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Tulsi-botanical variants, uses, constituents, and mode of working

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Abstract
There is increasing awareness and need for strengthening body's immunity. Tulsi is one among the plants that has potential to do so. The traditional sacred plant of India known for its medicinal and other uses is more relevant today than ever before. It is time to know more about different aspects of the adaptogenic herb and go all-out for its spread and use. This paper describes botanical variants of the plant, its medicinal and other uses, principal active constituents and their working at cellular level.

Keywords: medicinal plant, green pharmacy, green pesticide, antioxidant, COX-2

Introduction

Use of medicinal plants as such and herbal products is increasing steadily, principally to keep off accompanying ill effects of synthetic chemicals. Additionally, some among them strengthen body's immunity in fighting infecting pathogens. Need for such immunity was realized more since the breakdown of SARS-CoV-2 (Covid-19) pandemic in early 2020. It is now amply clear that enhanced immunity and oriental lifestyle are simple ways in hand to fight the pandemic. Much familiar adaptogenic Indian herb Tulsi or Tulusi (Holy basil, referred also by other names like Vrinda, Manjari, Vaishnavi and Tritattu) is an important plant in the context. Boosting body's immune system apart, tulsi mitigates many health hazards associated with sedentary lifestyle, obsession with junk food, obesity, diabetes, depression, inhaling odious automobile fumes and industrial discharges, and physical and mental stress to which today's fast spaced life is exposed to. It is an opportune time to know more about this sacred herb, plethora of its benefits and go for its extensive growing.

Tulsi in Indian Ethos

Tulsi (Sanskrit word meaning 'incomparable'), a much revered plant in the tenets of Hindu beliefs, is considered as the earthly manifestation of Goddess Lakshmi. Legend says that Tulsi was an ardent lover of Lord Krishna and so was cursed by Radha, the Lord's companion to descend on the earth as a plant. The holy plant occupying a high place in Indian ethos is grown in a specially built structure in the courtyard (tulsi manch) and treated like the temple in home. In urban dwellings with space constraint, tulsi is grown in earthen or masonry or plastic pots. Lighting of a lamp (deep/deepam) near the plant at dusk is a daily ritual in many homes. It is believed that death fears to enter a home where the divine plant is worshipped. Nurturing of the plant is said to lead to moksha (salvation), while uncared withering hinders the way for good fortune. Wearing tulsi mala (a string of beads, usually 108, carved from stem) during chanting of prayers marks veneration to God and integrates body, mind and soul during meditation.

Botanical Variations

Tulsi, a native of Indian subcontinent belonging to mint family, is an annual or short- lived perennial herb (~ 1 m) with square or quadrangular shaped green or reddish-brown branched hairy stems with a pubescent layer. The petiolate green or purple ovate or serrate or elliptical leaves, opposite in orientation, depending upon the species emit a distinct aroma sufficient for detection from about 100 m. Blooming is round the year. Flowers borne in verticillasters are small, tubular and are white or purple in hue with distinctly visible green or pinkish sepals. Fruits are nutlets and produce numerous seeds. The branched roots penetrate to a small depth permitting its growing in small shallow pots. Tulsi, a member of Lamiaceae family, belongs to the genus *Ocimum* (Greek 'Okimon' meaning aroma) under which there are 160 plus species. Among the seventeen species of *Ocimum* of any significance *viz. O. sanctum, O. tenuiflorum, O. kilimandscharicum, O. gratissimum, O. basilicum, O. camphora, O. canum, O. americanum, O. centraliafricanum, O. ovatum, O. micranthum, O. campechianum, O. citriodorum, O. viride, O. suave, O. selloi* and *O. minimum*, four are domesticated in India (Table 1). Cultivars of each of four species testify intraspecies botanical variations.

Table 1: Characteristics of *Ocimum* spp domesticated in Inia

Species	Known in local parlance as	Identifying features	Characteristics
O. sanctum (sanctum, Greek meaning sacred)	Rama tulsi	Shining green leaves (green leaf tulsi). Light purple flowers with a clove like aroma due to eugenol, the Phenolic substance in clove.	Grown in home and temple. High medicinal value.
O. tenuiflorum	Krishna or shyama tulsi	Purple leaves (purple leaf tulsi) with a peppery flavour. Botanical name derived from tender nature of the	Do

		phyllotaxic leaves.	
O. kilimandscharicum	Karpoor tulsi	Shining green leaves. High camphor (karpoor), a sublimate substance, content in plant parts, especially leaves.	Less medicinal value. High microbial action due to camphor.
O. gratissimum	Vana tulsi (wild leaf tulsi)	Less or unmodified form of the wild variant. Taller than other three (~ 3 m) with woody stems and lime-Coloured leaves with coarsely serrated edges.	Least medicinally potent due presumably to low phenolics content and antioxidant property.

Uses of Tulsi

In medicine

Ayurveda mentions use of crude tulsi preparations in folk medicine as remedies for health disorders ranging from cosmic to cosmetic in India and South East Asia during 3000 to 5000 B.C. Nagarjuna, the ancient philosopher, alchemist and physician, who first redacted *Sushruta Samhita* - the first treatise on medicine and surgery - described medicinal use of a plant during 1st century A.D. referring to tulsi, suggesting that the plant was then known by other names. The ancient medical wisdom of India was largely due to medicinal properties of tulsi. Tulsi was in use in other traditional systems of medicine too like Unani and Siddha. Roman, Greek, Mediterranean and other early civilisations too recognized medicinal use of tulsi. In Ayurveda, a glass of water treated with tulsi leaves in empty stomach is recommended for proper bowel movement and preventing abdominal bloating, colic pain and acid refluxes. Hot concoctions of tulsi with honey and ginger are used as remedies for common colds, fever, cough and sore throat, cephalalgia, malaria, influenza, inflammation, insomnia, wounds, skin infections, and relief from physical and mental fatigue. Concentrated decoctions are used for treating nausea and as vermifuges for deworming in man and bovine animals. Tulsi finds use also as a bronchodilator in providing relief to asthmatic discomfort and children down with measles. Village folk use tulsi as antidotes for stinges by wasp, bee and scorpion.

Tulsi oil rich in volatile constituents with pharmacological significance is used in aroma therapy and in making herbal toiletries *viz*. soaps, perfumes, tooth pastes and dental creams, gargling solutions, and mouth washes to keep off foul breath. Boiling fresh leaves with water for 20 minutes and then gargling with the cool filtrate for half a minute removes dental plaques and inhibits the growth of *Streptococcus mutans* responsible for tooth decay. Chewing or swallowing three to four fresh leaves in a gulp of water is also a common practice. The latter, chewing albeit more effective, boosts up body's immunity. Currently however, the steam volatile yellowish green oil extracted from leaves and flower spikes (0.1 to 1% yield on fresh weight) is more in use than fresh or dried plant parts. Perfect blending of tulsi oil with related oils like citrus, lemon grass, citronella, rose and jasmine oil enhances olfactory and medicinal property of the blended oil. Such preparations are as effective as commercial preparations containing eucalyptol and chlorhexidine gluconate. Tulsi proved effective in retarding the growth of tumor and cancer cells by reducing DNA damage and inducing apoptosis in experimental precancerous and cancerous cells, thus enhancing the recovery and survival of affected cells. Besides, some of the constituents possessing diuretic property reduce the formation of uric acid which forms stones in kidney and gets accumulated in joints causing gout, while some others lower blood glucose level, especially in Type 2 diabetics. Tulsi finds use also as a mind altering, and mood and memory enhancing agent, not however, acting like the usual agonistic psychoactive substances e.g. caffeine and nicotine present in tea and coffee, and tobacco, which if taken regularly forms a scheduled addiction. Tea and coffee replaced in part by similar preparations of tulsi give enormous health benefits and are no habit forming. In practice, medicinal properties of the constituents in isolation are often lower than the whole herb or its oil signifying that therapeutic properties result from synergism of one or more active constituents in their native state. Research results affirmed that the plant's unique composition of the pharmacological constituents can lower metabolic and psychological stress often resulting in morbidity and even mortality. Justifiably, tulsi is now in high demand across the world. India generates considerable foreign exchange through its export to Middle East, Europe, and North and South America.

In culinary

Essential oil of tulsi, especially karpoor tulsi rich in camphor, is used in packaging delicacies *viz*. pickles, sauces, ketchups, fruit drinks, beverages and confectionaries. Tea (black or green) can too be brewed with tulsi. Such tea preparation, often further blended with ginger and turmeric, is nourishing for the body and mind, and helps regain the frayed nervous system of the body. Such blended tea leaves are now available in packets/sachets in supermarkets. Acclaimed chef Ms Tarla Dalal described many recipes of tulsi tea and their benefits. One by name Detox Tea is prepared by boiling chopped tulsi leaves (1 tbsp) with Chopped ginger (1 cup), lemon juice (11 tsp), cloves (4), cinnamon powder (11 tsp) and chopped 3 4 4 lemon grass (1 cup) in 41 cups of water for 4 minutes followed by filtering and adding honey 4 2 (11 tsp) and a piece of candy (optional for enhancing taste) to each cup of decoction. Caffeine 2 and tannins free tea so prepared is soothing, tastes fine and can be taken six times in a day. For preparing juice, freshly cut foliage (1 cup) is macerated with water (1 cup) to a fine paste in a 2 blender followed by filtering and squeezing. One cup fresh juice a day greatly rejuvenates the body's immune system in fighting against invading pathogens. The fresh juice can be used also as a poultice on skin for curing fungal infections.

For clean air

Tulsi helps combating air pollution in cities and towns. A massive tulsi plantation was launched in 2010s to protect the majestic iconic Taj Mahal from being affected by air loaded with particulate matter and obnoxious gases. The drive was intended to provide an ecoprotection cover to the 17th

century mausoleum, Agra Fort and Ait-ul-Daula tomb, three world heritage monuments in the Taj Trapezium Zone.

In pest control

Some of the constituents of tulsi present especially in the leaves possess insecticidal, insect ovicidal, insect repellent and fungicidal properties. Tulsi was thus used in the past in pest control in field agriculture and storage of farm produce.

Principal Constituents with Pharmacological Significance

A tulsi plant is a storehouse of hundreds of substances with diverse chemical nature and functions, many with characteristic aroma and therapeutic value. Majority of them are phenolics, terpenes and terpenoids, alcohols, carboxylic acids and unusual monosaccharides. Most of them are secondary metabolites of the plant. Phenolics are the most abundant and account for nearly 50% of all the constituents in the essential oil. The composition however, varies depending upon species and cultivar, climate, geography, soil, package of agronomic practices, age of the plant, time and processing of harvest and the conditions of storage. Principal constituents of the plant and its oil are listed (Table 2).

Table 2: Principal Constituents of Tulsi with Pharmacological Significance

Constituent	Molecular formula & IUPAC name	Chemical nature	Characteristics
Eugenol and methyl eugenol	$C_{10}H_{12}O_2$ 1-Hydroxy-2-methoxy4-allylbenzene $C_{11}H_{14}O_2$ 1,2-Dimethoxy4-allylbenzene	Monoterpenoids. Phenolic Compounds. In methyl eugenol, the hydroxy (OH) group of eugenol replaced by a methoxy (OCH_3) group.	Most abundant constituents of tulsi oil. Impart a spicy Flavour. Possess insect ovicidal and repellent action. Antifungal, especially for yeasts, filamentous food-borne fungi and plant pathogenic *Botryosphaeria rhodina* and *Alternaria* spp. Methyl eugenol is less bioactive, but more stable.
Ocimenes	C10H16 3,7-Dimethylocta- 1,3,6-triene	Acyclic monoterpenes. Hydrocarbons. Trans-β-ocimene is the most abundant.	Impart a citrusy flavour and used in perfumery. Act as pollination markers, help plant defence against insects, fungi, parasites and predators and social regulation of honey bee colonies due to pheromone property. Anticonvulsant, anti-inflammatory, antihypertensive and antidiabetic (Type 2). Used in aroma therapy (green Pharmacy).
Ursolic acid	C30H48O3 (3β),3-Hydroxyurs-12- en-28-oic acid	Pentacyclic triterpenoid. Carboxylic acid.	Reported for molecular docking over SARS-CoV-2 membrane protein with possibility of future application in the design of drugs against the virus. Antimicrobial, antiatherosclerotic and gastroprotective. Antiestrogenic activity holds promise for future antifertility agents by Structural modifications of the molecule.
Camphene	C10H16 2,2-Dimethyl-3-methylidenebicyclo[2.2.1]heptane	Monoterpene. Bicyclic hydrocarbon.	Emits an acrid smoke. Antibacterial, antifungal and mosquito repellent. Anti-inflammatory, bronchodilator, lowers 'bad cholesterol' and used in cardiovascular treatment. Used as a food additive for flavouring.
Chavicol and methyl chavicol/estragole	C9H10O 4-Allylphenol C10H12O 4-Allylanisole	Monoterpenoids. Phenolic Compounds. In methyl chavicol, the phenolic hydroxy (OH) group of chavicol replaced by a methoxy (OCH3) group.	Safer alternatives of chlorine solutions for Enhancing shelf life of green vegetables. Effectiveness of incorporation of some herbal oils into edible oil coatings over the packaging film is due to these two substances in the former. Methyl chavicol is antimicrobial, cures
			Vomiting and loose motion, and provides soothing in bee stinges.
Methyl cinnamate	$C_{10}H_{10}O_2$ Methyl (*E*)-3-	Methyl ester of cinnamic acid.	Attractant for many insects for its sweet aroma and fruity smell like that of cinnamon. Content is

	phenylprop-2- enoate		maximum at seed setting stage. Used in flavouring food delicacies and perfumes and as an intermediate in making pharmaceuticals, Disinfectants, pesticides, air purifiers and cosmetics. Ester bond cleavage forms cinnamic acid that does have many medicinal functions.
Neral/Citral	$C_{10}H_{16}O$ 3,7-Dimethylocta- 2,6-dienal	Monoterpenoid. Aliphatic aldehyde.	Lemon like odour, Used in perfumery and fortification of lemon oil. Associated with growth of skin and hair. Used in synthesis of Vitamin A and lycopene.
Linalool	$C_{10}H_{16}O_2$ 3,7-Dimethylocta- 1,6-dien-3-ol	Monoterpenoid. Tertiary alcohol. In tulsi, linalool is present as a racemic mixture.	Pleasant citrusy smell. Used as relaxant and sedative.
1,8-Cineole	$C_{10}H_{18}O$ 1,3,3-Trimethyl- 2-oxabicyclo [2.2.2] octane	Monoterpenoid. Hydrocarbon with a bicyclic ring involving oxygen.	Involved in plant defence. Repellent for many insects E.G. *Aides aegpti* and *Plasmodium falciparum*. Significant insecticidal action against stored grain insect pests e.g. *Sitophilus oryzae, Rhyzopertha dominica* and *Callosobruchus maculatus*. Used in sinusitis and antitussive action because of its nasal decongestion property. Seves as a flavouring agent and as a component in mouth washes and tooth pastes for its antibacterial action against oral bacteria that
			produce foul breath due to substances like mercaptans, H_2S, skatole and aliphatic diamines e.g. putrescine and cadaverine.
*Iso*propyl palmitate	$C_{15}H_{31}COOC_3H_7$(*iso*) Propan-2-yl-hexadecanoate	Carboxyl ester. Isopropyl ester of palmitic acid (16 C saturated unbranched fatty acid)	Present in leaves and oil as a major constituent. Helps binding moisture to skin and hence used in cosmetics (skin Toners and emollients) as a moisturiser. Reduces skin impedance of cosmetics and ointments, Increasing their permeation and efficacy in topical applications.
β-Caryophyllene	$C_{15}H_{24}$ 4,11,11-Trimethyl-8-methylidenebicyclo[7.2.0]undec-4- ene	Sesquiterpenoid. Hydrocarbon with a bicyclic ring.	Insect repellent. Antimicrobial. Used in cosmetics and as food additive. Potential candidate for future use in osteoporosis.

Among the minor constituents, orientin imparts protection against chromosomal damage in lymphocytes caused by short wavelength radiation, while rosemary acid, apigenin, cirsimaritin, isothymusin and isothymonin (all flavones) possess promising antioxidant and anti-inflammatory properties.

Mode of Working

Constituents of tulsi work in different ways ranging from metabolism control to switch- on switch-off of specific genes at cellular level. Diverse modes of working in living cells (Table 3) *viz*. scavenging of free radicals, inhibition of key enzymes, detoxification and excretion of xenobiotics and inhibitory effect on HIV-1 reverse transcriptase bear testimony to the point.

Table 3: Mode of Working of Some Important Functions of Tulsi

Function	Mode of Working
Immunity and defence system	Antioxidants e.g. glutathione (a tripeptide of glutamic acid, cysteine and glycine) act as free radical scavengers. Free radicals are highly reactive molecular species and cause DNA damage, lipid peroxidation, and aggregation to proteins and other key biomolecules, thus disrupting functioning of cellular organelles and their membranes. Enzymes like superoxide dismutase (SOD), glutathione peroxidase (GPX) and catalase (CAT) also have similar function. Thus, SOD enzymatically dismutates highly reactive Superoxide anion (O2-) to form H2O2 which is further acted upon by GPX and CAT to form H2O. Free radicals however, have beneficial roles too e.g. assist immune cells in fighting infections by 'start or Stop' of making necessary proteins. Free radicals thus can be foe or
	Friend and a right between them and antioxidants has to be worked out. Tulsi helps maintaining this balance.

	Vitamin C, zinc and other minerals present in tulsi add immunity in fighting infecting microbes by eliminating toxins secreted by them and damage by pollutants (pesticides, heavy metals and toxic gases in air), side effects by drugs and pharmaceuticals and short wavelength radiation. Increased immunity is in correlation with cytokine secretion, histamine release, immunoglobins formation, antibody class-switching by activated B cells, phagocytosis, and expression of cellular co-receptors and lymphocytes.
Healthy functioning of heart	Due in part to α-linolenic acid, an ω-fatty acid which on metabolism produces eicosapentaenoic acid, a polyunsaturated fatty acid that Prevents coronary heart problems and atherosclerosis, besides acting as a precursor of diverse beneficial biomolecules.
Pain relief, fever and anti-inflammation	Some constituents e.g. eugenol act by inhibiting the enzyme cyclooxygenase 2 (COX-2) as done also by many synthetic antipyretic and analgesic nonsteroidal anti-inflammatory drugs (NSAID). COX-2 catalyses the rate limiting step of the conversion of arachidonic acid to prostaglandins which cause inflammation, mild to moderate pain and fever.
For sore throat and bronchodilator action	Clears off the mucous and helps sweeping out the phlegm and catarrhal fluid from the bronchial tube.
Antitumor and anticancer function	Some constituents enhance the activity of the liver detoxification cytochrome P450 enzymes which transform and deactivate and/or scavenge the xenobiotics out of the body.
Restoring homeostasis	Does so by acting as an adaptogen in assessing prevailing unusual conditions, if any, and then doing the required biological adjustment in restoring the body's derailed homeostasis. Acting this way, tulsi helps in getting rid off fatigue and depression.
Antifertility function	Alters lipid metabolism leading to antiestrogenic activity. The latter changes the functional quality of spermatozoa, reduced spermatogenesis and a decreased sperm count in males and implantation of ovum in females in rats as experimental animals.
Insecticidal activity	Insecticidally active constituents act by blocking voltage-activated sodium channels of insect cells, modifying physiological processes such as endocrine regulated growth, producing growth hormones, and impairing nervous system by inhibiting the enzyme acetylcholinesterase.

Growing Tulsi and Priority Research Areas

In view of enormous health benefits, other uses, and export potential, all-out efforts with innovative methods are to be launched for largescale growing of tulsi. In a novel approach, Tirumala Tirupati Devasthanam has been using compostable bags in place of usual plastic bags for selling laddu prasadam to devotees. The bags have a triangular patch at one end filled with tulsi seeds (~ 200). When thrown after use, the seeds accelerate the decomposability of the Green mantra bags and germinate under favourable conditions. Even with a small success rate in germination, there shall be many tulsi plants around us. Merely more plants alone however, shall not suffice. Genetic manipulation, genome sequencing and gene transfer *inter alia* between cultivars and species are to be tried for more biologically potent plants. Research works have already commenced towards these directions.

Summary

Tulsi, the sacred herb, is a much like a green pharmacy in home. Many countries across the world acknowledged tulsi's medicinal properties *viz*. antimicrobial, antispasmodic, gastroprotective, anticancer and antidiabetic. Tulsi helps relieve physical and psychological stress too. With new diseases like SARS-CoV-2 with no proven remedies and today's stressful lives with mentally crowded schedules, often complicated further by hypertension, diabetes and obesity, regular consumption of tulsi shall contribute much towards good health. It is an opportune time to know the plant more, make best use of it, go all-out for its growing in fields along the bunds and home with the mantra '*ghar ghar tulsi, har ghar tulsi*' (grow tulsi in each home) and fix priority research areas for harnessing the plant's potential.

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