Diseases of Marigold (Tagetes erecta) and their management: A Review

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Abstract
Marigold belongs to family Asteraceae and is extensively used for making garlands, beautification and other purposes i.e. pigment extraction, oil extraction and therapeutic use. Both leaves and flowers of marigold plant are important as medicine due to phenolic and antioxidant activities. Inspite of insecticidal, fungicidal, bactericidal, larvicidal properties of marigold, it is affected by various pathogenic microoganisms such as fungi, virus and bacteria that cause diseases and damage to the plant which resulted yield loss. In the present review, a brief introduction to various diseases of marigold, their symptoms and management strategies are discussed.

Keywords: Tagetes erecta, eco-friendly management, diseases, Marigold

1. Introduction
Marigold is one of the commercially exploited ornamental flower crops which belong to genus Tagetes and family Asteraceae. It has wide spectrum flowers with attractive colour, shape, size which grab the attention of various flower growers. Flowers of marigold are extensively used for religious and social purposes (Bos and Yadav 1998). They are a group of perennial herbs of varying habit and exhibit both type of pollination, self and cross pollination. Out of the 33 species of marigold, Two popularly grown species of marigold are African or Mexican marigold (Tagetes erecta L.) and French marigold (Tagetes patula L.), which originated in Mexico and South Africa, respectively. Although the origin of T. erecta (African marigold) is Mexico, but due to its adaptability, popularity and wide cultivation in India, it is presumed to be of Indian origin (Desai, 1967, Asif, 2008). It is majorly grown in Madhya Pradesh while Himachal is at ninth rank in area and production of marigold (Shukla and Thakur, 2018). The plant has economical importance due to its showy flowers, tagetes oil and anti-nematicidal properties (Usman et al., 1972). Flowers of marigold are sold as loose flowers in the market, highly suitable as a bedding plant and it is also used for beautification.

Both leaves and flowers of marigold plant have phenolic and antioxidant activities due to which they are used for medicinal purposes (Tripathy and Gupta, 1991, Khalil et al., 2007). Leaves paste is used externally to treat boils and carbuncles and leaf extract of the plant is good for ear ache. Extract of its flower is used as blood purifier, as a cure for bleeding piles and for treatment of eye diseases and ulcers (Bos and Yadav, 1998). Marigold plants have anti-nematicidal activity (Olabiyi and Oyedunmade, 2007) and found most effective against the nematode species Pratylenchus penetrans. The flowers are used to make food pigments as they are rich in carotenoid pigment. The powder of flower petals are used in poultry feed which ensure a good colouration of egg yolks and broiler skin (Shukla and Thakur 2018).

Inspite of insecticidal, fungicidal, bactericidal, larvicidal properties of marigold it is affected by various pathogenic microoganisms such as fungi, virus and bacteria that causes diseases and damage to the plant which resulted yield loss. Marigold suffers from various fungal, bacterial, viral and nematodal diseases and a brief introduction to these diseases and their management strategies are being discussed in the present review.

2. Major Diseases of Marigold and their Management
2.1 Fungal diseases
Marigold is one of the most important commercial flower crops of India in terms of cultivation and utilization. Though having repellent property, marigold is also affected by number of fungal diseases. Some of the important fungal diseases of marigold are flower blight (Alternaria zinniae), wilt and stem rot (Phytophthora cryptogea), Collar Rot (Phytophthora sp.; Pythium sp.), damping Off (Pythium sp.), Alternaria leaf spot, Fusarium wilt (Fusarium oxysporum) and Cercospora leaf spot (Cercospora megaloptanica) (Sohil, 1983; Pawar, 1971). Out of these leaf spot and flower blight incited by Alternaria tagetica is the most serious, prevalent all over the country. Shamso and Akta (2017), isolated a total of 20 species of fungi from Tagetes erecta and T. patula, out of which Aspergillus fumigates, Alternaria alternata, and Curvularia
2.1.1 Alternaria Leaf Spot

The disease is incited by Alternaria spp. The favourable temperature for germination of conidia of Alternaria helianthi is 25°C to 28°C and the presence of free water on leaf surface (Allen et al., 1982) and exposure to high moisture conditions for long time increased the severity of Alternaria tagetica (Hotchkiss and Baxter, 1983). According to Cotty and Misaghi (1985) growth, sporulation, zinniol production and number of lesions formed by Alternaria tagetica infection was found to be affected by light.

The fungus growth is also affected by both continuous and alternating light. The fungus grows optimally at 25°C and the growth was almost inhibited at a temperature of 35°C (Yu and Lee, 1989). Mazumdar (2000) studied the effect of various meteorological factors on the development of leaf blight of African and French marigold caused by Alternaria dianthi and found a significant correlation between rain fall, temperature and humidity which were suitable for the development of leaf blight in marigold. In alternaria leaf spot, brown necrotic spots formed on leaves, which increases in size during later stage of infection and the entire foliage gets damaged by the infection and results in poor vegetative growth. According to an estimate the disease resulted in a loss of flower yield upto 55-60% (Cotty and mishaghi, 1985) in northern Madhya Pradesh. The leaf spot and flower blight disease (Alternaria tagetica) has become a major biotic constraint in the full exploitation of high yielding scented marigold varieties. The infection can lead to premature defoliation and finally death of the plant. Alternaria zinniae cause inflorescence blight of marigold in which elongated lesions are formed on inflorescence. Light tan to dark brown, large irregular blotches appears on the leaves with zonation. Dithane M-45 (0.2%) and Carbenazim (0.05%) spray can be used to control the disease at regular intervals (Aktar and Shamsi, 2015, Singh et al., 2012, Bharwale et al., 2002). Some plants and plant products are also found to be useful in controlling Alternaria infection (Mamgai et al., 2013). Dubey (2001) also reported that Azadirachta indica in different forms is effective against Alternaria spp. while according to Gupta (2005) volatile oils from A. indica and Eucalyptus sp. were found effective against Alternaria tagetica (Chandel et al., 2010).

2.1.2 Septoria leaf spot

The disease is caused by fungal pathogen of Septoria sp. Septoria leaf spot is commonly occurred on chrysanthemum (Waddell, 1959, Magie and Overman, 1960, Chandel and Chandel, 2010). Earlier this disease in marigold was reported from Florida (Changsri, 1958). However, Shukla and Thakur (2018) firstly reported the septoria leaf spot of marigold from Himachal Pradesh, India. Symptoms of the disease mainly appear on leaves but these can also develop on pedioles, stem and calyx. Small, water-soaked circular spots appear on older leaves of the infected plants. The centre of these spots turns into grey colour and margins into dark brown colour as the disease progress. In the tan centres of spots, there is some readily visible dark brown, tiny dot like structures appear which are known as Pycinidia. After appearance of many spots, the affected leaves turns yellow in colour and then turn brown, become shrivelled and ultimately drop off (Shukla and Thakur, 2018).

The disease have a severity of about 30-70% in Marigold growing area of Himachal Pradesh, India and under favourable conditions it may reach upto 100 percent (Shukla and Thakur, 2018). For control of the disease the crop should be sprayed by 0.2% Dithane M-45 fungicide at regular intervals after appearance of first disease symptoms (Aktar and Shamsi, 2015, Bharwale et al., 2002). Hussain et al. (2013) used 33 plant extracts against leaf spot of ground nut and all extracts found effective against the pathogen but leaf extract of A. indica found more effective in comparison to others. Foliar spray of aerated compost tea reduced septorial leaf disease of tomato by 26.3% (Gangaiah et al., 2004).

2.1.3 Cercospora Leaf Spot

Cercospora leaf spot is caused by fungus Cercospora megalopotamica which causes the economic losses in term of yield and quality parameters of marigold crop. In Cercospora leaf spot, circular spots (Diameter of about 1/8 inch) with ash grey centres and dark brown or reddish-purple borders appear on leaves. To reduce the effect of fungus and to get high flower production, usage of fungicides in excess lead to resistance in the pathogens against fungicide (Gangavane, 1981, Arora et al., 1992, Waghmare et al., 2011). Bavistin and captan gave the best control against the Cercospora leaf spot of the marigold (Barbetti, 1987, Veena et al., 2013; Chandel and Kumar, 2017). A combination of the bio-formulation (garlic extract, cow urine, soap nut) was found effective in controlling the disease (Venkataramana et al., 2009, Chandel and Kumar, 2017). Uddin et al. (2013) used six plant extracts (Neem leaves extract, Garlic cloves extract, Biskatali leaves extract, Alamanda leaves extract, Arjun leaves extract and Debdaru leaves extract) against Cercospora leaf spot of mungbean and suggested the use of neem leaves extract for controlling the pathogen as it minimize the incidence and increased the yield of mungbean. Farrag (2011) firstly observed Cercospora leaf spot disease in Okra plant and reduced the disease
incidence by foliar application of Topsin M-70WP and lemongrass oil in different concentrations.

2.1.4 Wilt and Stem Rot
It is caused by the fungus Phytophthora cryptogea which infect the collar portions of the plants. In nursery, the infection resulted in damping-off which is aggravated by soil moisture while infected plants showed wilting in the field. French marigold and dwarf varieties of marigold are found less susceptible to the disease in comparison to African types of marigold. The disease can be controlled by treating the soil with Captan, Metalaxyl Mancozeb and Fosetyl-Al. (Kumar, 2012). Strains of Pseudomonas fluorescens can be used as biocontrol agents against Phytophthora cactorum that causes root rot of strawberry (Agusti et al., 2011). Aqueous and acetone extracts of Allium sativum and Azadirachta indica were found effective against Phytophthora infestans (Ngadze, 2014). In a study conducted by Yanar et al. (2011), out of 26 plants, Xanthium strumarium, Lauris nobilis, Salvia officinalis and Styrax officinalis were showed potent antifungal activity by completely inhibiting the mycelial growth of P. infestans. Acetone, methanol and hexane extracts of Terminalia bellerica and acetone extracts of Psoralae corylifolia showed complete inhibition of mycelia growth of P. Infestan (Rani et al., 2015).

2.1.5 Collor Rot
It is caused by a number of pathogens viz. Rhizoctonia solani, Phytophthora sp. and Sclerotium rolfsii. The occurrence of disease in nursery stage or in grown up plants depends upon type of soil, moisture content and other environmental factors (Sohi, 1984). In this disease black lesions developed on the main stem and roting at the collar regions causes plant death. The disease can be reduced by soil sterilization and controlled watering (Anonymous, 2012). Captan, Thiram and Manzate at 0.3% concentration can completely inhibit the growth of pathogen. Bitox-50 can also control the pathogen at 0.3 and 0.5 % concentration (Rout and Mishra, 2008). Plant extracts of Rauwolfia serpentine can be used against the pathogen and similarly biological antagonist (Streptoverticillium sp., Trichoderma sp. and Gliocladium virens) can also be used to significantly control the pathogen (Rout and Mishra, 2008). In studies carried out by Siddique et al. (2018), Chemical fungicide, leaf extract of Neem, Poultry manure and Trichoderma harzianum found effective in controlling Sclerotium rolfsii that causes foot and root rot disease of eggplant.

2.1.6 Powdery Mildew
The causal organisms are Oidium sp. and Leveillula taurica which produces whitish, tiny, superficial spots on leaves and later on whole aerial parts of plant is covered with whitish powder which contains conidia and conidiospores of the pathogens (Grover, 1952, Sreeramula, 1953). The disease can be controlled by spraying Sulfix (3g/litre of water), 0.5% Karathane (40 E.G.) or by dusting with sulphur powder at regular intervals (Anonymous, 2012). Cell-free culture filtrate and biomass of Ampelomyces quisqualis, Trichoderma harzianum and Saccharomyces cerevisiae were found effective against powdery mildew of grape (Singh et al., 2017). Singh et al. (2015), evaluated aqueous extracts of leaves of Azadirachta indica, Melia azedarach, Melothria perpusilla, Phlegacanthus thrysiflorus, Vitex trifolia and rhizome extract of Acorus calamus and Zingiber officinale against powdery mildew of oak tree (Quercus serrata). Out of these plants, rhizome extract of Zingiber officinale (at 15% concentration) was found to be most effective in disease control.

2.1.7 Flower Bud Rot
The causal agent for the disease is Alternaria dianthi. During the disease young flower buds shrivel, turn deep brown in colour and dry up while symptoms of the disease on mature buds are less prominent but these buds also fail to open due to the effect of pathogen (Mondal and Chaudhari, 1976). The pathogen also infects leaves of the plant causing blight and brown necrotic spots on margins and tips of older leaves. Spraying of 0.2% Mancozeb and 0.2% Dithane M-45 effectively controls the infection of flower bud and leaf (Singh et al., 2012). The antagonists like Chaetomium globosum, Trichoderma harzianum, T. koningii, T. viridae, Bacillus subtilis and Fusarium spp. found effective against different species of Alternaria (Vananacci and Harman, 1987, Babu et al., 2000). The extracts of Canna indica, Convvolulus arvensis, Cenchrus catharticus, Mentha piperita, Allium cepa, A. sativum, Argemone mexicana, Datura stramonium and Clerodendron inerm were effective in preventing the germination of A. brassicace isolated from leaves of cauliflower (Sheikh and Agnihotri, 1972, Mamgain et al., 2013).

2.1.8 Damping Off
The causal agent of the disease is Rhizoctonia solani and the disease is more frequent at the seedling stage. Necrotic spots and rings develop on the young seedlings and cause pre-emergence mortality in seedlings while appearance of water soaked, brown, necrotic ring on lower part of hypocotyl are post-emergence symptoms and due to these post emergence symptoms seedling collapse (Singh et al., 2012). It causes considerable loss if seedlings are not properly looked after and root system of the infected seedling appears partially or fully decayed (Subramanyan et al., 1975). Damping off disease of
marigold caused by Ceratobasidium sp. on T. erecta was first reported in India by Saroj et al., 2013. Soil sterilization by Formalin (2%) before sowing, spraying with Dithane Z-78 (0.2%) and soil drenching with 0.3% Brassicol and 0.1% Carbendazim are found effective in controlling the disease. Also a Proper drainage should be provided in the nursery bed to control the spread of the pathogen and 3-4 years crop rotation should be followed (Singh et al., 2012).

Sanuallah et al. (2018) evaluated extracts of cinnamon (Cinnamomum verum), moringa (Moringa oleifera) and clove (Syzygium aromaticum) in various concentrations against R. solani that cause damping off of tomato. Out of these, clove leave extract showed highest antifungal activity and inhibited complete mycelial growth.

### 2.1.9 Botrytis blight or Gray mold

The Causal agent of the disease is Botrytis cinerea. Disease symptoms appeared as dead blotches on leaves, flowers, and stems. Rotting of stems may cause plants to collapse, flower buds may fail to open and diseased flowers that open become decayed and drop prematurely. A covering of gray fuzzy fungal growth and spores appears on infected plant tissue (Anonymous, 2012).

The disease can be controlled by removing plant debris after appearance of disease symptoms, by providing proper air circulation, maintaining dry foliage and avoiding overhead watering. Other than these sanitary practices, use disease-resistant cultivars and replacement of susceptible plant material with tolerant cultivars can reduce the disease. Fungicides can also be used to control the pathogen (Dhiman and Arora, 1990, Anonymous, 2018a). Pseudomonas strain (QBA5) isolated from healthy tomato plant significantly inhibited the conidial germination and mycelial growth of B. Cinerea (Gao et al., 2018). The aqueous extract of Asteriscus imbricatus has inhibited completely the growth of B. cinerea (Senhaji et al., 2014). Fielding et al. (2015) evaluated eight plant extract against B. cinerea and out of them Galenia africana and Elyptropappus rhinocerotis extracts showed maximum inhibition.

### 2.2. Bacterial diseases

#### 2.2.1 Bacterial Leaf Spot of Marigold

Bacterial leaf spot of marigold is caused by Pseudomonas syringae pv. tagetis, the disease is seed borne and very destructive in immature marigold plants. It was observed for the first time in the United States (1978) in the field of Wisconsin (Styer et al., 1980) and also found in greenhouses in North Carolina during 1983 and 1984.

The symptoms of the disease are appearance of black spots on cotyledon of seedlings, necrotic spots on leaves surrounded by chlorotic tissues in an irregular pattern, chlorotic and distorted apical growth and in some cases the disease cause mortality of the infected plant. Shane and Baumr (1984) reported that the pathogen that causes bacterial leaf spot of marigold also causes diseases of zinnia, common ragweed, sunflower and Jerusalem artichoke. In the starting of infection symptoms appear under the leaf surface as tiny, watery, dark-green spots and then appear on upper leaf surface after one or two days as a brownish diffuse discouloration (Hellmers, 1955).

As bacteria causing the leaf spot of African Marigold is seed borne and to control the pathogen healthy seeds should be used. To control the pathogen spray of ‘Mercusan’ (0.1%) or ‘Midol-special-Mercuri’ (0.75%) should be used (Hellmers, 1955). Verma and Agarwal (2015) found that plant extract of Allium sativum and Terminalia chebula effective to control P. syringae pv. pisi. Ethanolic and methanolic extract of Lantana camera found effective against bacterial leaf spot disease of papaya (Hossain et al., 2018). Mougou and Boughalleb-M’hamdi (2018) studied the antibacterial potential of Bacillus species and garlic extracts against P. syringae and found them effective in controlling the pathogen.

#### 2.3. Viral diseases

Some of the marigold plants affected by viral disease and their symptoms comprises of yellowing, mosaic, vein chlorosis and mild curling. The infected plants were stunted and yielded poor number of twisted and deformed flowers and the reduction in growth appeared as the production of small leaves clustering around the main stem. Growth ceases and necrosis at the top observed in the severely infected plants. Marigold plant is naturally attacked by three different viruses viz. Cucumber mosaic virus (CMV) (Hanson et al., 1951), Marigold mosaic virus (MMV) and Marigold mottle virus (Naqvi et al., 1981).

CMV is identified as a member of cucumovirus which is transmitted by Aphis gossypii, A. craccivora and Myzus persicae and it was found to be seed transmitted in case of marigold plants. Naqvi et al. (1981) reported a potyvirus causing mosaic disease in marigold and they named it as Marigold mosaic virus. The thermal inactivation point of the virus was 55°C with dilution end point of 1:6000 (Sang and Varma, 1975). Elbeshehy et al. (2014) recommend the use of Thuja extract (6 g/L) to decrease the infection caused by watermelon mosaic potyvirus. Glycoprotein from the roots of Boerhavia diffusa acts directly on viruses to effectively control their growth (Awasthi et al., 2016).

#### 2.3.1 Aster yellows

It is Caused by Aster yellows phytoplasma and infected leaves become discolored (light green, yellow, white, red or purple) and stunted; flowers are small and deformed with improper coloration; Stems become weak and may form a clump (witches
broom). Infected plants cannot be recovered so to control the spread of the pathogen infected plants should be completely removed and destroyed as well as nearby perennial weeds should be removed as they can be a source of inoculums (Anonymous 2018a).

2.4 Nematode diseases
Marigold plant as described earlier has nematicidal activities but all Tagetes varieties are unable to resist all types of nematodes. For example, Cracker Jack marigold can control the southern root-knot nematode but this variety serves as a host for other nematodes such as stubby-root and reniform nematodes and other nematodes like Sting and awl nematodes can increase on Tagetes species (Rhoades 1980). Kanwar and Walia (2002) have reported efficacy of Chenopodium and neem in the management of root-knot nematode in tomato. Extract of tobacco, clove, betel leaves and sweet flag found most effective against the root knot nematode (Wiratno et al., 2009). Aqueous extract of mint have nematicidal properties against the root knot nematode (Caboni et al., 2013).

3. Conclusion
From the above review, it can be concluded that Marigold plant belonging to the Asteraceae family, is extensively used for various purposes such as for making garland and for beautification purposes. Marigold plant is medically important and also used to control the nematodal diseases of other plants. Marigold plant suffers from various diseases (Fungal, bacterial, viral and nematodal) and affected majorly by fungal pathogens. Some of the important fungal diseases of marigold are flower blight (Alternaria zinniae), wilt and stem rot (Phytophthora cryptogea), Collar Rot (Phytophthora sp.; Pythium sp.), damping off (Pythium sp.), Alternaria leaf spot, Fusarium wilt (Fusarium oxysporium) and Cercospora leaf spot (Cercospora megalopotamica). These diseases resulted in yield loss and can be controlled by chemical treatment as well as with the help of various plant extracts and antagonist such as Bacillus sp., Trichoderma sp. and Pseudomonas fluorescens.

4. References
http://plantpathology.ca.uky.edu/extension/publications#HERBACEOUSORNAMENTALS


