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Marigold (*Tagetes* spp.): A Diverse Crop with Multipurpose Value for Health and Environment: A Review

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ABSTRACT

Marigold (*Tagetes spp.*) is one of the most popular flower crop commercially exploited for multipurpose use. Apart from great demand of marigold flowers, the plants use in phytoremediation and allelopathic effect has been greatly exploited. Marigolds can be used against plant parasitic nematodes as a cover crop in rotation, as an intercrop, or as a crop residue amendment. Successful use of marigold as trap crop is well on record whereas its use as potential natural herbicide needs to be explored. Essential oils obtained from marigold possess antibacterial and antifungal properties and are widely used in perfumery industries, as insect repellent and as flavor component. Its extracts can be explored as alternative natural insecticides towards the stored products. Use of marigold for its medicinal value for curing various diseases has been well documented. Carotenoids extracted from flowers are being used commercially in pharmaceuticals. Marigold extract also finds application in coloring foods and various dairy products. Marigold petals are used as additives for poultry feed, as they provide bright colors in egg yolks, skin and fatty tissues and also as emulsifying gum. Silver and gold nanoparticles have been synthesized from marigold for antimicrobial activity. This review paper discusses the research undertaken for various uses of marigold plant worldwide.

Key words: Allelopathy, Carotenoids, Essential oil, Marigold, Medicinal properties, Nanoparticles, Phytoremediation.

The marigold genus *Tagetes* comprises of fifty six species of which twenty seven are annual and twenty nine perennial in nature. Of these species, the commonly grown ones are *T. erecta, T. patula, T. minuta, T. tenuifolia, T. lucida* and *T. lunulata* (Vasudevan *et al*., 1997). The species from the genus *Tagetes*, commonly known as Marigold are very ornamental plants easy to grow which relatively bloom for a long period. The name *Tagetes* is linked with the Italian God, Tages. Marigold belonging to family Asteracae is cultivated commercially for flowers throughout the world. Kaplan (1960) established that the genus is native to Central and South America especially Mexico, from where it spread to different part of the world during the early 16th century. Though *Tagetes* is native to the America, the two most commonly cultivated species are popularly known as African marigold (Krishnamurthy *et al*., 2012) and the French marigold. Marigold is comparatively a hardy plant usually having plant height of more than 150 cm and a life span of 120-150 days with a fairly good shelf-life. It can be grown in various agro-climatic and soil conditions. It also has the advantage of being cultivated in rainy, winter and summer season. Though, its commercial propagation method is by seeds, lately it is also being propagated by vegetative cuttings, especially through stem cuttings. The flowers of this species are generally available in bright shades of colour ranging from yellow to orange.

In addition to its commercial use as ornamental plant, numerous traditional utilities of different parts of the marigold plant have been reported. Leaves extract possesses anti-inflammatory and antioxidant activities (Parejo *et al*., 2005 and Li *et al*., 2011). Marigolds have several compounds in their tissue which have biological activity against a range of organisms (Ćetković *et al*., 2004). One such compound, thiophene, demonstrates antiviral, antibacterial, antifungal, nematicidal and insecticidal properties (Riga *et al*., 2005). The plants have a suppressive effect on free-living nematodes and have been used as an intercrop or in rotation to protect crops. It is also an important source of carotenoid pigment used in food, poultry and pharmaceutical industry. It is gaining industrial importance due to its huge potential in value addition (Kanwar and Khandelwal, 2013).

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Importance as ornamental plant

Four species of *Tagetes viz*., *T. erecta, T. patula, T. tenuifolia* and *T. lunulata* (Soule, 1996) are commonly grown for ornamental purpose. Three species *viz*., *T. erecta* (African marigold), *T. patula* (French marigold), *T. tenuifolia* (Signet marigold) are popularly grown for its ornamental flowers. French marigold is dwarf, compact and has the widest color range of marigolds. The flowers are mahogany red in color and this color is not available in the *African marigold*. African marigold is characterized by larger leaf size and bigger flowers which are either semidouble or fully double (Hortportal, 2014). The flowers of marigold are sold in the market as loose flowers in bulk, as specialty cut flower or for making garlands (Polara *et al*., 2014). Marigold plants make great edges, potted plants and are commonly grown in home and public gardens. The plants generally bear flower of bright yellow, orange or red colour. Many marigold varieties are strong in the orange and yellow colour range, but they also include some incredible maroons, reds and even creamy whites. Many hybrid species have been developed which are more attractive. Since the 1920's marigold breeding has developed hundreds of new varieties. The odorless marigolds, hybrids and triploids have all been advancements in breeding. *Triploids (T. erecta* × *T. patula*) are a wide cross between the African and French species. The plant is sterile and is not capable of setting seed but produces more flowers. The triploid marigolds are not subject to heat stress and continue blooming prolifically regardless of the heat. The flower form on triploids can be single, double or semidouble. Breeders are selecting marigolds for earlier flowering with specific improved characteristics such as increased flower size. The single marigold flower form has been given recent attention with several new varieties introduced. However, marigolds flowers are not sweet smelling flowers.

Phytoremediation

Marigold has been very well documented for phytoremediation of heavy metal polluted soil. Madanan *et al.* (2021) used *Tagetes erecta* for phytoremediation of heavy metal polluted lateritic soil. It was found effective phytoextractor for Zn and Cd, while an excluder for Pb. Moreover, they reported that use of Aztec marigold in phytoremediation will not pose risk to human health through food chain contamination, as it is not foraged. Jaipal *et al.* (2015) indicated that *Tagetes patula* (French mixed orange variety) may be used for phytoremediation of flyash contaminated soil and can tolerate heavy metal pollution. Karuppiah and Sarah (2019) noted that *Tagetes erecta* in association with rhizobacteria (*Bacillus cereus*-CK 505 and *Enterobacter cloacae*-CK 555) was found to accumulate high levels (94%) of Cr within a short period of 35 days. Environmental pollution with chromium (Cr) is harmful to humans, animals and plants, while in plants it causes diminished growth, anatomical alterations and death. In another study by Coelho *et al*. (2017), the potential value of marigold in the phytoremediation of Cr had been investigated and it was concluded that *T. erecta* accumulated levels above that proposed for hyperaccumulators, which can be used in the phytoremediation of Cr-contaminated soils. Heavy metals not only pollute soil but also adversely affect the aquatic environments. Marigold also helps in phytoremediation of zinc from synthetic wastewater (Awan *et al*., 2020) and has zinc accumulation capacity which is useful to treat zinc contaminated site.

Allelopathic effect

Allelo-chemicals can be defined as plant metabolites or their products that are released into the microenvironment and are toxic to other organisms (Halbrendt, 1996). Marigold when intercropped with tomato significantly reduced tomato early blight caused by *Alternaria solani* (Gómez-Rodríguez *et al*., 2003). Marigold produce several compounds that are biologically active including α-T compounds and polyacetylenes. Of these, α-T compounds are strongly photoactivated and phytoinhibitory and can be exploited to control nematodes and other plant pathogens such as *A. solani* (Gómez-Rodríguez *et al*., 2003) as well as biological control of weeds (Lambert *et al*., 1991) as reviewed under.

Nematode management

Marigold has been reported to be a nematode allelopathic crop, particularly towards root-knot and root-lesion species (Hooks *et al.,* 2010). *Tagetes* spp. has been known to suppress plant-parasitic nematodes Meloidogyne spp. and *Pratylenchus* spp. (Hooks *et al*., 2010). Literature also indicates that marigolds could prevent the population increase of 14 genera of plant parasitic nematodes. The allelopathic effect of marigold responsible for nematode suppression is mainly attributed to α-terthienyl (Gommers and Bakker, 1988). Marigold has been reported to kill plant parasitic nematodes as a standing cover crop and is ineffective after soil incorporation. It is found that the nematicidal activity of marigold is only detected in the root exudates (roots of the growing plant) but not in the homogenized extracts of roots and leaves (Jagdale *et al*., 1999). Marahatta *et al.* (2010) reported that root-knot nematodes infestation can be suppressed more efficiently by planting marigold close to a nematode infected plant or immediately into soil that was recently grown with a root-knot nematode colonized plant host. Marigold efficiently suppresses *Meloidogyne* spp. only when marigold is in active growing stage and is planted when the nematodes are in the active stage.

Marigold species *T. patula, T. minuta, T. erecta* (var. orange), *T. erecta* (var. yellow) has been found to reduce the number of second stage juveniles in tomato crop (Kalaiselvam and Devaraj, 2011). *T. patula* suppressed *Pratylenchulus penetrans* and *P. pratensis* and the Meloidogyne species *M. arenaria, M. incognita, M. javanica* and *M. hapla* (Suatmadji, 1969). *Tagetes erecta* also suppressed *M. arenaria, M. incognita* and *M. javanica*, but not *M. hapla* (Suatmadji, 1969). *Tagetes patula* limited penetration and development of *Rotylenchulus reniformis* (Caswell *et al*., 1991). However, *T. patula* is more effective than many other species and varieties of *Tagetes* in suppressing *M. incognita* (Ploeg, 2002). Evenhuis *et al.* (2004) hypothesized that marigold controlled nematode populations to greater depths than the soil fumigant and that the chemical treatment did not prevent increase of nematode populations later on, especially in the lower soil layers. Marigold as a cover crop in a rotation appears to be the most frequently employed method to control nematodes (Ploeg, 2002). It can also be incorporated as a green manure (Siddiqui and Alam, 1987) applied as a plant extract similar to nematicides (Mateeva and Ivanova, 2000) and can be inter-cropped with the cash crop. Among the intercrops, marigold intercropped with vegetables reduced nematode population in the soil, number of galls, egg masses per root system, number of eggs per egg mass and root-knot index compared to growing of vegetables as monocrop (Kumar *et al.,* 2005). *T. erecta* intercropped with banana, suppresses the important banana nematode pests *viz*., *Radopholus similis, Helicotylenchus multicintus, R. reniformis* and *Hoplolaimus indicus* (Alam *et al*., 1979). Whereas, under greenhouse condition it has been reported that bacterial wilt of tomato caused by *Ralstonia solanacearum* aggravated in soil having combined infection of the bacterium and the root-knot nematode (*Meloidogyne incognita)*. However, nematode buildup was hampered by the plant refuge of *T. erecta*, in the presence as well as in the absence of wilt pathogen (Aggarwal *et al*., 2005).

Trap crop

Trap crops are mainly grown as a control measure to keep pests away from the main crop and to protect it from pest attack. Marigold (*Tagetes erecta* L.) is potentially useful to maintain arthropod biodiversity, including certain species of predator thrips. Sampaio *et al.* (2008) reported that this plant hostages species of Orius (Hemiptera: Anthocoridae), which is the main thrips predator globally. Moreover, marigold planted in-between rows of onion crop have shown to promote the reduction of aphid, nematode and whitefly and virus diseased plants (Zavaleta-Mejia and Gomez, 1995). They also host other phytophagous species that are alternative prey for entomophagous species. Successful use of marigold as trap crop for management of tomato fruit borer on tomato is on record (Srinivasan and Moorthy, 1991) with marigold in 3:1 combination without using any type of insecticide (Hussain and Bilal, 2007). Srinivasan and Moorthy (1991) further indicated that use of African tall variety of marigold cv. Golden Age afforded maximum reduction of both eggs and larvae of *Helicoverpa armigera* in the intercropped tomato alongwith two sprays of 0.07% endosulfan superimposed on tomato with a consequent reduction in the number of bored fruits. Karabhantanal *et al.* (2005) revealed that the best IPM module against the tomato fruit borer, *H. armigera* consisted of trap crop (15 rows of tomato: 1 row marigold) + *Trichogramma pretiosum* (45,000 ha^{-1}) - NSKE (5%) - Ha NPV (250 LE/ha) - endosulfan 35EC (1250ml/ha). Cultivation of marigold significantly reduced the population of *Pratylenchidae* (Korthals *et al*., 2005). However, Bandyopadhyay *et al.* (2005) reported a marginal reduction in population (11-17%) of whitefly on mulberry plants with the use of marigold as trap crop. Some organic growers cultivate marigold for its pollen and nectar, which increase natural enemy fecundity and its survival (Baggen *et al*., 1999).

Natural herbicide

Potential utilization of dried powder of *T. minuta* as a natural herbicide for managing rice weeds has been investigated. Leaf powder of *T. minuta* applied to soil of rice field significantly reduced emergence and growth of weeds (*Echinochloa crus-galli* and *Cyperus rotundus*) under greenhouse condition and in rice field plots (Batish *et al*., 2007). Leaf extracts have also been reported to show burning of the radicle's tips of *Acacia asak* thus inhibiting its growth (Alhammadi, 2008). It is observed that seed germination of *Lotus corniculatus* var. *japonicas* is also significantly inhibited by *T. minuta* aqueous extracts (Kil *et al*., 2002).

Essential oil

Tagetes genus provides essential oil by steam-distillation from their flowers. This is known as Tagetes, Taget or Tagette oil. Taget oil is applied only in traces to avoid its toxic effect. It has an intense, cloying, fruity fragrance resembling apple and is used in cosmetics and in many floral perfumes (Groom, 1997). Oil is widely used in perfumery industries, as insect repellent and in curing bronchodilatory disease (Singh and Singh, 2005). The oil is also used as a flavor component in major food products including cola beverages, alcoholic beverages, frozen dairy desserts, candy, baked goods, gelatins, puddings, condiments and relishes (Meshkatalsadat *et al*., 2010). The major constituents of essential oil obtained by Rondón *et al.* (2006) in *Tagetes* sp. are piperitone (33.77 %), trans-β-ocymene (14.83 %), terpinolene (13.87 %) and β-caryophyllene (9.56 %). The essential oil of cultivated *Tagetes minuta* L. have been obtained by hydrodistillation from aerial part and the main components identified by Meshkatalsadat *et al.* (2010) are limonene (13.0%), piperitenone (12.2%), α-terpinolene (11.0%), piperitone (6%), (E)-tagetone (5.7%) and (Z)-ocimenone (5.1%). However, essential oil from *Tagetes* plant is of medium viscosity and difficult to work with if exposed to the air for a long time.

Essential oil from leaves and thiophene rich extracts from marigold roots have significantly good antifungal activity against a number of soil borne and foliar plant pathogens (Saha *et al*., 2012). *Tagetes* contains essential oils known for their insecticidal and antibacterial properties (Piccaglia *et al.,* 1996) as reviewed under.

Insecticidal properties

Volatiles from three species of the genus *Tagetes* have been isolated and characterized which have been well documented. Volatiles isolated from the *T. minuta* species showed higher insecticidal activity than those from *T. patula* and *T. erecta*. Comparison of extracts from the flower, foliage and roots of the plant showed that most of the activity is located in the flower.

The chemical composition and insecticidal properties of *T. erecta* and *T. patula* has been documented from flower, foliage and root. The major compounds identified in the extracts are β-caryophyllene, piperitenone, tetracontane, C_{33} botryococcane and decane. Hexane extract of flowers of *Tagetes erecta* shows better insecticidal property against aphids and *Spodoptera frugiperda* (Ravikumar, 2010). *T. minuta* plants have a potential to be used in a mixed or inter-cropping system to reduce the pest attack. The leaves of *T. minuta* are used locally in Africa and India to repel blowflies and safari ants (Scholtz and Holm, 1986). The active compounds in the plant which act as antifeedants are alpha-pinene, limonene and borneol. Borneol is also a component of many essential oils and is a natural insect repellent. The essential oil components including compound alpha-terpineol is also responsible for the insecticidal and pesticidal properties of the plant (Salehi *et al*., 2011). The efficiency of water extracts of *T. minuta* has been demonstrated by Ali *et al.* (2010) who reported that an aqueous extract of *T. minuta* leaves at concentration of 1:2.5 g/ml (w/v) was quite effective in reducing mustard aphid (*Lipaphis erysimi*) by 96% when sprayed on Indian mustard. The crude extract of *T. minuta* obtained using water as a solvent is as effective as crude extracts from organic solvent systems in killing cabbage aphids. Aqueous extracts of *T. minuta* also reduces fecundity of cabbage aphids with the magnitude comparable to those obtained from organic solvents (Phoofolo *et al*., 2013). *T. minuta* oil extracted by steam distillation of shoot extracts kills larvae of the sugarbeet root maggots, *Tetanops myopaeformis*, at higher concentrations whereas at lower concentrations, it prevents successful pupation from occurring (Dunkel *et al.,* 2010). Green *et al.* (1991) suggested some potential of *T. minuta* oil or its components for the control of *A. aegypti* and other mosquitoes. The volatiles are highly effective toward both larvae and adult mosquitoes (Wells *et al.,* 1993).

Remarkable control efficacy on leaf miner is observed with marigold plant. Catalina and Ekaterini (2009) reported that first instars of cabbage maggot (*Delia radicum*) were susceptible to fresh root tissue extracts of *T. erecta* and *T. patula*. White cabbage intercropped with *T. patula* suffered significantly less cabbage aphid infestation when compared with a mono-cropped cabbage (Jankowska *et al*., 2009). *T. erecta* showed repellency action but only to a shorter period of exposure against maize weevil, *Sitophilus zeamais* Motsch (Parugrug and Roxas, 2008). The highest insecticidal activity has been obtained with extracts isolated by SSDE by using methylene chloride as a solvent (Wells *et al*., 1993).

Bactericidal properties

The flowers of *T. erecta* contains ‘Patulitrin’ flavonoid that possess antibacterial potential against *Alcaligens faecalis, Bacillus cereus, Campylobacter coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus vulgaris* and *Streptococcus mutans* (Rhama and Madhavan, 2011). Volatile oils of *T. minuta* are used for antibacterial proportion. The essential oil of *Tagetes terniflora* (Tereschuk *et al.,* 2003) and *Tagetes lucida* have been reported to have antibacterial activity against *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Streptococcus pyogenes* (Caceres *et al.,* 1991), *Escherichia coli*, *Salmonella enteritidis*, *Salmonella typhi*, *Shigella dysenteriae* and *Shigella flexneri* (Caceres *et al.,* 1990).

Various *Tagetes* oils appeared to inhibit gram positive bacteria and fungi (Hethelyi *et al*., 1988). From scientific studies it is observed that thiophenes (natural phytochemicals that contain sulfur containing ring) may be the active ingredient in Tagetes species and they have been used against gram negative and gram positive bacteria *in vitro.* Further, the studies reveal that *T. erecta* has antibacterial effect against airborne disease causing gram positive and gram negative bacteria and mainly against skin infection causing bacteria and hence can be useful in developing drugs for diseases like dermatitis, acne, skin races and also can be developed as antiseptic (Dasgupta *et al*., 2012).

Incorporation of marigold plant residues results in lowest *Nitrosomonas* population in the soil (Suresh and Ramanathan, 1994). Flower and root extract exhibit significant antibacterial activity against *S. lutea, E.coli* and *B.circulence* (Verma and Verma, 2012).

Storage pest control

T. erecta root extracts are more toxic to the lesser grain borer (*Rhyzopertha dominica*) and the red flour beetle (*Tribolium castaneum*) in comparison to standard insecticide malathion (0.05 mg/ml) (Morallo-Rejesus and Decena, 1982). Marigold leaf powder (5%) showed a higher residual toxicity (57.09%) than *Azadirachta indica* (50.06%) and *Cynodon dactylon* (43.28%) leaf powder. Compared with the commercial insecticides (malathion and carbaryl), *Azadirachta indica* seed extract and marigold leaf powder possess a potential as alternative natural insecticides towards the red flour beetle in stored products (Islam and Talukder, 2005). Broussalis *et al.* (1999) reported that dichloromethane and methanol extracts from *T. erecta* had significant insecticidal activity against the stored-product beetle, *Sitophilus oryzae*. Flower extract of *T. erecta* can be used as pesticide against *Tribolium castaneum* (Nikkon *et al*., 2009).

Medicinal properties

Different parts of *Tagetes* plants have several therapeutic uses in traditional medicine across the world. These include treatment of pain, inflammation, cancer and various gastro-intestinal disorders (Kirtikar *et al*., 1993). Different species of *Tagetes* have been found to possess antimicrobial, anti-inflammatory, hepatoprotective, wound healing and analgesic activities (Rhama and Madhavan, 2011 and Gopi *et al*., 2012). *Tagetes* sp. has been used in folk medicine to treat intestinal and stomach diseases and some of them have been found to possess biological activity (Tereschuk *et al*., 1997 and Broussalis *et al*., 1999). Marigold is said to purify blood and flower juice is given as a remedy for bleeding piles (Ghani, 1990). Infusion of plant is used against rheumatism, cold and bronchitis (Natarajan *et al*., 2005). Other *Tagetes* species that share some of these therapeutic properties include *T. patula* and *T. minuta*. It has been used to treat colics, diarrhoea, vomit, fever, skin diseases, hepatic disorders and also useful in eye health protection (Ivancheva and Zdravkova, 1993). Dietary carotenoids are used to treat cancer and photosensitivity diseases (Naik *et al*., 2003). Phytochemical studies of different parts of marigold plant have resulted in isolation of various chemical constituent such as thiophenes, flavonoids, carotenoids and triterpeniods. The plant have shown to contain biochemical like quercetagetin, a glucoside of quercetagetin, phenolics, syringic acid, methyl-3, 5-dihydroxy-4-methoxy benzoate, qercetin, thienyl ethyl gallat (Kiranmai and Ibrahim, 2012).

The flower has numerous pharmacological activities such as antipyretic, astringent, carminative, stomatic and scabies. It is used as wound healing, reducing inflammation, smoothing and softening the skin and thus used in skin care products, as it assists the cell rejuvenation (Kadam *et al*., 2013).

This genus is recognized as a source of carotenoids which possesses anticancer and anti-ageing properties (Block *et al*., 1992) and flavonoids having pharmacological properties (Tereschuk *et al*., 1997). In fact, marigold flowers are one of the richest sources of natural carotenoids (Boonnoun *et al.,* 2012) with high xanthophyll content (Manik and Sharma, 2016). Carotenoids have excellent antioxidant properties while α and β-carotene, xanthophylls and retinoids have been reported to inhibit some types of cancers. *Tagetes erecta* is rich in the xanthophylls, lutein, which occurs acylated with fatty acids (Gregory *et al.,* 1986). Lutein also shows greater antioxidant activity than the other two common carotenoids, β-carotene and lycopene (Wang *et al*., 2006). It suppresses mammary tumor growth and enhances lymphocyte proliferation (Chew *et al*., 1996) and reduces the risk of age related degeneration of the human macula (Landrum *et al*., 1997), the age related macular degeneration (AMD) (Seddon, 1994).

Though the positive effects of various antioxidant and anti-inflammatory properties of marigold preparations have been observed but however, there is need for studies on cytoprotective and cytotoxic activity of chemical compound particularly flavonoids in marigold.

Natural food colorant and additive

Marigold flower petals are a significant source of the xanthophylls and have a much higher concentration of this pigment compared to other plant materials. Xanthophyll is a yellow to orange-red coloured natural pigment. Significantly pure xanthophylls can be used as a food colorant and therefore exist a huge demand of this pigment in food industries (Verghese, 1998). The main coloring component of marigold flower is lutein ($C_{40}H_{56}O_2$). The extract with only the purified form with a lutein content of known concentration and a pure crystalline lutein isolated from marigold flower is allowed for food use (Vernon-Carter, 1996) as a natural colorant. It is used as a food colouring agent and nutrient supplement (food additive) in nutraceutical industries in a wide range of baked goods and baking mixes, beverages and beverage bases, breakfast cereals, egg products, fats and oils, gravies and sauces, soft and hard candy, infant and toddler foods, milk products, processed fruits and fruit juices, soups and soup mixes in levels ranging from 2 to 330 mg/kg (Cantrill, 2006). The Lutein ester concentration in fresh Marigold flowers varies from 4 mg/Kg in greenish yellow flowers to 800 mg/Kg in orange brown flowers. Dark-colored flowers contain about 200 times more lutein esters than the light colored flowers (Sowbhagya *et al*. 2013).

Well-preserved flowers exhibit a high yield of xanthophyll content in contrast to the unpreserved flower. The stability and amount of xanthophylls extraction increases on saponification and subsequent purification with Ethylene Dichloride (Pratheesh *et al*., 2009). Pretreatment of marigold flowers with sodium hydroxide citric acid followed by hydraulic pressing results in higher pigment yield (Sowbhagya *et al.,* 2013).

Poultry feed

Lutein supplements are often used to pigment and enrich layer chicken eggs. There is demand of lutein in poultry industries as dried petals which are added to the poultry feed after grinding in order to intensify the yellow colour of egg yolks and broiler skin (Singh *et al.,* 2008). There is possibility of yolk pigmentation through the use of natural products in feeds of layers. Because lutein in egg yolk is highly bioavailable, as most of fats and fat-soluble compounds (Chung *et al.,* 2004) and lutein content in eggs can be manipulated by the use of lutein in layer diets, it is possible to use lutein feed additives to develop lutein-enriched eggs Leeson and Caston, 2004). From an economic point of view, marigold pigments achieve the desired colour at considerably lower costs than the corresponding synthetic varieties (Seemann, 1998). Rajput *et al.* (2012) concluded that dietary supplementation with marigold flower extract enhanced carcass and shank color, antibodies against ND and AI and improved growth performance of broiler chickens. They further suggested that marigold extract at the level of 200 mg/kg diet may be used to enhance humoral antibodies and to improve carcass color and performance of broilers.

Emulsifying gum

The grounded flower petals of *Tagetes erecta* contain a water-soluble gum (marigold flower polysaccharide, MFP). MFP has emulsifying and emulsion-stabilizing properties equivalent to those of *Acacia* gum (Medina and BeMiller, 1991).

Nanoparticles

Nanotechnology has high potential in processing of industrial crops and by-products in order to extract valuable biological active compounds. Nanotech approach *i.e* microemulsion (ME), as a novel green technique for lutein extraction from *Tagetes erecta* as an industrial crop has been successfully conducted (Mehdi and Soliman, 2019). Silver nanoparticles have been synthesized using flower broth of *Tagetes erecta* as reductant by a simple and eco-friendly route. The aqueous silver ions when exposed to flower broth are reduced and resulted in green synthesis of silver nanoparticles (Padalia *et al.,* 2015). Similarly, an environment friendly technique for green synthesis of gold nanoparticles has been developed using the flower extract of *Tagetes erecta* as reducing agent for reduction of Au3+ in aqueous solution (Krishnamurthy *et al.,* 2012). Further, phytochemical profile, antioxidant activity and cytotoxicity assessment of *Tagetes erecta* L. flowers have shown encouraging results with more promising biological action (Burlec *et al.*, 2021).

CONCLUSION

Marigold is one of the most important commercially exploited flower crop cultivated for flowers used in garlands, decoration and in landscape gardening. Phytoremedial as well as allelopathic potential of marigold as nematicide and natural herbicide has been explored. Essential oils are being used for insecticide and perfumery. Medicinal properties of *Tagetes* species and bio-molecules which are responsible for pharmaceutical property of marigold as well as use of nanotechnology in extraction of biocompounds have also been documented. Silver and gold nanoparticles have been synthesized from marigold for antimicrobial activity. Carotenoids extracted from flowers are being used commercially in pharmaceuticals, food supplements and poultry feed additives and thus, marigold can truly be called as a wonder ornamental crop with multipurpose use. However, there is need for extensive research on cytoprotective and cytotoxic activity depending on the chemical nature of the compound present in marigold.

Conflict of interest: None.

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