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Since the dawn of civilization, ornamental plants have attracted the curiosity of humans. Ornamental plants are important to humankind not only economically, environmentally and industrially but also spiritually, historically and aesthetically, as they sustain human life through direct and indirect gains by providing a wide range of products for survival and prosperity. The ornamental plants are commonly used to beautify the yards, public parks, health resorts and landscapes. Some ornamental plants are grown for showy and attractive foliage. Their foliage may be deciduous, turning bright orange, red and yellow before dropping off in the fall or evergreen round the year. Ornamental plants also have certain secondary benefits such as sources of drugs, medicines, providing shade, privacy, wind protection, in making perfumes and many other products.

In India, floriculture has been identified as a sun-rise industry. Owing to steady increase in demand of flowers, floriculture has become one of the important commercial trades in agriculture. Commercial floriculture has emerged as hi-tech activity taking place under controlled climatic conditions inside greenhouse. A wide variety of ornamental plants are native to India owing to its diverse geography. India has an advantage of a perfect and economic setting for a potential profitable floriculture sector. A mild winter, abundant sunlight, a suitable agro climatic condition, low labour cost and availability of skilled man power are the factors that can prove Indian floriculture as a potential earner of foreign exchange.

The major flower growing states in India include, Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Maharashtra, Uttarakhand, Uttar Pradesh, Delhi, Haryana, Kerala, Himachal Pradesh and North Eastern states. According to the report of National Horticulture Board, the total area under flower crops in India was estimated around 253.7 thousand hectares (Anonymous, 2012). The cultivation of ornamental plants is mainly practiced in Southern States especially in Tamil Nadu and Karnataka, as these shares for more than 50% of cultivation in acreage. Karnataka is the leading state in floriculture, accounting for 75% of India’s total flower production (Yadawad et al., 2011).
In spite of the export potential, the performance of the Indian floriculture sector has not been encouraging. India ranks 23rd amongst world exports of floriculture products and it’s share in world exports is negligible at around 0.38% worth US$ 47 million (Anonymous, 2006). The world floriculture industry is in a state of unrest, with drastic changes in supply and demand positions. There are about 120 countries actively involved in the floriculture industry as global manufactures (Anonymous, 2006). World trade in floriculture is estimated at US $ 100 billion. It has been growing at the rate of 15 per cent per annum. Netherland accounts for more than half of all world floriculture export (Van Hemert, 2005). In terms of production value, the Netherlands, United States, Japan, Italy, Germany and Canada are the largest producers.

Nematodes are the most abundant and ubiquitous multicellular organisms on earth. They are found in almost every type of habitat, from the bottom of the deepest ocean to near the tops of the highest mountains, from the tropics to the polar regions, and from every conceivable habitat (Hooda, 2001). Most of the nematodes are beneficial because of their free-living and saprophytic nature and play a major role in decomposition of organic matter and nutrient recycling. Nematodes can feed on bacteria, fungi, algae, plants and they can also parasitize insects, animals and humans.

Plant parasitic nematodes have been recognized as one of the limiting factors in the normal production of agricultural and horticultural crops including ornamental plantation all over the world. Extent of damages, however, varies depending upon the nematode, crop and its cultivars, agro climatic conditions and other biotic and abiotic factors. Among the plant parasitic nematodes the root-knot nematodes, *Meloidogyne* spp. have been of interest to nematologists worldwide probably due to their widespread distribution and being most serious agricultural pests which are responsible for heavy losses both in quantity as well as quality (Ogunfowora, 1977). The genus *Meloidogyne* comprises of about 97 described species and almost every kind of cultivated and wild plants are parasitized by one or the other species of root-knot nematodes (Hunt and Handoo, 2009).

The infection of root-knot nematodes can be easily recognised, because of the very prominent and specific symptoms of root galls or knots that are formed at the infection site. Root-knot nematode infection starts when infective second-stage juveniles (*J*₂) hatch from eggs in the soil and penetrate plant roots behind the root cap
and migrate intercellularly in the cortical tissue to the vascular cylinder and then become sedentary. Then they inject secretions into five to seven undifferentiated procambial cells in the vascular cylinder near the head of the J$_2$ to become multinucleate (Hussey and Grundler, 1998) and to form very specialized feeding cells called giant cells, on which the juveniles (J$_2$) and later the spherical females feed. Furthermore, cell size increases dramatically, walls are remodelled by formation of ingrowths and the cytoplasm becomes dense with an increase in cell organelles (Baum et al., 1996). With nourishment from the giant-cells, the root-knot nematodes complete their life cycle. Then females lay eggs into a gelatinous matrix outside the root surfaces.

Ornamentals like other crops harbour a multitude of nematode fauna in many countries like *Meloidogyne hapla* Chitwood on *Rosa* spp., *Fatsia japonica*, *Sarcococca ruscifolia*, *Abelia grandiflora*, *Photinia fraseri*, *Spiraea bumalda* and *Viburnum carlesii* in Belgium, Italy and U.S.A. (Coolen and Hendrickx, 1972; D’Errico et al., 2003; Russo et al., 2007; Bernard and Witte, 1987); *Meloidogyne incognita* (Kofoid and White) Chitwood and *Meloidogyne arenaria* (Neal) Chitwood on *Dianthus caryophyllus*, *Celosia argentea*, *Amaranthus viridis*, *Achillea*, *Geranium*, *Heuchera*, *Linaria*, *Salvia* and *Ilex* spp. in Japan, Nigeria, Pakistan and U.S.A. (Yamamoto and Todia, 1995; Cho et al., 1996; Caveness and Wilson, 1977; Soomro et al., 1993; Walker and Melin, 1998; Williams-Woodward and Davis, 2001) and *Meloidogyne javanica* (Treub) Chitwood on *Ocimum basilicum* and *Carnation* in Pakistan and Japan (Gul and Saeed, 1987; Yamamoto and Todia, 1995). The *Aphelenchoides besseyi* Christie and *Aphelenchoides ritzemabosi* Schwartz on *Begonia* in Brazil (Oliveira and Kubo, 2006); *Pratylenchus penetrans* Cobb on *Rosa laevigata*, *Rosa corymbifera*, *Chrysanthemum* and *Jasminum sambac* in Belgium, Japan and Pakistan (Peng et al., 2003; Komatsu et al., 2007; Shakeel, 1992); *Xiphinema*, *Trichodorus* and *Paratrichodorus* on *Camellia japonica* in Spain (Abelleira et al., 2004) have also been reported.

In India, root-knot diseases caused by *Meloidogyne* spp. have been reported earlier by various workers in different ornamental plants. Such as *M. incognita* on *Philodendron selloum*, *Gladiolus*, *Lilium maculatum*, *Rosa indica*, *Dianthus caryophyllus*, *Chrysanthemum* spp., *Polianthes tuberosa* and *Jasminum* spp. (Mishra and Mishra, 1993; Khanna et al., 1998; Johnson et al., 2002; Singh and Kumar 2002;
Khanna and Jyoti, 2004; Khan et al., 2005a; Jally et al., 2006; Seenivasan, 2010), *Meloidogyne arenaria* on *Polianthes tuberosa* and *Coleus forskohlii* (Jayaraman et al., 1975; Kumar et al., 1987; Sundrababu and Vadivelu, 1988 and Bhandari et al., 2007) and *Meloidogyne javanica* on *Helianthus annuus*, *Petunia alba*, *Portulaca grandifolia*, *Celosia grandifolia*, *Polianthes tuberosa*, and *Impatiens balsamina* (Zazzerini and Tosi, 1997; Haider and Khan, 1986; Jayaraman et al., 1975 and Khan et al., 2006). Besides root-knot nematodes, other plant parasitic nematodes viz., *Tylenchorhynchus* spp., *Pratylenchus* sp., *Criconemoides* sp. and *Xiphinema* sp., *Helicotylenchus* spp. and *Pratylenchus delattrei* Luc have also been found associated with some ornamental plants like *Tagetes* sp., *Bougainvillea* sp., *Cestrum nocturnum*, *Thuja* sp., *Rosa* sp., *Hibiscus rosa-sinensis*, *Geranium* sp., *Croton* sp., *Acalypha* sp. and *Crossandra* sp. (Pathak and Siddiqui, 1997; Anitha, 1997; Jain et al., 1996 and Srinivasan and Muthukrishnan, 1975).

The accurate information on the extent of crop losses caused by plant parasitic nematode is difficult to assess. However, many workers have expressed approximate losses. Crop losses due to root-knot nematode attack range from slightly less than one percent to total destruction (Krisshnappa, 1985). Hussey and Janssen (2002) estimated approximately 5% of global crop loss due to infection of *Meloidogyne* spp. Sasser and Freckman (1987) reported 11.1% loss in ornamental plantation throughout the world due to plant parasitic nematodes. In India the loss is predicted at about 14.6% and could go as high as 50-80% in some crops (Bhatti, 1992). The infection of *Meloidogyne* spp. has been reported to reduce *Dianthus caryophyllus* production worldwide by 10 to 20% (Cho et al., 1996) and also cause qualitative and quantitative decline in the production of *Gladiolus hortulanus* in India (Khanna et al., 1998). Nagesh and Reddy (2000) estimated the yield losses in carnation and gerbera due to *M. incognita* infection as 26.6% and 31.1%, respectively.

There are also some reports of crop losses in terms of money. The estimated annual loss due to nematodes in USA was of the order of $10,383,743.00 in 16 field crops, $225,145,900 in fruits and nut crops, $266,989,100 in vegetable crops and $59,817,634 in ornamental crops (Anonymous,1971). The losses in ornamentals due to nematodes were also estimated to the tune of $60 million in U.S.A. (Hague, 1972). Sasser and Freckman (1987) have indicated annual crop losses due to plant parasitic nematodes on worldwide basis to the tune of $100 billion.
In India little information is available related to extent of losses in monetary terms due to plant parasitic nematodes in agricultural crops. Van Berkum and Seshadri (1970) have calculated these losses in India in terms of money. They estimated the annual losses due to ‘ear cockle’ disease caused by *Anguina tritici* (Steinbuch) Filipiev on wheat (*Triticum aestivum* L.) amounting to $10 million, losses due to *Pratylenchus coffeae* Zimmermann on coffee (*Coffea arabica* L.) as $3 million and due to ‘Molya’ disease caused by *Heterodera avenae* Wollenweber to $8 million in Rajasthan province alone. Jain et al. (2007) recorded the maximum loss to the extent of 779.30 million rupees in rice due to *Meloidogyne graminicola* Golden and Birchfield, *Heterodera oryzicola* Rao and Jayaprakash and *Aphelenchoides besseyi* Christie. They also estimated the national loss due to plant parasitic nematodes in 24 different crops to the tune of 21068.73 million rupees.

Fungi are extremely diverse and common plant pathogens. All the plants are attacked by some kind of fungi and each of the parasitic fungi can attack one or many kinds of plants. More than 70% of all major crop diseases are caused by fungi and led to significant yield losses in most of the agricultural and horticultural crops (Agrios, 2005). Most of the important fungal pathogens involved in the production of diseases in plants including ornamentals are soil borne root infecting fungi *viz.*, *Macrophomina phaseolina* (Tassi) Goid., *Rhizoctonia solani* Kuhn., *Fusarium* spp., *Pythium* spp., *Phytophthora* spp., *Sclerotium* spp. and *Verticillium* spp. Among these fungi, *Rhizoctonia* diseases occur worldwide on almost all vegetables, multiple field crops, turf grasses, shrubs and trees.

The symptoms of *Rhizoctonia* disease may vary somewhat on the different crops and even on the same host, depending on the stage of growth at which the plant becomes infected and the prevailing environmental conditions. The most common symptoms caused by *R. solani* on most of the plants are damping off of seedlings, root-rot, stem-rot, stem-canker and foliage blights or spots. Ornamentals are also no exception to *R. solani* diseases *viz.*, *Antirrhinum majus* L. (Sharma and Mahmud, 1950), *Chrysanthemum cinerariaefolium* Vis. (Alam et al., 2004), *Impatiens balsamina* L. (Siradhana et al., 1964), *Dianthus barbatus* L. (Gupta and Prasad, 1985), *Dianthus chinensis* L. (Holcomb and Carling 2000), *Lantana camara* L. (Garibaldi et al., 2003), *Petunia hybrida* (Hook.) Vilm. (Wright et al., 2004), *Larix deciduas* Mill., *Gladiolus hybridus* L. (Soleimani and Kashi, 2005), *Digitalis purpurea*
Soil is a complex ecosystem harbouring a wide variety of life forms such as nematodes, fungi, bacteria, viruses, insects and protozoa etc. Under such an ecological conditions it is not unnatural that naturally occurring microorganisms interact with each other primarily because of their competition for food and survival providing an opportunity to show various types of interactions viz., neutralism, competition, amensalism, parasitism, commensalism and mutualism. All such interactions have three major components namely the host plant, the nematode and one or more other pathogenic or saprophytic organisms. These pathogenic interrelationships often show additive, synergistic or neutralistic effects on plant disease development.

Plant parasitic nematodes often play a major role in disease complexes. Besides, causing direct yield losses, they interact with other organisms to produce disease complexes, breakdown resistance against the other pathogens and reduce plant tolerance to environmental stress (Taylor and Sasser, 1978). Most of the studies on interaction involving nematodes and fungi have been made with pathogenic fungus as one of the components in disease complex. Even some non pathogenic fungi or weak pathogens have been found to inflict damage when present with nematodes. It has been observed that root-knot nematodes possesses outstanding abilities to cause physiological changes in plants that can induce susceptibility in plants to be attacked by fungi present in the rhizosphere, whether pathogenic or non pathogenic (Powell, 1979). The combination of nematode and fungus often results in a synergistic interaction where the crop loss is greater than expected from either pathogens alone or an additive effect of the two together.

Important disease complexes involving certain fungi and nematodes have been investigated from time to time. Atkinson (1892) reported for the first time the interaction of root-knot nematode, *Meloidogyne* species with *Fusarium* wilt of cotton. Since then synergistic, additive interactions of root-knot nematodes and several soil-borne fungi including *R. solani* have been well documented by Powell (1971, 1979), Mai and Abawi (1987), Taylor (1990), Franel and Wheeler (1993), Evans and Haydock (1993) and Back et al. (2002). The disease complex involving *M. incognita* and *R. solani* has been reported in many crops by several workers such as on tobacco (Batten and Powell, 1971), cotton (Carter, 1975), cucumber, pepper and tomato (Choo...
et al., 1990), grapevine (Walker, 1997), okra (Bhagawati et al., 2007), soybean (Anwar et al., 1997; Anwar and Khan 2002), sunflower (Mokbel et al., 2007), Cock’s comb (Anwar et al., 2009), french bean (Bhat et al., 2011), and tomato (Chahal and Chhabra, 1984; Kumar and Haseeb, 2009; Vidya Sagar et al., 2012). Similarly, disease complex caused by *R. solani* and *M. javanica* in cowpea (Kanwar et al., 1988), watermelon (Mehta et al., 1989), mungbean (Gupta and Mehta, 1989), peanut (Abdel-Momen and Starr, 1998) and soybean (Agu, 2002), by *R. solani* and *M. hapla* in alfalfa (Irvin, 1965), radish (Khan and Muller, 1982) and peanut (Filonow and Russell, 1991) and by *R. solani* and *M. arenaria* on cotton (Brodie and Cooper, 1964) have also been reported earlier.

*Pseuderanthemum atropurpureum* W. Bull. (Family-Acanthaceae) is an evergreen shrub, commonly known as black leaf shooting star and commercially propagated by stem cutting. It is mostly grown as suitable foliage plant in tropical and sub-tropical areas and is suitable for group planting. It has become choice amongst gardeners due to it’s beautiful foliage, profuse branching giving it an elegant shape. Verma and Khan (1985) reported the presence of highly antiviral agents in *P. atropurpureum* leaf extract.

During the survey for diseases of fungi and plant parasitic nematodes on ornamental plants, the simultaneous occurrence of species of root-knot nematode, *Meloidogyne* and root-rot fungus *Rhizoctonia* in *P. atropurpureum* was noticed in A.M.U. Campus of Aligarh. It was observed that there were some plants growing in pots/beds which were badly damaged or even dead due to severe root-rot as well as collar/stem rot caused by the fungus as compared to the nearby plants growing in other pots/beds where such symptoms were not observed except mild root-rot. It was further found that when species of *Meloidogyne* and *Rhizoctonia* were present singly in *P. atropurpureum* the damage was comparatively lesser, whereas, in the concomitant infection of both the pathogens the plants were badly damaged. The plants infected by root-knot nematode showed distorted feeder roots and root galls of large to moderate size. While, the plants infected with fungus alone showed mild root-rot symptoms. In addition to this, the stunted growth and yellowing of leaves were also recorded in the plants infected with either *Meloidogyne* or *Rhizoctonia* species.

Isolation of nematode from root and soil and fungus from the roots of such plants showed heavy infection of root-knot nematode, *Meloidogyne incognita* and
root-rot fungus, *Rhizoctonia solani*. The fungus was isolated from rotted roots on Potato Dextrose Agar medium. The resultant mycelial growth was transferred to the same medium in Petri plates and incubated at 28 ± 2°C. The root-rot fungus and infected roots were sent to the Head, Division of Plant Pathology, IARI, New Delhi for reconfirmation of the identity of the fungus. The fungus was identified as *Rhizoctonia solani*. The screening of available literature showed that the root-knot nematode, *M. incognita* and root-rot fungus, *R. solani* not only constitute the first disease complex of *P. atropurpurum* but also reported as new host for *M. incognita* and *R. solani* from India and elsewhere.

Keeping in view the economic importance of *P. atropurpureum* as an ornamental plant and the highest frequency of occurrence of root-knot nematode, *M. incognita* with root-rot fungus, *R. solani*, it was felt necessary to study whether this aggravated damage was casual or due to the result of interactive effects of *M. incognita* and *R. solani*. At the same time it was also considered desirable to evaluate the efficacy of organic additives, biocontrol agents and nematicide in the management of disease complex caused by *M. incognita* and *R. solani* in *P. atropurpureum*. Therefore, with this aim in view, the following experiments were planned and conducted.

(i) Survey of plant parasitic nematodes associated with *Pseuderanthemum atropurpureum* growing in Aligarh district of Western Uttar Pradesh.

(ii) Occurrence of *Rhizoctonia solani* and different species and races of *Meloidogyne* infecting *Pseuderanthemum atropurpureum* in Aligarh district of Western Uttar Pradesh.

(iii) Studies on the pathogenicity of root-knot nematode, *Meloidogyne incognita* on *Pseuderanthemum atropurpureum*.

(iv) Studies on the pathogenicity of root-rot fungus, *Rhizoctonia solani* on *Pseuderanthemum atropurpureum*.

(v) Studies on the effect of individual, concomitant and sequential inoculation of *Meloidogyne incognita* and *Rhizoctonia solani* on plant growth and disease development in *Pseuderanthemum atropurpureum*. 

(vii) Studies on the life-cycle of *Meloidogyne incognita* on *Pseuderanthemum atropurpureum* in presence and absence of *Rhizoctonia solani*.

(viii) Management of *Meloidogyne incognita* – *Rhizoctonia solani* disease complex in *Pseuderanthemum atropurpureum* by using a nematicide as bare root-dip treatment and some fungi.

(ix) Management of *Meloidogyne incognita* – *Rhizoctonia solani* disease complex in *Pseuderanthemum atropurpureum* by using chopped leaves of some plants.

(x) Management of *Meloidogyne incognita* – *Rhizoctonia solani* disease complex in *Pseuderanthemum atropurpureum* by using sawdust of some plants.

(xi) Integrated management of *Meloidogyne incognita* – *Rhizoctonia solani* disease complex in *Pseuderanthemum atropurpureum* by using carbofuran as bare root-dip treatment, fungal biocontrol agents, chopped leaves and sawdust of some plants.