Methicillin Resistant *Staphylococcus aureus* (MRSA) by using disc diffusion method. Zone of inhibition increased significantly with all antibiotics[42]. The chemical constituents of individual and mixed ethanolic leaf extracts from *A. indica* and *O. sanctum* were tested for antimicrobial activity. The mixed extract showed better activity against fish pathogens indicated by zone of inhibition, minimum inhibitory and minimum bactericidal concentration[43]. Liquid inhibition test was used to evaluate the antibacterial activity of aqueous extract, chloroform extract, alcohol extract and oil of *O. sanctum* leaves against *E. coli*, *P. aeruginosa*, *S. typhimurium* and *S. aureus*. *O. sanctum* extract was effective against *E. coli*, *P. aeruginosa*, *S. aureus* and *S. typhimurium* giving optical density reduction from 0.20 to 0.85, chloroform extract being most effective against *P. aeruginosa* giving 0.85 reductions in optical density[44]. Disc diffusion method was used to test ethanolic extracts of *O. sanctum*, *A. indica*, *T. aestivum*, *P. emblica* and *S. potatorum* for antimicrobial activity. *O. sanctum* (82.05% removal of *E. coli*), *A. indica* (71.79% removal of *E. coli*) and *T. aestivum* (64.1% removal of *E. coli*) proved to have the greatest potential. In all herbs, maximum removal of *E.coli* was found at 30 min contact time onwards[45].By cup diffusion method, aqueous ethanolic extracts of *O. sanctum* (Tulsi), *E. caryophyllata*(Clove), *A. bidentata* (Datiwan) and *A.aindica*(Neem) were subjected to in vitro antibacterial assay against human pathogens *E. coli, S. typhi, S. paratyphi, S. aureus, K. pneumoniae, P. aeruginosa*. All extracts proved to be potent, the maximum result being shown by clove[46]. By disc-diffusion method, antibacterial activity of *O. sanctum* L. essential oil was evaluated against *E. coli*, *Klebsiella*sp., *P. mirabulus*, *P. aeruginosa*and *S. aureus*. Maximum zone of inhibition was seen against *S. aureus* (20.0 mm & 41.5 mm) and minimum against *E. coli* (10.2 mm & 17.8 mm) for the concentration of 5 µL and 10 µL oil, respectively. In *P. mirabulus*, *P. aeruginosa* and *Klebsiella*sp, the inhibition zones were 15.1 mm & 26.0 mm, 10.2 mm & 20.0 mm and 11.1 mm & 19.4 mm, respectively, for the same concentration of the essential oil[47]. Antimicrobial activity against *E. coli* and *Staphylococcus aureus* by *O. sanctum, M. koenigii*and *A. vulgaris* leaf extracts showed significant results, thus, proving the potential of the herb[48].

5.12 *Anti cancer Potential*

Ethanolic extract (mixed in equal proportion) of *W. somnifera, O. sanctum* and *T. cordifolia* was given to a patient under chemotherapy. In-vitro cytogenic analysis showed that these drugs decreased chromosomal aberrations[49]. The antitumor mechanism of ethanol extracts of *O. sanctum* was studied in A549 cells and the Lewis lung carcinoma animal model. Cytotoxicity against A549 cells was exerted by the extract. Cleavage of poly (ADP-ribose) polymerase (PARP), releasing cytochrome C into cytosol and activation of caspase-9 and -3 proteins was also observed. Growth suppression of Lewis lung carcinoma in a dose-dependent manner was observed. Hence, ethanol extract of *O. sanctum* has antitumor potential[50]. A polyherbal formulation NR-ANX-C (composed of the extracts of *W. somnifera, C. sinensis, O. sanctum*, shilajith and triphala) was tested for antioxidant and antiulcer potential. The formulation was tested at 25 and 50 mg/kg dosage. It proved to be more effective than ranitidine in reducing ulcer index and at 50 mg/kg NR-ANX-C showed results similar to omeprazole in preventing ulcer formation. A dose- dependent decrease in gastric juice volume and total acidity and increase in gastric pH and total adherent gastric mucus was also seen in NR-ANX-C treated groups. Lipid peroxidation was also reduced. NR-ANX-C can be used as an adjuvant in the treatment of gastric ulcer[51]. Methanol induced ulcer in wistar rats was treated with aqueous extract of *O. sanctum* (100mg/kg and 200 mg/kg) given orally. Antioxidant potential of gastric mucosa increased, thus, preventing mucosal damage and proving the antiulcer activity of the herb[52]. Another herbal formulation Prolmmu was tested for anticancer effect on ethinyloestradiol induced ovarian adenocarcinoma in rats. Increased activities of serum glutamate pyruvate transaminase (SGPT) and serum alkaline phosphatase (SAP) due to ethinyloestradiol were significantly ($p<0.05$) decreased by Prolmmu (500 mg/kg, orally, daily for 4, 8 and 12 weeks after 20, 16 and 12 weeks of EO administration in groups 3, 4 and 5, respectively). The ovarian tissues of group 2 revealed marked fibrous tissue proliferation of follicular epithelium. Regeneration, improvement and normalization of ovarian tissues were observed. Prolmmu proved to have anticancer effect on ethinyloestradiol induced ovarian cancer[53].

5.13 *Anti inflammatory Potential*

Using carrageenan induced paw edema model, anti-inflammatory activity of *O. sanctum* leaf paste was studied. Adult albino rats were divided into 3 groups: control (vehicle), standard (Indomethacin 100 mg/kg) and fresh tulsi paste (500 mg/kg). Drug administration was done orally, 1hr before phlogistic agent. The percent Inhibition was 0%, 76% and 67% for control, standard and test, respectively. *O. sanctum* gave 88.15% inhibition comparable to 100 mg/kg of indomethacin[54].

5.14 *Antioxidant Potential*

Forty-two broiler chicks (day-old) divided into six groups of seven chicks each were given supplementation of *O. sanctum* leaf powder (0.25% and 0.5%), organic selenium (0.3 ppm) and their combinations, to check their effect on levels of antioxidative enzyme. Levels of Superoxide dismutase (SOD), Glutathione peroxidase (GSH-Px) and Catalase were measured in plasma at the end of 3rd and 6th week of age. Dietary selenium (0.3 ppm) supplementation increased GSH-Px activity and *O. sanctum* leaf powder (0.5%) increased SOD and Catalase levels. Combinational diet of both proved to be more effective, thus, proving to combat oxidative stress in broilers to the best[55]. DPPH, Nitric oxide and reducing power assays were used to test the antioxidant activity of *O. sanctum* leaves. IC_{50} value of 16.39±0.31 and 16.20±0.33 µg/mL was observed for DPPH and Nitric oxide scavenging assays, respectively. In reducing power assay significant antioxidant activity was seen[56]. Ferric reducing antioxidant power (FRAP) assay, improved ABTS radical cationdecolorization assay and DPPH free radical scavenging assay were used to study antioxidant activities of *O. sanctum* and *O. basilicum*. Folin- Ciocalteau micro method was used to analyze total phenolic contents. The results were better for *O. bascilicum* as compared to *O. sanctum*[57]. DPPH radical, nitric oxide radical, superoxide anion radical and hydroxyl radical scavenging assays were used to evaluate the antioxidant and free radical scavenging activity of aqueous ethanolic (1:1) extract of *O. sanctum* (AEOS) in various systems in a dose dependent manner. Aqueous ethanolic (1:1) extract of *O. sanctum* (50, 100, 200, 300, 400 and 500 µg/mL) showed 38.06, 41.45, 44.83, 49.06, 57.78 and 65.98% inhibition, respectively, on peroxidation of linoleic acid emulsion. IC_{50} value was found to be 34.21 µg/mL in DPPH radical scavenging assay and 18.69 µg/mL of ascorbic acid. Nitric oxide radicals were scavenged giving 86.91 µg/mL IC_{50} value and curcumin had 86.91 µg/mL IC_{50} value. Superoxide generated by PMS/NADH-NBT system was scavenged with IC_{50} value of 73.38 µg/mL and for curcumin IC_{50} was 24.67 µg/mL. Hydroxyl radical generated by the deoxyribose method was also inhibited with 42.69 µg/mL IC_{50} value. Standard Catechin showed IC50 value of 17.71 µg/mL. Aqueous ethanolic (1:1) extract of *O. sanctum* can be considered as a natural antioxidant[58]. *O. sanctum* plants were treated with paclobutrazol (PBZ) and Abscissic acid (ABA) to analyze the changes in the enzymatic and non-enzymatic antioxidant responses. Non-enzymatic antioxidants (ascorbic acid) decreased in the ABA treated plants and increased in the PBZ treated plants along with α-tocopherol content. Enzymatic antioxidants (ascorbate peroxidase and superoxide dismutase) were also enhanced. When compared with the control plants, catalase activity increased[59].

5.15 *Thrombolytic Potential*

O. sanctum, *C. longa*, *A. indica, A. occidentale* along with Streptokinase (positive control) and water (negative control) were used to investigate thrombolytic activity of herbal preparations. An in vitro thrombolytic model was used for study. The percentage (%) clot lysis was statistically significant ($p<0.0001$) when compared with vehicle control. Moderate clot lysis activity was shown by all plant extracts being 30.01 ± 6.168% for *O. sanctum*, 32.94 ± 3.663%for *C. longa*, 27.47 ± 6.943% for *A. indica* and 33.79 ± 2.926% for *A.occidentale*. Streptokinase (positive control) showed 86.2 ± 10.7 % clot lysis effect. Hence, herbal preparations possess in vitro thrombolytic potential[60].

5.16 *Mast Cell Stabilizing Potential*

Ethanolic extract of *O. sanctum*, flavonoid fraction and standard (Prednisolone) were given for 14 days to albino rats sensitized by horse serum and triple antigen containing *B. pertussis*. Mast cell of intestinal mesentery was studied. Mast cell degranulation up to 12.55% and 80.90% was seen in unsensitized and sensitized rats, respectively. Standard and ethanolic extract inhibited mast cell degranulation to an extent of 72.25% and 62.44% (100 mg/kg body weight) and 67.24% (200 mg/kg body weight), respectively. By flavonoidal fraction, 54.62% and 60.48% inhibition at 75 and 150 mg/kg body weight, respectively, was observed[61].

5.17 *Anti cataleptic Potential*

Anticataleptic potential of a polyherbal formulation NR-ANX-C (containing *W. somnifera,O. sanctum, C. sinensis*, triphala and shilajit extracts) in intraperitoneally (1mg/kg) induced haloperidol catalepsy in mice was studied. Five groups of male albino mice were made. Cataleptic score was measured as the time the animal maintained an imposed posture. Scopolamine (1 mg/kg) was used to compare the anticataleptic potency of herbal formulation (10, 25 and 50 mg/kg). Oxidative stress and degree of catalepsy was also estimated by superoxide dismutase level in brain tissue. Minimum cataleptic score was in the NR-ANX-C (25 mg/kg) treated group and minimum SOD activity was in the same group[62]. *O. sanctum* anti-cataleptic activity was studied considering 2.7% ursolic acid in it, which has antioxidant properties. Haloperidol (1.0 mg/kg i.p.) was used to induce catalepsy. After 15 min, significant reduction

of cataleptic score was observed on a standard bar test with the standard drug Levodopa (30 mg/kg, i.p), the aqueous extract (300 mg/kg, i.p) and the alcoholic extract (300 mg/kg, i.p) of the leaves of *O. sanctum*. Except 0 and 15 min, the results were significant for alcoholic and aqueous extracts[63].

5.18 *Anti anxiety Potential*

O. sanctum extract (100 mg/kg body weight) was evaluated for its effects on restraint stress in rats. Memory impairment resulted in mice due to 21 days' stress. Decrease in latency to enter the target quadrant in Morris water maze test compared to the stressed animals and increase in latency to enter the dark compartment during retention test in passive avoidance tests both after 24 hours and 48 hours, were the positive results after oral feeding of the extract. Memory was also improved in stressed rats. *O. sanctum*, thus, has anti-stress potential[64]. Antifatigue activity of 70% alcoholic extract of *O. sanctum* was investigated in rats. *O. sanctum* extract (150, 300 and 450 mg/kg b.wt.) was given every day along with weight-loaded forced swim test on alternate days. Test was conducted for a period of 2 weeks. *O. sanctum* lowered malondialdehyde (MDA) and lactic acid levels in liver and muscle tissues. Serum biochemical parameters also reduced. Best performance against fatigue was observed at 300 mg/kg b.wt. dosage[65].Comparative antidepressant activity of *O. sanctum* (OS) and imipramine using animal models of depression was carried out. Forced Swimming Test (FST), Reserpine Reversal Test (RRT), Haloperidol- Induced Catalepsy (HIC) and Pentobarbitone Sleeping Time (PST) in male wistar rats were used as models of depression study. Imipramine (15 mg/kg/i.p) and herbal extract of OS (500 mg/kg/p.o) was given. Reduction in immobility time in FST, RRT and protection against HIC, compared to control, respectively, was observed after single administration. The antidepressant activity of OS was comparable to imipramine and indicates the potential for its use as an adjuvant in depression treatment[66].Thirty-five volunteers (21 male and 14 female) of average age 38.4 years were given *O. sanctum* extract (500 mg/capsule, twice daily, p.o. after meal). Standard questionnaires based on different psychological rating scale at baseline (day 0), mid-term (day 30) and final (day 60) were used for clinical investigations. Results revealed that *O. sanctum* significantly ($p<0.001$) lessened anxiety disorders, correlated stress and depression and increased the willingness to adjustment. *O. sanctum* is an anxiolytic agent[67].

5.19 *Termite and Mosquito Repellency Potential*

Antitermitic activity of crude extracts (hexane, butanol, chloroform, methanol, ethyl acetate and water extracts) of inflorescence, leaf, root and stem of *O. sanctum* was studied against the termite species, *H. indicola*. After eleven days, the result was maximum for ethyl acetate leaves extract giving termite mortality of 84.45 ± 27.21 and minimum mortality was seen for stem extract of water i.e. 43.89 ± 39.97. Maximum repellency (29.1) was seen for methanol root extracts while minimum (21.3) for water extracts[68]. Ether extract of *O. sanctum* was tested at 150, 200, 230, 250, 300, 350, 400, 450, 500, 550, 650 and 900 mL volume against *Anophele*, *Culex* and *Ades* of adult 3-5 days old mosquitoes in small net, large net and large room conditions. High concentration of *O. sanctum* leaf extract showed greater repellent activity in all net containing mosquitoes, whereas,low concentration of extract showed greater activity in small net but lesser in large net. Hence, high concentration of *O. sanctum* leaf extract can be used in mosquito repellent formulation[69]. Antiviral activity of methanolic extracts of *A. paniculata, C. limon, C. citratus, M. charantia*, *O. sanctum* and *P. citrosum* on dengue virus serotype 1 (DENV-1) was evaluated. Maximum non-toxic dose (MNTD) was in the decreasing order of *M. charantia*>*C. limon*>*P. citrosum*, *O. sanctum*>A. paniculata>*C. citratus*. Antiviral assay showed that *A. paniculata* had the most viral inhibition followed by *M. charantia*. Extracts of *O. sanctum* and *C. citratus* showed less inhibition effect[70].

5.20 *Chemopreventive Potential*

Study of the chemopreventive activity of ethanolic leaf extract of *O. sanctum* on cell proliferation, apoptosis and angiogenesis during N-methyl-N'- nitro-N-nitrosoguanidine (MNNG)-induced gastric carcinogenesis was carried out on rats. Four groups consisting of ten rats each were made. Group 1 rats received MNNG (150 mg/kg body weight) by intragastric intubation three times (two week interval between treatments). Group 2 rats, in addition to MNNG (150 mg/kg body weight), received ethanolic *O. sanctum* extract (300 mg/kg body weight) three times/week. Group 3 rats were given ethanolic *O. sanctum* extract (300 mg/kg body weight) only. Group 4 was the control. After 26 weeks, all the rats were killed. *O. sanctum* extract lessened the symptoms of MNNG-induced gastric carcinomas[71].

5.21 *Genoprotective Potential*

The blood of cigarette workers was found to be genotoxic. When they were given essential oil of *O. sanctum* (12 μg/mL of culture) the toxic effect reduced, thus, showing the genoprotective role of the herb[72].

5.22 *Plant Disease Resistance Potential*

Activities of enzymes of rice seeds (Phenylalanine amino lyase (PAL), Catalase, Peroxidase, Polyphenol oxidase (PPO) and Tyrosinase) were studied. Exposure of fungus *R. solani* with control was done after the seeds were treated with leaf extracts of *C. citrus* and *O. sanctum*. Then mechanism of different enzymes was studied (0, 24, 48, 72, 96 and 120 hours after fungus exposure). *C. citrus* resulted in 2-4 fold increase in enzyme activities and *O. sanctum* in 2-

3 fold increase. Ethanolic leaf extracts gave best results[73]. The pathogenic fungus *F. solani*f. sp. melongenae was isolated from infected plant parts. *A. indica, A. annua, E. globulus; O. sanctum* and *R. emodi* plant extracts (5, 10, 15 and 20% concentration) were tested to control brinjal wilt pathogen. Considerable reduction in the growth of pathogen was observed[74]. Control of powdery mildew of Bhendi (*E. cichoracearum*DC) was carried out by ten treatments *P. fluorescens*I18 (0.2%), *P.fluorescens*1(0.2%), *O. sanctum* 10%, Neem Seed Kernel Extract 5%, K_2HPO_4 50 mM, Salicylic acid 1mM, *O. sanctum* 5% + *P. fluorescens*I18 (0.2%),Neem Seed Kernel Extract 5 % + *P. fluorescens*I18 (0.2%), Carbendazim 0.1% and control. Two sprays with the time interval of 30 and 60 days after sowing were given. Neem Seed Kernel Extract 5%+ *P. fluorescens*I18 0.2% followed by 9.49% with *P.fluorescens*I18 0.2%, 10.36% with carbendazim and 11.9% with *P. fluorescens*-1 gave disease incidence of 8.83% (minimum value). As compared to control, NSKE 5%+*P. fluorescens*I18 followed by 42.44% in *P. fluorescens*I18, 41.84% with 0.1% carbendazim and 39.73% with *P. fluorescens*-1 also increased the yield to 43.43% over control[75].

5.23 *Europathogen Resistance Potential*

Essential oils of *C. aromaticus* and Rama and Shyama Tulsi were tested for anti-urinary tract infection potential. Rama Tulsi and *C. aromaticus* oils proved to be most active against bacteria causing infection, whereas, Shyama Tulsi was least potent. Concentrations of 0.5 μL/mL-6 μL/mL (MIC) gave best results[76].

6. CONCLUSION

Plants are used as medicines since the beginning of mankind. In this modern era of research and development, herbal medicine is not kept unnoticed and plants are still used either as medicine or medicinal substitutes. *O. sanctum* has gained extra importance in the field of ayurvedic (herbal) medicine because of its vast pharmacological activities which are increasing day by day with research. Recently work has been done to compare the phytochemistry and pharmacology of *O. basilicum* and *O. sanctum*[77]. The present review focuses on the botanical characteristics, phytochemistry and ethno medicinal and pharmacological applications of the herb. Study on *O. sanctum* can lead to improvement of synthetic medicine and can make the availability of low cost drugs to people.

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