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# Volatile Composition and Biological Activities of Tagetes (Marigold): An Overview

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## Abstract

*Tagetes* commonly known as wild marigold is a plant belonging to family Asteraceae. *Tagetes minuta* L., commonly known as African marigold, is reputed as a source of '*Tagetes* oil' of trade that finds an extensive use in food, flavoring, pharmaceutical, perfumery and cosmetic industry. The plant is valued for its essential oil, which is present almost in every part of the plant with little percentage in the stem and roots. The plant is native to South America and has been introduced to many countries since the time of Spanish conquest. Many species of this genus, such as *T. minuta, T. erecta, T. patula*, and *T. tenuifolia*, are cultivated as ornamental plants and studied for their medicinal properties based on the basis of their use in folk medicine. Different parts of the *Tagetes* species are used as remedies to treat various health problems, including dental, stomach, intestinal, emotional, and nervous disorders and muscular pain, across the world. Furthermore, these plants are studied in the field of agriculture for their fungicidal, bactericidal, and insecticidal activities. The plant occurs in temperate forests and mountain regions of the world. Himachal Pradesh, Uttrakhand and Jammu & Kashmir are the main sources of "*Tagetes* oil" in India where it occurs at an altitude of 1000 to 2500m AMSL. The major constituents (90-95%) of *Tagetes minuta* essential oil are Z-ß-ocimene, limonene (hydrocarbons) and acyclic unsaturated monoterpenes ketones, dihydrotagetone, tagetones (E, Z) and ocimenones (E, Z). The plant possess pharmacological, phytotoxic effect, antibacterial and antifungal effect, insecticidal properties, nematicidal properties, antiviral and antimicrobial activity and also find use in perfume and flavour industry. Its oil has a great demand, so the species holds a lot of potential for undertaking its large-scale cultivation.

**Keywords:** *Tagetes Minuta*; Marigold; Essential Oil; Plant

## Introduction

*Tagetes* (marigold) is an important genus belonging to the Asteraceae family and consists about 56 species [1]. The genus *Tagetes* (Asteraceae), is native to the central and southern parts of America, Argentina and Mexico. Most members of this genus are annual and perennial, branched herbs or shrubs known for the horticultural and essential oil-yielding purpose [2,3]. Members of the genus *Tagetes* have a long history of human use as beverages, condiments, ornamentals, and medicinal purpose such as analgesics, antiseptics, carminative, diuretic, antispasmodic,

anthelmintic, stimulants, vermin repellents, and for treatment of stomach and intestinal diseases. Different parts of the *Tagetes* species are used as remedies to treat various health problems, including dental, stomach, intestinal, emotional, and nervous disorders, as well as muscular pain, across the world. Furthermore, these plants are studied in the field of agriculture for their fungicidal, bactericidal, and insecticidal activities. [4-6]. *Tagetes minuta* L., commonly known as African marigold, is a highly aromatic annual perennial herb growing naturally as weed and/or cultivated for 'Tagetes oil' of trade [7]. *T. minuta* used in indigenous medicines as a natural source of raw material due to its anti-microbial, anti-inflammatory, anti-fungal insecticidal and acaricidal activities [8-10]. Moreover, the essential oil of *T. minuta* finds an extensive use in food, flavoring, pharmaceutical, perfumery and cosmetic industry [11]. *Tagetes* oil is commercially produced mainly in Argentina, Australia, Brazil, France, Spain, Venezuela, Iran and other countries. Tagetes oil and its terpene constituents has been reported to possess antibacterial, antiinflammatory, hypotensive, larvicidal, insecticidal, aphicidal activities [10-14]. *Tagetes* spp. can be cultivated as ornamental plants or can be found as wild species [15]. There are many species of this genus, such as *T. minuta, T. erecta, T. patula*, and *T. tenuifolia*, that are studied because of their application in the field of agriculture, where they exhibit fungicidal, bactericidal, and insecticidal activities, as well as anticancer properties [16,17], resulting in their exploitation as beverages and condiments in folk medicine [18,19]. Marigold extracts are characterized by the presence of diverse compounds with different properties, namely phenylpropanoids, carotenoids, flavonoids, thiophenes, and others [20,21]. A search for this study comprises the medicinal plant knowledge from previously published articles in databases that include indexed journals. The databases evaluated were Science Direct, Scielo, Web of Science, Scopus and the publications from all years included in the databases were evaluated [22].

## Distribution and Plant Cultivation

*Tagetes* spp. especially *Tagetes minuta* has been widely cultivated around the world due to its agrochemical and pharmacological properties [23]. Native to South America including countries like Argentina Chile, Bolivia, Peru and Paraguay [24,25]. It has been introduced in Europe, Asia, Africa [26-29], India [30] and Australia [31]. It has been deliberately distributed across the tropics, subtropics and several temperate countries as an ornamental, medicinal or perfume plant as well as accidentally as a weed [32]. According to Maheshwari [33], its plants have naturalized themselves in Himalayan and sub Himalayan regions up to 2000 m in waste places, roadsides, rocky hill slopes and cultivated fields of Uttarakhand, Uttar Pradesh, Himachal Pradesh, Sikkim, Arunachal Pradesh, Nagaland and Meghalaya. According to Thappa, et al. [34], the plant is found in the western Himalayas of India between altitudes of 1000 to 2500 m. Himachal Pradesh, Jammu & Kashmir and hills of Uttar Pradesh are the main growing regions where it occurs in its natural habitat. The Wild growth of *Tagetes minuta* in these regions forms the most important source of '*Tagetes oil*' in India [35]. The wild growth of *T. minuta* in these regions forms the most important source of "*Tagetes* oil" in India [36]. Mild climates are most suitable for the luxuriant growth of *Tagetes* species. Flowering in these species greatly improves during mild climates in temperatures ranging from 14.5–28.6°C. The essential oil composition of fresh aerial parts of *T. minuta* var. Vanphool were harvested in four different growth stages, viz. flower initiation, full flowering, late flowering and seed setting stages from the winter crop with soil condition as was sandy-loam in texture, with neutral pH. The maximum temperature ranges between 35-45°C, and minimum between 25°C, was reported from Uttrakhand. The major constituents distributed in essential oils were (*E*)-ocimenone, (*Z*)-ß-ocimene, (*Z*)-tagetone and (*Z*)-ocimenone as major components [37]. Sandy loam is ideal for the cultivation of *Tagetes* spp. The crop of *Tagetes* is suitable for cultivation in the plains and on the hills, as a monocrop or intercrop in orchards/forest aromatic trees or as widely spaced crops such as rose-scented geranium. It is amenable for integration with traditional agricultural or aromatic crops in suitable field rotations. Cool temperatures induce germination, whereas high temperatures encourage profuse vegetative growth and flowering. Direct seeding (2.0–2.5 kg seeds/ha) or transplanting of 100–200-mm-long 30–60-day-old seedlings (0.50–0.75 kg seeds/ha for raising the nursery) with (300–600) x (150–300) mm spacing is practiced. Closer spacing of 300x (150–300) mm for direct broadcasted or line-sown seeded crops and a wider spacing of (450–600) x300 mm for transplanted crops is recommended. In less fertile soils, a closer spacing of 300x300 mm is suggested. Seeds germinate in 7–10 days [38]. Nipping apical buds 50–60 days after seed sowing or 30–45 days after transplanting promotes the growth of branches and produces a crop canopy with a higher proportion of leaves and flowers. The crop can withstand short periods of moisture shortage. Phosphorus and potassium are usually applied basally, while nitrogen is applied in three equal splits upon planting, active vegetative, and flower bud initiation stages. Wild marigold is harvested manually with sickles during full flowering (4–7 months duration) or seed setting stages 200–300 mm above ground level [39-41]. Crop duration is short (main 10 days, ratoon 30–60 days) in south India irrespective of whether the crop is planted in rainy (July/September) or winter (December) seasons [42,43]. In the rainy seasons, weeds become the major problem for the yield of marigold. If the weeds are not removed in time, great loss occurs in terms of growth and productivity [22].

## Biological Activities of *Tagetes* Spp.

Essential oils (EOs) have been recognized to possess several different biological activities for a long time. Several among these secondary plant metabolites exhibit marked antimicrobial effects that have made their use as an antiseptic and/or preservative in food well known, since the ancient times. Some common biological activities of *Tagetes* spp. are given below.

| S. No | Name of species | Biological activities | References |
|---|---|---|---|
| 1. | *Tagetes minuta* | Strong antibacterial activity against following strains reported-*Escherichia coli, Klebsiella pneumoniae, Pseudomonas auregnosa, Salmonella typhi, Staphylococcus aureus, Streptococcus viridian*, *Bacillus licheniformis, Bacillus subtilis* and *Pasteurella multocida* | [44-49] |
| 2. | *Tagetes minuta* | Oil showed repellent and growth inhibitory properties against insect pests larvicidal activity of oil against larvae of *Ades aegypti* | [50-52] |
| 3. | *Tagetes minuta* | Antifungal activity reported as-*Rhizoctonia solani*, *Fusarium oxysporum*, *Penicillium digitatum*, *Aspergillus niger, Verticillium fungicola* and *Trichoderma harzianum* | [53-55] |
| 4. | *Tagetes minuta* | Effectiveness of EOs of *T. minuta* against mosquitoes of *Anopheles gambiae* | [56] |
| 5. | *Tagetes minuta* | Phytotoxicity activity reported toward common weeds, including green amaranth (*Amaranthus viridis*), vegetable amaranth (*A. tricolor*), hairy beggars tick (*Bidens pilosa*), little seed canary grass (*Phalaris minor*), nettle leaf goosefoot (*Chenopodium murale*), and barnyard grass (*Echinochloa crus-galli*) | [57] |
| 6. | *Tagetes minuta* | Extracts obtained from leaves of *T. minuta* showed antimicrobial activity against both Gram-positive and Gram-negative bacteria | [58] |
| 7. | *Tagetes terniflora* | Extracts at concentrations of 200 mg/mL, except for bacteria *Zymomonas mobilis* and *Lactobacillus plantarum*, and yeast *Saccharomyces cerevisiae* | [59] |
| 8. | *Tagetes lucida* | Extracts also showed high activity against Gram-negative bacteria and phytopathogenic fungi in the study conducted by Cespedes et al. | [60,61] |
| 9. | *Tagetes patula* | Antifungal effect on *Penicillium digitatum* and *Botrytis cinerea* strains | [62] |
| 10. | *Tagetes patula* | Volatile oil from the *T. patula* leaf on a *C. albicans* strain by disc diffusion. Miconazole (1000 µg/mL) and clotrimazole (1000 µg/mL) were used as controls. The result recorded an inhibition zone of 7.7 mm, a result similar to the inhibition determined for miconazole (10 mm) and clotrimazole (9.3 mm). The MIC for the essential oil was 3180 µg/mL | [63] |
| 11. | *Tagetes putula* | Volatile oil was investigated against the *C. albicans* strain using the cavity diffusion method. Alzamora et al. used micoral (100 mg), sporostantin (330 mg), mycostatin (10,000 UI/mL), and oxonasol (200 mg) as controls. he EO showed good anticandidal activity with a 26-mm inhibition zone, compared to any statin | [64,65,71] |
| 12. | *Tagetes erecta* | Volatile oil was investigated against microorganisms in vitro *Alcaligenes faecalis, Bacillus cereus, Campylobacter coli, E. coli, K. pneumoniae, P. aeruginosa, Proteus vulgaris, Streptococcus mutans,* and *Streptococcus pyogenes, B. cereus, B. subtilis, S. aureus, Staphylococcus albus, Bacillus megaterium, Listeria monocytogenes, Corynebacterium rubrum, E. coli, Pseudomonas pseudoalcaligenes, Pseudomonas testosterone, Proteus morganii, P. aeruginosa, Enterobacter aerogenes, K. pneumoniae, Proteus mirabilis, C. albicans, Cryptococcus neoformans, Candida glabrata,* and *Candida apicola E. coli, C. albicans* | [66-71] |

## Volatile Composition from *Tagetes* Species

There are a number of *Tagetes* species and the volatile oils reported from different parts of these species, as aerial, capitula reported. Volatile oils reported from aerial parts of *T. patula* from India, Egypt, and South Africa showed the presence of (*Z*)-ß-ocimene and (*E*)-ß-ocimene, limonene, (*E*)-tagetone and (*Z*)-tagetone, methyl heptenol, ß-caryophyllene, piperitone, piperitenone, ά-terpinolene, (*Z*)-and (*E*)-tagetenones, (*Z,Z*)-alloocimene, and (*Z*)-ß-ocimene epoxide respectively [72,73]. Singh and coworkers reported components of volatile oils from capitula or whole

flowering plants from Kashmir and Himachal Pradesh (India) which is dominated by (*Z*)-ß-ocimene, (*Z*)-and (*E*)-tagetenone, dihydrotagetone, (*Z*)-and (*E*)-tagetone and volatile oils reported from Lucknow (India) dominated by dihydrotagetone, (*Z*)- and (*E*)- tagetone, (*Z*)- and (*E*)-tagetenone, (*Z*)-ß-ocimene [73,74]. Volatile oils reported from Zambia and Andhra Pradesh (India) dominated by dihydrotagetone, (*Z*)-ß-ocimene, (*Z*)-and (*E*)-tagetone, (*Z*)- and (*E*)-tagetenone [73]. According to Gupta and Vasudeva [72] volatile oils of mature fruits with seeds of *T. lucida* contained (*Z*)-ß-ocimene, (*Z*)-tagetone, (*Z*)-tagetenone, and (*E*)-tagetenone, in addition to dihydrotagetone, (*E*)-ß-ocimene, limonene, ß-phellandrene and sabinene. Volatile oils from aerial parts of *T. lucida* mainly contain phenylpropenes and terpenes [72]. Ciccio [75] Marotti and coworkers reported that the volatile oils are dominated by methyl chavicol (estragol) from *T. lucida* [76]. Literature survey revealed that the, volatile oils from aerial parts of *T. filifolia* showed high amounts of (*E*)-anethole (76.9–87.5%) and methylchavicol (10.7–19.3%), in addition to variable amounts of (*Z*)-anethole (tr–68.2%), and lower amounts of isomenthone (4.5%), menthone (4%), 1,8-cineole (1.5%), pulegone (1.1%), germacrene D (1%), bicyclogermacrene (1%), (*E,E*)-ß-farnesene (0.8%), cumin aldehyde (0.7%), and spathulenol (0.5%) [72,75]. A report of the essential oils of *T. filifolia* from Argentina was characterized by only two components: (*E*)-anethole (74.5%) and methylchavicol (23.7%) [77]. This chemical composition is uncharacteristic of Tagetes species, and is close to the specific chemotype of *T. lucida*, rich in (*E*)-anethole [78]. Volatile oils of aerial parts from *T. terniflora* presented by (*Z*)-tagetone (31.0%), (*Z*)-ß-ocimene (15.4%), (*E*)-tagetenone (15.4%), (*Z*)-tagetenone (14.5%), (*E*)-tagetone (10.3%), and dihydrotagetone (6.5%) as the main components, in addition to (*E*)-ά-ocimene, limonene, isomenthone, spathulenol, (*Z*)-anethole, and (*E*)-anethole [72]. Volatile oil composition from leaves in *T. terniflora* from Argentina showed a similar composition, with (*E*)-ß-ocimene (27.3%), (*Z*)-and (*E*)-tagetone (26.0%), (*Z*)-and (*E*)-tagetenone (17.5%), and dihydrotagetone (16.8%). Again in another report of volatile oils from aerial parts of *T. tenuifolia* showed (*Z*)-ocimenone (9.1–26.3%), (*E*) ocimenone (9.6–26.3%), dihydrotagetone (13.4–17.3%), tagetones (5.5–12.9%), limonene (8.7–10.2%), and ß-ocimene (tr–6.0%) [79,80]. Another species like *T. mandonii* characterized by (*Z*)-ß-ocimene, (*E*)-ocimene, tagetenones, tagetones, limonene, spathulenol, and (*Z*)-anethole from aerial parts [72]. The literature survey revealed that the analysis of the volatile oils of *T. maxima*, which is now recognized as a synonym of *T. mandonii* [72] showed the composition was dominated by (*Z*)-tagetone (31.3%), dihydrotagetone (26.7%), and (*E*)-tagetenone (22.4%), whereas other minor compounds comprised (*Z*)-tagetenone (5.4%), (*E*)-tagetone (2.8%), methyl eugenol (1.0%), (*Z*)-ß-ocimene (1.0%), p-menth-4-en-3-one (1.0%), ß-caryophyllene (0.3%), (*E*)-myroxyde (0.3%), germacrene D (0.2%), (*Z*)-myroxyde (0.2%), (*E*)-ß-ocimene (0.2%), limonene (0.2%), 1,8-cineole (0.2%), ά-humulene (0.1%), and sabinene (0.1%) [81]. Pichette and coworkers reported volatile oils from aerial parts *T. multiflora* dominated by (*Z*)-tagetone (47.3%), (*E*)-tagetenone (17.2%), and (*Z*)-ß-ocimene (12.8%) as the main components, and dihydrotagetone (8.1%), (*Z*)-tagetenone (3.5%), (*E*)-tagetone (1.5%), ά-phellandrene (0.7%), ß-caryophyllene (0.7%), p-menth-4-en-3-one (0.7%), ά-humulene (0.3%), 1,8-cineole (0.2%), germacrene D (0.2%), sabinene (0.1%), (*E*)-ß-ocimene (0.1%), and (*Z*)-myroxyde (0.1%) as a minor compounds [81]. Volatile oils of from flowering stems of *T. lemmonii* were rich in ethyl-2-methyl butyrate (0.3%), ά-phellandrene (0.2%), (*E*)-ß-ocimene (2.1%), dihydrotagetone (42.5%), alloocimene (2.8%), (*Z*)-tagetone (0.04%), (*E*)-tagetone (16.1%), ß-caryophyllene (0.2%), (*Z*)-tagetenone (3.9%), (*E*)-tagetenone (14.2%), and germacrene D (0.5%) [82]. Volatile oils from *T. rupestris* (Argentina) contained (*Z*)- and (*E*)-ocimenes, (*Z*)-and (*E*)-tagetones, and (*Z*)- and (*E*)-tagetenones as the major compounds [83]. Volatile oils from capitula and leaves of *T. subulata* were characterized by terpinolene (26.0%), piperitenone (13.1%), and limonene (10.8%) [84]. Essential oils from *T. caracasana* (Venezuela) contained (*E*)- (64.3%) and (*Z*)-tagetone (13.7%) as the main compounds [84]. Volatile oils of leaves of *T. pusilla* from Venezuela contained (*E*)-anethole (70%) and 4-allylanisole (30.0%) as the main compounds, although, in volatile oils from Bolivia, the only observable compounds were (*E*)-anethole (92.2%) and ά-pinene (0.4%) [85]. Volatile oils of *T. mendocina* from Argentina contained (*E*)-ß-ocimene, (*Z*)-tagetone, (*E*)-tagetone, (*Z*)-ocimenone, ά-pinene, and (*E*)-ocimenone as the main components (3.5%) [86].

## Traditional Uses of *Tagetes* Species

Tagetes species are used as remedies to treat various health problems worldwide. In Mexico *T. filifolia* in Prima tribe prescribes a cup of tea prepared with its branches for stomachache [87] and in Argentina, it is used for wound infection [88]. In Bangladesh, the leaves of *T. patula* are applied on boils and carbuncles and used against kidney troubles, muscular pains, and piles. Their juice is prescribed for earache and ophthalmia [89]. In Pakistan, both leaves and flowers of *T. patula* are collected and used as an antipyretic [90]. In Kenya *T. minuta* used as wounds and sores are also healed with leaf and flower decoctions or infusions of while a topical application of its sap is used [91]. Rahman et al. reported that use of *T. minuta* for wound healing in dental disorders [92]. Ata and coworkers attributed a general use in skin diseases [93]. In Argentina, Bolivia, Brazil, Paraguay, and Peru, *T. minuta* infusions and decoctions are considered as digestives, appetizers, cholagogues, carminatives, gastric sedatives, antidiarrheal and vermifuges. They are

administered against food poisoning as antiparasitics and to cure dyspepsia, gastritis, intestinal colic, and flatulence, while the chewed fresh leaves are recommended for removing bad breath. The leaf decoction is prepared as an expectorant or an antiabortive, and is also used in order to reduce milk secretion. The infusion regulates menstrual flow and is used for vaginal washes in cases of infected flows. The whole plant is a febrifuge and diuretic [91]. *T. minuta* leaf and flower infusions are now incorporated in home medicines of the descendants of Polish migrants in Argentina as a prophylaxis after labor [94]. Ijaz and coworkers reported on Pakistani uses of *T. minuta* leaves against cough and stomach disorders [95]. Furthermore, their use against children's cough (three decoction teaspoons thrice per day for a week) and headache is rooted in Southern Uganda [97]. In Bolivia, the infusion of the *T. minuta* is used as a tonic for nerves [91], while, in Brazil, it is used as a sedative to drink before sleeping , *T. lucida*, known to the Aztecs as a remedy for fever, diuresis, and epilepsy, was also used to treat tumors and age-related brain disorders such as dementia and fear. *T. lucida*, together with *T. erecta* and *T. tenuifolia*, is an important plant for treating folk illnesses considered cold (cold in the stomach), "calor en el estómago" (heat in the stomach), and "empacho" (indigestion), as well as constipation, baby and child diarrhea, and eye irritation [98]. The use of *T. erecta* was documented in phytomedicine from Guatemala to cure the respiratory system against pneumonia, asthma, and tuberculosis, to cope with colic, for use as an antibiotic, analgesic, and antileukemic, and for wound healing, and immune system stimulating, as well as against headache, tetanus, and various parasites [99]. Plants collected for medical purposes in India, *T. erecta* flowers are used to treat several skin diseases (sores, wounds, burns, ulcers, eczema, boils, and carbuncles), as well as earache, piles, and muscular pains [100]. Its extract is used in two teaspoons twice daily for 8–10 days combined with common salt and minerals treat kidney problems, specifically removing blocked urine [100,101]. The leaves are used to relieve pain and remove inflammation [102]. *T. erecta* is used in Spanish and French herbal medicine as an external detersive, resolutive, and vesicant [103]. The inhabitants of Madagascar recognize that *T. erecta* has antimalarial properties, while the people of Rodrigues Island cure fever due to infection by drinking one cup per day of an infusion of three flowers [104,105]. Mauritians suggest a glass of *T. lucida* flower decoction in the case of abdominal pain related to circulatory system diseases and in the case of neonatal jaundice for breastfeeding mothers [106]. In Indian folk veterinary medicine applies drops of *T. erecta* flower extract thrice a day to cows and buffalos for otitis [107], and applies leaves to limit bleeding and to cure broken horns, external injury, and eye diseases [108]. In southern Ethiopia, leaves and stems of *T. minuta* are chopped, mixed with water, and given orally to cattle and sheep affected by anthrax, blackleg, and amoebiasis [109].

## Medicinal Uses and Biological Activities of the Genus *Tagetes*

A literature survey revealed that out of many species only following species were related to some treatment of symptoms associated with bacterial and fungal diseases, namely *T. erecta, T. filifolia, T. lucida,* and *T. minuta*.

| Species | Uses | Parts used | Preparation | Method of application | References |
|---|---|---|---|---|---|
| *T. lucida* | Digestive problems, gum diseases, caries, toothache, rheumatism, ulcers in mucus membranes and vaginal fluids, antiseptic, bronchitis | Aerial parts | Infusion, decoction | Topical mouth wash, local application | [110,111] |
| *T. minuta* | Diarrhea, digestive for children, wounds in the mouth | Leaves, seeds | No information available | Topical | [92,109,112] |
| *T. erecta* | Gastrointestinal disorders, diarrhea, stomachache, dysentery, ulcer, dental problems, skin diseases, rash, cut, wounds, boils, sore throat, cough | Flowers, leaves | Infusion, crushed leaves, juice from the leaves, paste of leaves, decoction | Oral/local application for wounds and dental problems; oral as leaf juice; local application: paste of leaves used in the treatment of ulcers and wounds; topical: leaves boiled in water to wash affected area and to relieve itchiness and rash | [113-119] |
| *T. filifolia* | Severe colic, diarrhea, | Whole plant, fresh or dried | Not informed | Oral: 10 g per L mixed with Poleo, Manzanilla, Muña, or Chancas de comida and Hinojo; 3 cups daily for 1 week to 1 month | [120,121] |

**Insecticidal Activity:** *Tagetes minuta* essential oils have been known for repellent and growth inhibitory properties against insect pests [122]. Morgan stated that its oils significantly reduces grain damage due to insect infestation with no adverse effects on seed germination, color and odor hence can be used as sustainable alternatives to synthetic insecticides in maize storage especially by small holder farmers [123]. Nchu, et al. reported that [124] its essential oil may be a potential source of anti-tick agents especially for controlling *Hyalomma rufipes* tick. *E*-ocimenone is responsible for the larvicidal activity of oil against larvae of *Ades aegypti* [125,126] studied the insecticidal activity of floral, foliar and root extracts of *Tagetes minuta* against adult Mexican bean weevils and found that its flower and leaf extracts can be fast acting insecticides [126].

**Acaricidal Activity:** According to Andreotti *et al*. plant essential oils have also been used in the control of *Rhipicephalus microplus* in cattle. *Tagetes minuta* essential oil had a significant effect in controlling the spread and reproduction of ticks by affecting their egg production and killing the surviving ones on the bodies of the affected cattle [127].

**Nematicidal Properties:** Alam *et al*. 1977 reported that the nematode-suppressant effects of *Tagetes* spp. [128]. Siddiqui and Alam while studying the effect of intercropping of tomato, egg plant, cabbage and cauliflower with *Tagetes minuta* (for suppressing root-knot nematode) observed significant inhibition of root-knot development caused by Meloidogyne in tomato [129,130].

**Allelopathic Uses:** Batish, et al. (2006) observed that *Tagetes minuta* leaf powder mixed with rice field soil significantly reduced emergence and growth of weed species both in pots under greenhouse conditions as well as rice field [131]. Even its aqueous extract has been found to be inhibitory to seed germination of *Lotus corniculata* and *Lactuca sativa* [132] and callus induction in *Oryza sativa*, *Brassica campestris* ssp. *napus* var. *pekinensis*, *Raphanus sativus* var*acanthiformis*, and *Sesamum indicum* [133].

## Uses

Essential oils of *Tagetes* species have been used for many purposes. According to Zhang *et al*. 2009, the powders and extracts of *Tagetes* are rich in the orange-yellow carotenoid [134], found in the oil of florets of *Tagetes minuta* (petals), and other species of marigolds. This carotenoid has been identified, isolated, and approved by the European Union (INS Number E161b) for use as food color as well as flavor in various foodstuffs like condiments, pasta, vegetable oil, margarine, mayonnaise, salad dressing, baked goods, confectionery, dairy products, ice cream, yogurt, citrus juice, mustard etc, [135]. Antidepressant activity via negative modulation on GABAergic function, tranquilizing, hypotensive, bronchodilatory, spasmolytic and anti-inflammatory bioactivities [136] as well as antifeedant activities [137] are other important attributes of the essential oil of *Tagetes minuta*. It has also several medical benefits such as remedy for colds, respiratory inflammations, stomach problem, antispasmodic, anti-parasitic, anti-septic, insecticide and sedative [138].

### Market Scenario of Tagetes Essential Oils Worldwide

As the demand for its oil is increasing, this species holds a lot of potential for undertaking its large-scale cultivation. Brazil is one of the major producers of *Tagetes* Oil [139]. The worldwide production was around 1.5 tonnes in 1984 [140]. South Africa, India, Zimbabwe, Egypt, France, and Argentina are the major producers of *Tagetes minuta* oil. In 2003, South African *Tagetes* oil production amounted to an estimated 6.5 tonnes. Current production in Zimbabwe and India is estimated at 2 and 4 tonnes, respectively. However, global demand for *Tagetes minuta* oil for all applications is estimated to amount to more than 12 tonnes [141]. It's from a paper published by Singh, et al. [142], about 3t of high-quality oil is being produced annually from the state of Himachal Pradesh (India) alone priced at Rs.1935-2160 per kg whereas oil produced from other parts of North India is Rs. 1170-1260 [143]. As the yield of extraction of *Tagetes minuta* oil amounts to only 0.1-0.4%, it is a relatively expensive product. Yield per hectare is around 25 tonnes of raw plant material and between 12.5 and 17.5 kg of *Tagetes minuta* oil. Recently, FOB prices for high-quality oil increased somewhat to about $ 190-250 kg, due to decreased availability. Prices for low quality *Tagetes* oil can be as low as $ 90 kg [5]-1-1(about Rs. 6120) [141]. The retail price of one liter of *Tagetes minuta* oil has been quoted at US $177.78 (approximately Rs.12, 119.26) [144].

### Imports of *Tagetes* Essential Oil:

India imported *Tagetes* oil worth USD 10,028 with the total quantity of 42 liters. Switzerland is the largest supplier of *Tagetes* oil accounting for imports worth USD 9,037 followed by France and United States which exported *Tagetes* oil worth USD 677 and USD 147, respectively. Bombay Air Cargo accounted for 98% of imports followed by Nhava Sheva Sea, which account for 2% of imports. The average price of *Tagetes* oil per unit is USD 241.21, and the average value per shipment is USD 346 [145].

### Exports of *Tagetes* Essential Oil

The oil is traded under HS Code 3301. India exported *Tagetes* oil worth USD 54,572 with a total quantity of

475litres. Germany is the largest buyer of *Tagetes* oil accounted for exports worth USD 49,580, followed by Taiwan and United States which imported *Tagetes* oil worth USD 2,160 and USD 997, respectively. Delhi Air Cargo accounted for 100% of exports followed by Chennai Air Cargo which account for 0% of exports. The average price of *Tagetes* oil per unit is USD 114.96, and the average value per shipment is USD 1,605 [145].

## Conclusions

*Tagetes* is an aromatic plant that is widely distributed and used for many purposes worldwide. This review showed that *Tagetes* genus is rich in aromatic compounds and resinous exudate, and the EOs of these plants are rich in ocimenes, limonene, terpinene, myrcene, tagetones, dihydrotagetone, and tagetenones, which are the primary odorants, and lower amounts of sesquiterpene hydrocarbons and oxygenated compounds. The volatile oil of its species is also biologically active for many activities. In Uttrakhand there its farming for essential oil will also improve the economy of farmers.

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