

Marigold: From Mandap to Medicine and from Ornamentation to Remediation

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Abstract

Importance of medicinal plants to health care has been great and herbal preparations are being produced at industrial scale particularly in developing countries. The plant products obtained have a long history of use in therapeutics, aromatherapy and food depending on the chemical constituents and their bioactivity. In the recent past, marigolds have received a great attention in scientific research, because of their multiple use and also the information available about their phytochemistry and bioactivity. *Tagetes* species commonly known as marigold is native to Mexico, being used for medicinal and ornamental purposes. The plant is useful due to its unique phytoconstituents for a range of diseases and disorders and is reportedly effective against piles, kidney troubles, muscular pain, ulcers and wound healing and the flowers are helpful in fever, stomach and liver complaints and also in eye diseases. In India, marigold is also extensively used on religious and social occasions such as in the beautification of mandaps and pooja places; offerings at temples; marriage decorations and landscape planning due to variable size and colour of its flower. Present review is an effort to bring together the different strategies developed for the growth and cultivation of marigold, its ecophysiological and remediation relevance under a variety of environmental conditions and possible allelopathic potential. It includes reports on pharmacological aspects like antibacterial, antifungal, larvicidal, hepatoprotective, insecticidal, mosquitocidal, nematocidal, wound healing, antioxidant, anticancer and antidiabetic properties/activity of *Tagetes*.

Keywords

Tagetes spp, Pharmacological Aspects, Phytoremediation, Allelopathic

1. Introduction

Tagetes, a native of Mexico and other warmer parts of America, naturalized in both tropics and subtropics [1], belongs to family Asteraceae. In India, these were introduced by Portuguese [2]. The name marigold is applied to several genera of Asteraceae (compositae) with golden or yellow capitula and there are about 33 species of the genus *Tagetes*, five of which have been introduced in Indian gardens viz. *T. erecta* L., *T. minuta* L., *T. patula* L., *T. lucida* and *T. tenuifolia* [3]. Amongst these, *Tagetes erecta* L. is commonly grown for its bloom and natural dye (xanthophyll) extraction and others for their essential oils [4]. The global demand for natural pigments/dyes obtained from plants and microorganisms has increased in the recent past, because of awareness of people regarding environmental and health problems caused due to the consumption of synthetic dyes [5]. Nowadays application of natural pigments and dyes is diverse ranging from food, cosmetic, pharmaceutical to textile industries and they may provide a real alternative to their artificial counterparts particularly because of the dangers involved in their use for living beings and environment [6] [7].

Tagetes species possess variable height bearing pinnately divided leaves and lanceolate and serrated leaflets. Flowers orange, yellow, golden and white in color with floral heads have both ray and disc florets. The plant grows well in most of the soils but soil with good drainage is most suitable. Seeds and cuttings are used for propagation. African marigold has globe shaped large flower and the flowers are yellow to orange. French marigold flowers are small with red, orange and yellow color and red and orange bicolor patterns are ideal for edging flowerbeds [8] [9]. Marigold has the basic chromosome number 12 and is highly cross-pollinated. *Tagetes erecta* and *Tagetes tenuifolia* are diploid with chromosome number 24. *Tagetes minuta* and *Tagetes patula* are tetraploids. *Tagetes patula* is an allotetraploid between *Tagetes erecta* and *Tagetes tenuifolia*. Size of plants and flowers in marigold decreases with the increase in ploidy level unlike other plants [9].

African marigold is one of the most important commercial flower crops grown in India and the world over. *Tagetes erecta* seems to be of Indian origin because of its adaptability even though it has been introduced [10] [11]. Its attributes like variable height and flower colour are of special significance in beautification and landscape plans. The flowers of marigold especially African type (*Tagetes erecta* L.) are one of the richest sources of xanthophyll pigments in the flower petals, of which lutein accounts for approximately 80% - 90% [12]. Flower petals synthesize and accumulate carotenoids 20 times greater than leaves, presenting a good model for molecular biological and biochemical work on the carotenoid biosynthesis in plants. The carotenoids extracted from *Tagetes erecta* are used in poultry feed as additives to enhance colouration of

chicken skin and egg yolk [13] at a considerably lower cost than other synthetic or natural carotenoids [14]. Commercial extraction of marigold carotenoids in India is done in Cochin, Hyderabad, near Satyamangalam forest (Tamil Nadu) and Telagi near Harihar and Bangalore (Karnataka) [15] and are exported to different countries. The flowers are important natural resources for xanthophylls, particularly lutein [16] [17]. Dietary lutein can be used for prevention of cancer and improved immune function [18]. The plant shows nematicidal, fungicidal and insecticidal activity because of certain bioactive compounds present in it [19]. The flowers are utilized as a source of pigments for food coloring at industrial scale [20]. The essential oil obtained is anti-inflammatory, antiseptic, antispasmodic, astringent, diaphoretic and possess skin healing properties [21]. Floral extract is good for eye diseases, petal juice heated with ghee cures the bleeding piles and purifies the blood. The dried petals are used against ringworms, wounds, bedsores, persistent ulcer and also as a mouth wash [22]. This review focuses on the important medicinal, remedial and allelopathic properties of *Tagetes* and also the different strategies for the better growth and cultivation with special reference to India.

2. Pharmacological Activity

2.1. Anti-Fungal

The methanolic extracts from *Tagetes patula* exhibit phytotoxic dose-dependent action against *Botrytis cinerea*, *Fusarium moniliforme* and *Pythium ultimum* and correlation both in light and dark treatments has been observed between the toxicity and the process of photoactivation of the thiophenes present in the extracts [23]. *Tagetes erecta* plants are effective against the black spot of cucumber caused by *Phytophthora* spp and also *Pseudoperonospora cubensis* (see [24]). Extracts in organic solvents of *Tagetes minuta* exhibited growth inhibition/ antifungal activity against most isolates of *Fusarium* spp but not against *Aspergillus* spp [25]. Extracts of *Tagetes erecta* L. flowers in different solvents show variation in the activity against fungal strains [26] indicating the importance of solvent used in extraction while evaluating the antimicrobial activity of medicinal plants. 2,5-dicyclopentylidene cyclopentanone (TEF), a fungicide obtained from *Tagetes erecta* L. inhibit the wilt caused by *Fusarium oxysporum* f. sp. *niveum* (FON) in watermelons [27].

2.2. Anti-Bacterial

The essential oil of *Tagetes minuta* exhibits antibacterial activity, particularly against gram-positive bacteria which however, shows variation with region [28]. The methanolic extracts of *Tagetes patula* flowers were effective against a number of bacteria like *Corynebacterium* spp, *Staphylococcus* spp, *Streptococcus* spp, and *Micrococcus luteus* having inhibition zone diameters from 9 to 20 mm [29]. Root extracts of *Tagetes* possess antimicrobial activity against different bacterial and fungal strains with MIC values ranging from 12.5 - 100 µg/mL [30]. Leaf extracts of *Tagetes erecta* L. showed significant antibacterial activity against

Bacillus subtilis, *Staphylococcus lutea* and *Bacillus circulens* [31] and *Acinetobacter baumannii*, *Propionibacterium acne* [32]. Compounds like “Patulitrin” a flavonoid obtained from the floral extracts of marigold *Tagetes erecta* L. [33], acylated flavonol glycosides and essential oil from *Tagetes minuta* were effective against different bacterial isolates [34] [35] [36].

2.3. Insecticidal

Chemical fertilizers and synthetic pesticides cause environmental contamination directly or indirectly affecting human beings and animals. Use of plant extracts as alternative source of insecticides can reduce such problems. *Tagetes* showed better insecticidal property against *Sitophilus oryzae* [37], aphids and *Spodoptera frugiperda* [38]. Leaf extracts of *Tagetes erecta* can control *Spodoptera frugiperda* as bioinsecticides, in an ecofriendly way [39]. Extracts from *Tagetes erecta* and *Tagetes patula* showed significant insecticidal activity against *Sitophilus zeamais* and may replace synthetic products [40]. Bed bugs can be controlled using oil from *Tagetes patula* [41].

2.4. Larvicidal

Tagetes minuta was effective against the larvae of *Aedes aegypti* [42] and *Anopheles stephensi* [43]. Larvae of *Aedes aegypti* were most susceptible to essential oil from *Tagetes patula* followed by *Anopheles stephensi* and *Culex quinquefasciatus* [44]. Nanoparticles synthesized from marigold caused larval mortality and green synthesis of copper nanoparticles (CuNps) can kill the mosquito larvae of *Culex quinquefasciatus* [45]. Flowers of *Tagetes patula* are very effective natural larvicide and the larval mortality rate depended on the time elapsed and dose applied [46].

2.5. Mosquitocidal

Leaves of *Tagetes erecta* have been used for the treatment of malaria in Madagascar and the thienyl compounds from the roots are insecticidal and nematocidal [47]. Application of *Tagetes minuta* floral extract containing 5-(but-3-ene-1-ynyl)-2,2'-bithiophene, 5-(but-3-ene-1-ynyl)-5'-methyl-2,2'-bithiophene, 2,2',5',2''-terthiophene and 5-methyl-2,2',5',2''-terthiophene exhibit significant toxicity against *Aedes aegypti* and *Anopheles stephensi* [43]. Extracts (*n*-hexane fractions) from the seeds of *Tagetes erecta* showed significantly better antimalarial activity than their ether-fractions [48]. The root and floral extracts of *Tagetes erecta* showed considerable schizonticidal activity against *Plasmodium falciparum* [30] and mosquitocidal activity against *Culex quinquefasciatus* [49] respectively. Extracts of *Tagetes patula* [46] and *Tagetes erecta* [50] were effective against *Aedes aegypti*, the principal vector of dengue viruses.

2.6. Nematicidal

The resistance of marigold to nematodes has been reported by Goff [51]. *Tagetes*

patula and *Tagetes erecta* suppressed the root-knot nematode infection. Aerial parts of *Tagetes patula* may exhibit greater nematicidal activity *in vivo* than root extracts [52]. The nematicidal activity of marigold depends on the species, cultivar and age of the plant and also on the way it is used *i.e.*, intercrop/cover crop or as soil amendment, seeding rate and the temperature [53]. “Alpha-terthienyl” obtained from marigold extracts has a role in reducing nematodes [54]. Crude ethanol-water (CEWE) and crude ethanol-water defatted (CEWDE) extracts of *Tagetes patula* exhibited nematicidal activity against *Meloidogyne incognita* and *Meloidogyne javanica*, as well as nematostatic activity against *Meloidogyne paranaensis* [55]. Ethyl acetate fraction from CEWE (above 250 $\mu\text{g}\cdot\text{mL}^{-1}$) resulted in high mortality rates for *M. incognita* [55].

2.7. Hepatoprotective

An important vital organ liver has been involved in the maintenance of diverse metabolic functions and detoxification of xenobiotics, drugs, viral infections and chronic alcoholism [56] [57] and impairment of liver function causes serious consequences. Hepatoprotective activity of *Tagetes erecta* against carbon tetrachloride induced hepatopathy resulted in increased serum ALT, AST, ALP and bilirubin levels [58]. Protection of liver from induced hepatotoxicity by *Tagetes erecta* was reflected by the reduction in the elevated levels of biochemical markers [59]. Alcoholic extracts of leaves of *Tagetes lucida* show protection against paracetamol-induced hepatotoxicity in rats as indicated by reduced lipid peroxidation and strengthening of antioxidant defense system [60].

2.8. Antioxidant

Solvents of different polarity have been used for the extraction of phenolic and flavonoid contents of marigold. Ethanolic extracts of marigold showed the highest antioxidant and radical scavenging activity [61]. The flowers of Indian marigold can be used to produce lutein, a natural antioxidant which can be utilized as a food supplement [62]. A direct correlation between phenolic content and antioxidant activity has been found. Methanolic extract of *Tagetes erecta* L. flowers had maximum phenolic content, ferric reducing antioxidant power (FRAP) and superoxide free radical scavenging (SO) activity. In ethyl acetate extract ABTS and DPPH did not show positive correlation with total phenolic contents. Ethyl acetate extract had maximum flavonoid content. Flowers of *Tagetes erecta* can be used as a natural source of antioxidants to combat the oxidative stress related disorders [63]. Methanolic extracts of the flowers of *Tagetes erecta* L. scavenge superoxide radicals strongly [64] and protect the human skin against photo-aging by reducing oxidative damage, suppressing metalloproteinase-2 (MMP-2) and stimulating collagen synthesis [65].

2.9. Wound Healing

Medicinal plants belonging to different families have wound healing ability with

efficient repair mechanisms in natural ways [66]. Alcoholic extracts of *Gymnema sylvestre* and *Tagetes erecta* L. resulted in significant increase in activity in terms of wound contraction in treated animals [67]. The hydro alcoholic extracts of *Gymnema sylvestre*, *Tagetes erecta* independently and their combined extract accelerated the wound healing activity [67]. Marigold (*Tagetes erecta*) improves the platelet and white blood cell count and reduces the bleeding and clotting time [68]. Leaf extracts of marigold showed good blood coagulation activity [69] and reduce the average bleeding/blood coagulation time in rabbit and mice [70].

2.10. Anti Cancer/Anti Tumor

Tagetes erecta L. contains highest amount of lutein which has been linked with decreasing the risk of age-related macular degeneration (AMD), cancer and cardiovascular diseases [71]. Plants have played a leading role in cancer treatment [72]. Essential oils derived from plants exert better therapeutic activity than their isolated major compounds. The anticancer activity of the essential oil of marigold was indicated to be higher against NB4 and EACC cell lines [73]. The cytotoxic activity of the essential oils of *Tagetes erecta* L. (TE-OE) against different tumor cell lines suggested that they may be used to treat cancer without affecting normal cells [74]. Quercetin, 6-hydroxykaempferol (50 µg/mL) obtained from *Tagetes erecta* L. exhibited significant anticancer activity against A549 and HEPG2 cells whereas, protocatechuic acid and quercetagenin were effective against A549 cells [75]. Crude extracts containing different flavonoid fractions and the flavonoid fraction rich in quercetin and quercetagenin possessed maximum cytoprotective activity and patuletin at high dose can exert cytotoxic effect on Jurkat cells [76]. Chemical nature of the compound and its concentration is important in deciding its cytoprotective and cytotoxic activity.

2.11. Antidiabetic

Rodda *et al.*, [77] have evaluated *Tagetes erecta* L. for its antidiabetic potential against alloxan induced diabetes together with *Foeniculum vulgare* in albino rats. Decrease in blood glucose level, total cholesterol, LDL, triglycerides, body weight and rise in HDL was found in the rats treated with extracts of the selected medicinal plants independently and in combination indicating towards their antidiabetic potential. Quercetagenin, the flavonoid extracted from marigold inflorescence exhibited strong anti-diabetic activity and inhibited α -glucosidase and α -amylase non-competitively [78]. *Tagetes lucida* results in a decrease in glucose level and increased insulin concentration in diabetic rats. The alcoholic extracts of the aerial parts of *Tagetes lucida* exhibited hypoglycemic, hypolipidemic and hepatoprotective properties by scavenging free radicals, inhibiting lipid peroxidation and protecting β -cells with increased insulin secretion and decreased glucose levels in blood [79]. Saisugun *et al.*, [80] have reported antidiabetic activity associated with esterified lutein obtained from flower petals of marigold. Reports on pharmacological activities of *Tagetes* are being presented in **Table 1** and **Table 2**.

Table 1. Important pharmacological/medicinal properties of vegetative parts of marigold (*Tagetes spp*).

Plant used	Plant vegetative part/s used	Plant extracts/ compounds used	Important activity/ application	References
<i>Tagetes minuta</i>	Leaves	Leaf powder	Herbicidal activity against two invasive weeds <i>Echinochloa crus-galli</i> and <i>Cyperus rotundus</i> .	[81]
<i>Tagetes erecta</i>	Leaves	Chloroform, methanol and ether extracts	Antinociceptive and Anti-inflammatory properties.	[82]
<i>Tagetes erecta</i>	Growing plants (particularly roots are effective)	Use of plant through intercropping	Nematicidal activity against <i>Meloidogyne incognita</i> .	[83]
<i>Tagetes erecta</i>	Leaves	Essential oil containing α -terpinolene, (<i>E</i>)-ocimene, piperitone, dihydrotagetone etc.	Schistosomicidal activity against adult <i>Schistosoma mansoni</i> worms.	[84]
<i>Tagetes minuta</i>	Leaves	Essential oil containing dihydrotagetone, E-ocimene, tagetone, <i>cis</i> - β -ocimene, Z-ocimene, limonene and epoxyocimene as the major components	Antioxidant and anti-inflammatory activity.	[85]
<i>Tagetes minuta</i>	Leaves/Aerial parts	Essential oil containing dihydrotagetone, E-ocimene, tageton, <i>cis</i> - β -ocimene, Z-ocimene, limonene and epoxyocimene as main components	Cytotoxic activity against KB and HepG2 cell lines and also show good antioxidant and antimicrobial activity.	[86]
<i>Tagetes erecta</i>	Leaves	Essential oil containing dihydrotagetone, E-ocimene, limonene and α -terpinolene as the major constituents	Cytotoxic activity against eight different tumor cell lines <i>i.e.</i> , B16F10, HT29, MCF-7, HeLa, HepG2, MO59J, U343, U251.	[74]
<i>Tagetes erecta</i>	Root, stem and leaf	Direct use of different extractions mainly the sonication assisted extraction	Significant antibacterial activity against <i>Streptococcus mutans</i> as compared to <i>Pseudomonas aeruginosa</i> .	[87]
<i>Tagetes lemmonii</i>	Leaves	Direct use of leaf extracts	Insecticidal activity against <i>Tribolium castaneum</i> .	[88]
<i>Tagetes erecta</i>	Fresh Leaves	Essential oil containing piperitone, piperitenone, ocimine, neophytadiene and caryophyllene etc.	Phytotoxic to <i>Echinochloa crus-galli</i> (L.).	[89]

Table 2. Important pharmacological/medicinal properties of floral parts of marigold (*Tagetes spp*).

Plant used	Plant floral part/s used	Plant extracts/ compounds used	Important activity/use	References
<i>Tagetes erecta</i>	Floral parts	Lutein	Antioxidant activity, mutagenicity, anti-mutagenicity, clastogenicity and anti-clastogenicity.	[71]
<i>Tagetes erecta</i>	Floral parts	Essential oil containing sesquiphellandrene as major compounds	Antifeedant activity against <i>Spodoptera litura</i> larvae.	[90]
<i>Tagetes erecta</i>	Floral parts	Syringic acid and β -amyryn	Effective against hyaluronidase, elastase and matrix metalloproteinase (MMP-1) inhibitory activity as compared to standard oleanolic acid.	[91]
<i>Tagetes erecta</i>	Flowers	Ethanollic extracts	Mosquitocidal potency against larvae of <i>Culex Quinquelfasciatus</i> .	[49]
<i>Tagetes patula</i>	Flowers	Patuletin dye	Greater antioxidant ability as compared to base and catechol.	[92]
<i>Tagetes erecta</i>	Flowers	Ethyl acetate extract	Antioxidant and tyrosinase inhibitory activity.	[93]
<i>Tagetes minuta</i>	Floral part	Essential oil containing trans-ocimene, l-verbenone, limonene, tegetone and 2-pinen-4-one as the major components	Larvicidal activity on <i>Anopheles gambiae</i> .	[94]
<i>Tagetes minuta</i>	Flowers and Seeds	Butanol and ethyl-acetate extracts	Antibacterial activity against <i>Micrococcus luteus</i> , <i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i> and <i>Pseudomona spikettii</i> .	[34]
<i>Tagetes erecta</i>	Floral parts	Lutein/lutein nanocapsules	Cell growth inhibition /antiproliferation activity against Hep G2 cells.	[95]
<i>Tagetes patula</i>	Floral parts	Crude extracts containing flavonoids patuletin, quercetagetin, and quercetin and their derivatives as well as the carotenoid lutein	Cytoprotective, cytotoxic anti-inflammatory and antioxidant activity against hydrogen peroxide-challenged human lymphoblastoid Jurkat T-cells.	[76]
<i>Tagetes erecta</i>	Floral parts	Direct use of different extracts	Larvicidal activity against <i>Culex quinquelfasciatus</i> .	[96]
<i>Tagetes patula</i>	Flowers	Ethanollic extracts from flowers	Antimicrobial activity of flowers (Fl _{Et(OH)70%}) against <i>Microsporium canis</i> and <i>Trichophyton rubrum</i> .	[97]

Continued

<i>Tagetes erecta</i>	Petals	Lutein	Esterified lutein shows good anti-diabetic activity, it also shows wound healing, coagulant and anti-inflammatory like activities.	[80]
<i>Tagetes minuta</i>	Floral parts	Tagetones A and B	Compound A showed cytotoxic activity towards MCF7 and A549 cancer cells and B against HCT116 cancer cells.	[98]
<i>Tagetes patula</i>	Flowers	Direct use of aqueous flower extracts	Bio-controlling properties for tomato plants against canker, early blight, wilt, fruit spot, blossom end rot and sun scald.	[99]
<i>Tagetes Patula</i>	Flowers	Methanolic extracts	Antihyperlipidaemic and antioxidant activity on propylthiouracil induced hyperlipidemic rats.	[100]

3. Marigold and Phytoremediation

Phytoremediation is an emerging technology and the underlying mechanisms are required to be understood for optimization [101]. A large number of plant species have already been tested for accumulating toxic elements in the above ground biomass. Metals are essential for diverse metabolic processes in all organisms nevertheless, many metals can be toxic and plants regulate the uptake and distribution of metals. Primarily metal uptake occurs through roots making them the primary sites for regulating their accumulation whereas, under acute conditions roots along with shoots accumulate the metals [102].

Nugget marigolds grow well in arsenic-contaminated areas, accumulating arsenic. Phosphate fertilizer increased arsenic uptake during the flowering stage [103]. Higher concentration of citric acid resulted in reduced accumulation of Zn, Cu, Pb and Cd. Higher concentration of EDTA and citric acid (30 mg·L⁻¹) improved the phyto extractability of marigold to remediate the soil contaminated with metals and resulted in significant reduction in growth of marigold [104] accumulation of Zn was greater followed by Cu, Pb and Cd in leaves with 30 mg·L⁻¹ EDTA treatment. *Tagetes patula* remediates the cadmium infested soils efficiently with improved activity of antioxidant enzymes like ascorbate peroxidase (APX), glutathione reductase (GR) and superoxide dismutase (SOD) in leaves whereas, the activity of antioxidant enzymes was reduced considerably in roots [105]. Marigold showed significant cadmium accumulation potential in comparison to sunflower and cosmos [106]. Thamayanthi *et al.*, [107] have reported that cadmium level up to 20 mg·kg⁻¹ in soil was beneficial but above 100 mg·kg⁻¹ was toxic for the growth of marigold plants. Choudhury *et al.*, [108] have noticed *Brassica Juncea* and *Tagetes Patula* to be good heavy metal accu-

mulators and have highlighted their effectivity in landfills in which contaminated Buriganga riverbed sediments have been used. Marigold is one of the flower crops which can be used for phytoremediation exhibiting significant potential for the removal of cadmium [109]. Phytoextraction of heavy metals in marigold was observed during initial growth and marigold plant in 12 weeks showed maximum uptake for chromium followed by lead and copper [110].

Biodegradation of a textile dye (Reactive Blue 160) by *Tagetes patula* is due to the potential of enzymes viz. tyrosinase, lignin peroxidase, laccase and NADH-DCIP reductase from the roots which has application in the decolorization and detoxification of this dye [111]. *Tagetes erecta* exhibited greater bioaccumulation of Cr in roots than in the aerial shoots [112] and in association with rhizobacteria accumulate high levels (94%) of Cr in 35 days [113]. Hence, *Tagetes erecta* L. is a hyperaccumulator and has potential for phytoremediation which can be a beautiful and effective alternative.

4. Marigold and Allelopathy

Different plant species produce chemical substances in the form of secondary metabolites which have been implicated in diverse biological activities including allelopathy [114] [115]. These chemical substances are known as allelochemicals which vary with tissue or organ [116] [117] [118] [119]. Marigold (*Tagetes*) is a rich source of several secondary metabolites including phenolics which have utility in pharmacology, however, there are also a few reports available on its allelopathic nature.

The aqueous extracts of different parts of *Tagetes* species inhibited the germination of both radish and lettuce. Inhibition of radish root growth with the application of leaf, stem and root extracts of African marigold was greater in comparison to those of lettuce [120]. Aqueous leaf and stem extracts of *Tagetes erecta* showed autotoxicity *i.e.* inhibiting its own seed germination and seedling growth and the degree of inhibition was concentration dependent. Greater inhibition in seed germination, hypocotyl and radicle length was recorded with 10% aqueous leaf extracts, indicating the presence of higher concentration of toxic compounds in leaves [121]. Papaya associated with *Tagetes erecta* can damage the nematode population of soil and can exert indirect control over harmful microbes by promoting the growth of PGPR *Pseudomonad* and *Bacilli* strains [122]. Aqueous extracts of leaves of *Tagetes minuta* inhibit Johnson grass and Sun spurge weeds. Aqueous leaf extracts were inhibitory to all the tested parameters of Johnson grass at 75% and 100% concentrations. 50% and 75% of plant extracts did not affect the root length of sun spurge nevertheless, shoot length and germination were significantly reduced at 50% and 100% concentration [123]. Santos *et al.*, [124] have worked out the phytochemical and allelopathic evaluation of *Tagetes erecta* and *Tagetes patula* and on the basis of phytotoxic compounds present in them, their use in the management of organic agriculture particularly in vegetables have been suggested. The volatile oil from *Tagetes minuta*

significantly reduced germination, growth, chlorophyll content and respiratory ability of *Chenopodium murale* L. *Phalaris minor* Retz. and *Amaranthus viridis* L. weeds in a dose dependent manner. Treated root tips of *Allium cepa* showed aberrations like distorted, binucleated and trinucleolated cells causing arrest of mitotic activity [125]. Both oil and *cis*- β -ocimene were strongly allelopathic against *Cassia occidentalis* L., a common wasteland weed but the effect of *cis*- β -ocimene was greater in comparison to oil [126] and maximum effect was seen on *Amaranthus tricolor* with complete inhibition at 1 μ l/ml, whereas, *Echinochloa crus-galli* was least affected (amongst the tested plants) with complete inhibition at 5 μ l/ml concentration [127].

5. Marigold and Salinity

Salinity is considered as one of the limiting factors in the agricultural production throughout the world. Saline soils occur naturally (primary salinization) or can be the result of human anthropogenic activities (secondary salinization). Salinity converts the fertile and productive soil/land to barren/desert causing alterations and ultimately loss of natural flora [128]. Small changes in salt concentration may suppress vegetative growth and plant development because of water deficiency influencing the whole plant metabolism [129]. Secondary soil salinity is drawing considerable attention over the last few decades and is experienced because of mismanagement of irrigation, poor biological drainage system, intensive industrialization and use of chemicals in farming etc. Studies are available dealing with ornamental plants used in landscapes although salt stress causes serious damage to these species [130] [131]. Degraded waters having high salinity and alkaline pH must be considered as valuable alternatives because of scarcity of fresh water resources for landscape sites although such waters may pose problems to the plant establishment and growth. Increased salinity levels decreased the leaf Ca^{2+} in spite of threefold increase in substrate Ca^{2+} whereas, Mg^{2+} increased with increase in salinity. Potassium concentration in marigold irrigated with pH 6.4 water tended to decrease in leaves as EC_w increased, probably because of proficient Na^+ exclusion mechanism restricting Na^+ accumulation in the leaves [132]. *Tagetes* was more tolerant to salinity than *Ageratum* however, the inhibiting effect was obvious in plants treated with 2% NaCl [133]. Application of glutathione and ascorbic acid was effective in improving growth of *Tagetes* under both saline and non saline conditions [134]. Under saline conditions, Ca^{2+} , Mg^{2+} , K^+ , and Na^+ uptake of marigold served as important parameters in indicating the effects of stress [135]. CaCl_2 , ascorbate and salicylic acid have been effective priming agents to ameliorate the adverse impact of salinity, resulting in lower uptake of Na^+ and higher uptake of K^+ in french marigold seedlings [136]. Enhancement of potassium ions can improve its tolerance to salinity stress [137]. Plant growth under water and salinity stress conditions and impact of potassium supplementation on it has been discussed in Ahanger *et al.*, [138]. Application of marigold in medicine and for other purposes justifies

research interest among the scientists regarding its growth/cultivation and production at commercial level.

6. Cultivation and Production

Changing lifestyle, increased urbanization and flower trade at global level in a last few decades has expanded the commercial dimensions of floriculture. Concerns about environmental conservation have given a boost to landscape gardening, town planning and use of plants in beautification. In India loose flowers hold the major share in area and production and are mostly in the hands of small and marginal farmers [139]. Currently 191,000 hectares of area is under horticulture with annual production of 1,031,000 metric tonnes of loose flowers and 69,027 lakh number of cut flowers in India Horticulture Database, [140] and marigold ranks first among the loose flowers followed by chrysanthemums, jasmine, rose and tuberose [141]. Area under marigold cultivation is 43,000 ha with a production of 360,000 metric tonnes in [141]. The major loose flower production states in India are: Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Mizoram, Gujarat, Maharashtra, West Bengal, Haryana, Chhattisgarh etc. [141]. Marigold finds its commercial uses because of its adaptability to a variety of climatic conditions, longer blooming period and beautiful flowers with good shelf life. The acreage in India under commercial cultivation of marigold has gone up dramatically [9].

It is also grown as a part of multi crop system, rotated with other agricultural/horticultural crops and also grown as mixed crop on the borders with other plants. The plant shows resistance to saline and other adverse conditions [142] [143]. The rapid growth and well-developed root system of *Tagetes erecta* and its ability to act as a pioneer on poor soils indicates its suitability for the remediation of areas degraded by metal pollution. Phytoremediation technologies using reduction, removal, degradation or immobilization of the contaminants have received considerable attention in the recent past [144]. Some marigold cultivars which are used as cut flowers or in landscaping maintain the quality of plants at an electrical conductivity of $<8 \text{ dS}\cdot\text{m}^{-1}$ [145]. Enough information for environmental designers and growers of ornamental plants is not available to recommend the appropriate plant species for the areas infested with salinity problems [135].

6.1. Role of Nutrients/Fertilizers

Fertilizer is an essential key input for the productivity of crops. Nitrogen is considered to be crucial because of its being a constituent of protein and nucleic acid [146]. Potassium has been involved in the synthesis of peptide bond; protein and carbohydrate metabolism participating in rapid cell division and differentiation [147]. Phosphorus and potash increase nutrient uptake because of more photosynthesis due to more chlorophyll formation and increased leaf area [147]. Nitrogen and phosphorus are required in sufficient quantities for better growth

and flowering of marigold [148]. Supplementation of potassium enhances quality and flower yield of marigold [149]. Optimal fertilizer management is required for attaining high ornamental value and reducing production costs of flower production [150]. Fertilizer input contributes almost half of the increase in total yield for most crops [151]. Balanced fertilization is essential for better yield per unit area. Phosphorus application (60 and 80 kg·ha⁻¹) is effective for the growth and flower production of marigold [152]. 150 - 200 kg N plus 200 kg P₂O₅ ha⁻¹ seems to be optimum for the yield of marigold [153]. However, 15-10-10 g/m² NPK was beneficial for dramatic improvement of various vegetative, reproductive and yield parameters of *Tagetes erecta* L [154]. Application of 90-40-90 kg NPK ha⁻¹ along with blanket dose of 2 kg B and 4 kg Zn ha⁻¹ gave the best performance for marigold production [155]. Ye *et al.*, [156] have conducted experiments using samples from two types of soils *i.e.* Acidic Ferralsols (AF) and Calcaric Cambisols (CC) and found that nitrogen application with wheat straw facilitates the growth and also enhances Cd mobility in the soil and its uptake by hyperaccumulator species (*T. patula*) however, the enhancement was greater in CC than in AF.

6.2. Role of Bio-Fertilizers and Mycorrhizal Inoculation

Organic farming helps in soil health and sustaining yield [157]. It is mainly based on principles of restoration of soil organic matter in the form of humus, increasing microbial population, contributing to soil health [158]. Biofertilizers containing living cells of different types of micro-organisms are capable of mobilizing nutritive elements from non-usable to usable form through biological means [159]. Bio-fertilizers differ from inorganic fertilizers as they are cultures of special bacteria and fungi. Some microorganisms promote plant growth, increase germination and vigor in young plants, leading to crop improvement [160]. Application of bio-fertilizers reduces per unit consumption of inorganic fertilizers and enhances the quality and quantity of flowers [161]. Bio-fertilizers help in the fixation of atmospheric nitrogen and improve phosphorus uptake by plants [162] [163]. Application of biofertilizer (VAM 10 kg/ha) and chemical fertilizers (200 kg N, 80 kg P, 80 kg K) yielded growth characters of maximum value in *Tagetes erecta* [164]. Application of *Azotobacter* and phosphorus solubilizing bacteria (PSB) with FYM and 50% recommended dose of nitrogen and phosphorus improved growth, flowering behaviour and yield considerably. Application of *Azotobacter* + PSB + FYM @ 30 t/ha + nitrogen @ 100 kg/ha and phosphorus @ 50 kg/ha was best for the growth of *Tagetes erecta* L. [165]. African marigold (*Tagetes erecta* L.) showed maximum plant height, flower size and yield per plant with 200 kg N, 80 kg P and 80 kg K ha⁻¹ and three different levels of bio-inoculants viz; B₀ (without bioinoculant), B₁ (10 kg VAM ha⁻¹) and B₂ (2 kg phosphobacterine) gave maximum secondary branches and yield per plant [166]. Bio-fertilizers applied together with chemical fertilizers improved the characters of marigold (*Tagetes erecta* L.) qualitatively and quantitatively [167].

N, P, K combined with biofertilizers positively affected plant height, plant spread, number of branches per plant, number of leaves per plant, flower yield per plant/plot/hectare [168]. Application of vermicompost enhances plant growth and flower number in *Tagetes erecta* L. and the effect on photosynthetic pigments was best at 60% vermicompost medium [169]. Vegetative growth characters and number of flowers were best produced by the application of $N_{120} P_{80} K_{40} \text{ ha}^{-1}$ followed by vermicompost $5 \text{ t} \cdot \text{ha}^{-1}$ and poultry manure $3.16 \text{ q} \cdot \text{ha}^{-1}$ [170]. Application of bio-inoculants along with chemical fertilizer is beneficial for vegetative growth and flower attributes [171]. Substitution of pine bark compost with 50% fly ash vermicompost was effective for the growth of marigold seedlings [172]. Growth and yield of African marigold increases when inorganic fertilizers were supplemented with biofertilizers and organic manures like vermicompost and cow urine. Application of *Azospirillum* + phosphate-solubilizing bacteria + cow urine (5%) + vermicompost was most effective in increasing vegetative growth and yield attributes [173].

Arbuscular mycorrhizal fungi (AMF) constitute a major component of rhizosphere microflora in natural ecosystems forming obligate symbiotic associations with many angiosperms, including several medicinal species [174]. AMF enhances the uptake of relatively immobile nutrients by the host plant, particularly P and various micronutrients. Mycorrhizae play multiple role in agro ecosystems and improve physical (through the external hyphae), chemical (enhancing nutrient uptake) and biological (through the soil food web) status [175] improving the resilience of plant communities against environmental and nutritional stresses [176] [177]. Bio-fertilizers as soil bio-inoculants multiply and participate in nutrient cycling, benefitting crop productivity [178]. Colonization of mycorrhizal fungi affects growth, pigments, phosphorus content and flower quality of *Tagetes erecta* L. positively and alleviate the stress imposed by withholding water [179]. The symbiotic association of *Glomus intraradices* possibly accumulates Cu in its vesicles thereby enhancing the copper tolerance of *Tagetes erecta* L. and improving the indices of phytoaccumulative yields [180]. Inoculation of arbuscular mycorrhizal fungus *Glomus constrictum* protected marigold plants from heavy metal toxicity and improved biomass production and other growth parameters of *Tagetes erecta* [181]. The activity of antioxidant enzymes in marigold plants inoculated with AMF was higher under cadmium stress. AMF can improve scavenging of reactive oxygen species (ROS) and reduce Cd concentration to alleviate Cd stress in *Tagetes erecta* L. [182]. Biofertilizers keep the soil environment rich in all kinds of micro- and macro-nutrients through nitrogen fixation, phosphate and potassium solubilisation/mineralization, release of plant growth regulating substances and biodegradation of organic matter in the soil [183].

6.3. Role of Growth Regulators

A number of chemicals have been tried on ornamental plants with a view to have compact plants and/or to retard the growth rate to enable supply flowers within

the stipulated time [184]. Growth promoters as well as retardants have been used in floriculture to manipulate plant growth in a desired way [185]. Abscisic acid (ABA) analog 8' acetylene ABA methyl ester (PBI 429) was demonstrated to move both acropetally and basipetally in marigold seedlings. Tissue concentration of the ABA analog was more when the compound was applied as a root-dip in comparison to foliar application [186].

Commercially the plant growth retardants are exploited for suppressing apical dominance, retarding vegetative growth, inducing lateral buds and producing large number of flowers resulting in higher flower yield and easy cultivation in various crops [187]. Foliar application of either Maleic hydrazide (MH) at 1000 ppm along with boron at 0.2% or Gibberellic acid (GA_3) at 200 ppm affected quality parameters and resulted in maximum flower weight and seed yield [188]. The combined treatment (*Azotobacter* + spray of GA_3) enhances vegetative parameters as well as flower yield in *Tagetes erecta* L. more as compared to the application of GA_3 and *Azotobacter* independently [189]. Maximum improvement in vegetative characters, flowering and yield attributes was found in plants treated with GA_3 at 100 ppm concentration [190]. Foliar application of GA_3 after one month of transplantation was most effective with respect to vegetative growth and flowering behavior of African Marigold (*Tagetes erecta* L.) [191]. NAA, BA and Kinetin application significantly improved growth and yield characters of *Tagetes erecta* L. Application of NAA affected growth and yield attributes more conspicuously in comparison to BA and Kinetin [192].

6.4. Role of Biotechnology

Plant biotechnology plays a significant role in improving planted material and increasing the available germplasm to the plant breeders in agriculture, horticulture and forestry. Incorporation of specific traits has been undertaken through gene transfer using tissue culture and molecular biological techniques. These techniques provide higher multiplication minimizing the risk of infection in comparison to conventional breeding methods and find application in micro propagation, embryo rescue, germplasm storage, somatic embryogenesis, virus and pathogen elimination and in vitro production of phytochemicals using plant cell/organ culture [193].

Extraction of several secondary metabolites and essential oils from marigold indicates towards the importance of establishing a reliable plant regeneration system for further genetic manipulation, however, there are fewer reports available in this respect. A wide range of explants sources, different types and combinations of plant growth regulators for organ or embryo formation have been used [194] [195]. Misra and Datta [196] developed direct differentiation of shoots from leaf segments of white marigold without any intervening callus and these plants when grown in field were significantly better indicating added commercial value of the tissue culture raised plants in successive generations. Callus formation however, was better in loose cells of leaf blade as compared to

arranged cells of nodes [197]. Friable callus was induced from leaf explants of yellow and white flower of *Tagetes erecta*. The pigmentation of the callus developed from yellow (YF) and white flower (WF) varieties was different. Callus of YF had lutein and zeaxanthin, whereas in WF callus lutein, zeaxanthin, β -cryptoxanthin and β -carotene are the main pigments [198]. Hairy root clones/cultures of *Tagetes erecta* L. exhibited significant variation in growth pattern and total thiophene contents in comparison to wild type [199] which can be used for producing thiophenes at large scale. Plantlets of *Tagetes erecta* were regenerated via somatic embryogenesis from foliar explants [200] required for genetic transformation and breeding to improve pigment and metabolite production.

7. Conclusion

Tagetes is extensively grown both in tropics and subtropics and good/healthy growth needs proper fertilization. In India marigold particularly flowers find profuse use in different religious and social practices. The plant also has wide ethno medicinal importance attributed to the bioactive compounds and essential oil found both in leaves and flowers, having commercial application as medicine, food colorant, dying agent and so on at industrial scale. *Tagetes* plays a significant role in the metal contaminated soils in addition to its protective role for plants against harmful nematodes and microbes while using in crop rotation and intercropping with other crops. *Tagetes* shows tolerance to saline soils and can be used to improve saline soils, however, utility of marigold in improving saline soils may further be investigated. Further work particularly related to allelopathy, phytoremediation and phytochemical constituents may be useful.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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