REVIEW ARTICLE

Stem Gall of Coriander: A Review

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Abstract

Coriander (*Coriandrum sativum* L.) is an important highly nutritive crop belonging to family Apiaceae. To meet increasing global demand and consumption, coriander productivity must be enhanced. However, biotic stresses such as diseases have impeded coriander cultivation both in the tropics and subtropics. Of them, stem gall of coriander, incited by the fungus *Protomyces macrosporus* unger, is one of the most common, widespread and serious diseases throughout the world and causes significant yield losses. Symptomatology, biology, and etiology of stem gall and its control through fungicides, bio-product and bio-control have not been widely studied, and substantial information is still required on the inoculum potential, growth models and epidemiological parameters of stem gall, the influence of changing the climate, impact of extensive use of fungicides and disease resistance. These critical factors may influence the development and emergence of stem gall. Because of the increasing demands of coriander in the world, control of stem gall is gaining importance. The present review deals briefly with different aspects of stem gall disease with major emphasis on its ecology, pathology, epidemiology, and management. Some new approaches such as biological control, integrated management strategies, and some other aspects are also discussed.

Keywords: Coriander, Management, Protomyces macrospores, Stem gall.

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Introduction

Coriander (*Coriandrum sativum* L.) is an annual herbaceous plant (2n = 22), which belongs to the family Apiaceae and generally grown in winter season as the main crop in India (Singh and Verma, 2015). It is commonly known as cilantro or dhania or Chinese parsley and has originated in the Mediterranean region. It is probably one of the first spices used by mankind, having been known as early as 5000 BC. Globally, it is cultivated in India, Malaysia, UAE, Singapore, United Kingdom, South Africa, and Indonesia. India is the largest producer, consumer and exporter of coriander (Saxena and Gandhi, 2015) with Rajasthan occupying the first place in area and production among all states followed by Madhya Pradesh, Gujarat, Assam, Andhra Pradesh, Karnataka, Orissa, Tamil Nadu, Uttar Pradesh, Bihar, Chhattisgarh, Haryana, West Bengal, Maharashtra, Himachal Pradesh and Punjab (Tiwari and Agarwal, 2014). In India, this seed crop is grown in about 672.7 thousand ha with an annual production of 863.5 thousand tonnes (Spices Board, 2018). Its seeds (fruits) and leaves are extensively used as a natural additive in cooking, added to food to improve its appearance and flavor (Bhat *et al*., 2014). All parts of this herb are used as a flavoring agent and/or as traditional remedies for the treatment of various diseases and disorders in the folk medicine systems of different civilizations (Sahib *et al*., 2012). Pandey (2010) reported that coriander is an important source of chemicals like alpha-pinene, gamma terpinene, limonene, cymene, various non-linalool alcohols, esters, flavonoids, cumarines, isocoumarins, phthalides, and phenolic acids. Coriander oil contains coriandrol, gireniol and vebriniol.

This crop suffers from a number of biotic and abiotic stresses which are detrimental to plant health and seed quality. Several disease-causing pathogens are seed borne. They are associated with seeds externally, internally, extraembryal, intraembryal, as contaminant and inert matter. Their seed to plant transmission may be local or systemic or both. Among the fungal diseases of coriander, stem gall disease caused by *Protomyces macrosporus* Unger is the most destructive and versatile disease. It is the most common, widespread, and damaging disease affecting almost every cultivar irrespective of geographical and ecological differences (Khare *et al*., 2017).

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Occurrence and Geographical Distribution

The disease is prevalent in all coriander-growing areas of India and is considered as a limiting factor for the successful cultivation of the crop. It is one of the longest-known diseases on coriander in the world. The disease was first reported by Unger (1833) in Great Britain, and the causal organism was described as *Protomyces macrosporus*. This disease has been reported from all coriander growing areas of the world such as Scotland, Ireland, Norway, Denmark, Sweden, Germany

and in North America, North Africa and South Asia where the favorable temperature is prevalent (Valverde and Templeton, 1984). Bhardwaj and Shrestha (1985) reported this disease from Chitwan valley of Nepal and found it as one of the most serious and widespread diseases of coriander.

In India, stem gall disease of coriander was reported for the first time from Pusa (Bihar) by Sydow and Butler (1911). Later, Gupta (1954) found this disease to be very common in the northern part of Madhya Pradesh and adjoining districts of Rajasthan and Uttar Pradesh. Singh *et al*. (1984) conducted a survey of coriander fields in seven districts of Uttar Pradesh viz. Muzaffarnagar, Varanasi, Agra, Balia, Allahabad, Kanpur and Jhansi and reported that the intensity of this disease ranged between 7.5–24.4 percent with a maximum at Muzaffarnagar and minimum in Jhansi. Similarly, a survey of coriander fields in 3 districts of Himachal Pradesh was conducted by Paul (1992) and he reported the disease intensity between 10.76 to 60 percent, 0.32–7.3 percent and 0.2–2.35 percent in the district of Kangra, Mandi and Kullu, respectively. Bag (1998) reported this disease for the first time from Arunachal Pradesh. Later, Verma *et al*. (2014) recorded its occurrence from different sites of Jabalpur, Madhya Pradesh and reported that the percentage of infection varied between 5 and 9 percent with an average of 3.6 percent.

Losses

In general, losses inflicted by stem gall of coriander depend upon the locality, time of infection, cultivar, control measures, and environmental conditions. Because of these factors and their interaction, damages caused by the disease are highly variable and are often underestimated. Economic losses due to stem gall are direct and are threatening to the farmers as infected fruits lose their value as consumption and as propagules. Several workers have reported the varying degree of losses in different parts of the world. Mundkur (1959) reported that in the severe incidence of stem gall, no fruits were produced. Gupta (1954) observed 23 percent disease intensity of stem gall in coriander fields in Gwalior resulting in a 15 percent yield loss. However, Gupta and Sinha (1973) reported 0.2 to 1.3 percent seed yield losses on eighteen cultivars of coriander due to 3.8–21 percent disease intensity of stem gall on coriander under field conditions and the affected fruits also lose their condiment value (Gupta, 1975). Singh *et al*. (1984) reported a total disease intensity of 7.5 to 24.4 percent causing 9.6 to 33.8 percent losses in expected yield of coriander attacked by *P. macrosporus* in Uttar Pradesh. Naqvi (1985) reported 2.5 to 22.81 percent losses in yield in twenty cultivars of coriander with 7.37 to 75.93 percent disease intensity on per plant basis due to this disease. Lakra (1999) estimated 16.6–50 percent seed yield loss due to stem gall disease with 22 to 66 percent disease intensity in a field trial conducted in stem gall sick plot at Hisar, Haryana. Malhotra *et al*. (2016) also observed a mean loss of 15 percent in fruit yield when about 23 percent plants were infected.

Symptoms

The infection of stem gall disease takes place at an early stage of seed germination, but the symptoms appear much later (Shrivastava, 1955). The mycelium invades the host tissues intercellularly and concentrates mainly around the vascular bundles. They are altered morphologically, and hypertrophy and hyperplasia of infected plant host tissues result in the formation of swellings on stems, leaves, flowers, fruits and other aerial parts of plants (Buren, 1915). The disease appears in the form of swellings of leaf veins, leaf stalks, peduncles, stems and on fruits. The swellings on the veins give a swollen hanging appearance to the leaves. These tumors are initially glossy but later rupture and become rough. The swellings are mostly elongated, and their size varies according to the size of the infected part, those on the stem being usually larger than those on the flower stalk. Systemic infection provides greater distortion to the plant and plant parts. The inflorescence may show outgrowth on the surface, and uniform invasion of the fruit makes it abnormally large, but partial invasion may lead to distortion (Gupta, 1962). Redfern and Shirley (2002) found that this disease is usually apparent in early spring when the greatly distorted leaves first appear. On veins, mid-ribs, and petioles, the gall appears as translucent yellow-white swellings that are often elongated and blister-like.

Causal Organism

Stem gall of coriander is one of the economically important diseases. Depending upon the symptoms produced, several Protomyces spp. have been reported to cause this disease. Gupta (1958) observed that the mycelium of the fungus is found only in the tumors. The fungus causes hypertrophy and hyperplasia. The layered thick chlamydospores function as the resting spores of the fungus. The pathogen survives in the soil in the form of chlamydospores and this act as the primary source of infection. Pavgi and Mukhopadhyay (1969b) reported that the disease is caused by fungus *P. macrosporus*. The distinguishing morphological characteristics of *P. macrosporus* is the formation of chlamydospore or endospores. The chlamydospores of *P. macropsorus* were yellowish brown, spherical or globose to oval, single-celled, smooth and measured 40 to 81 µ in diameter. A mature chlamydospore was protected externally by hard, thick and unsculptured exospores enclosing a medium thick mesopore and membraneous endospore.

Unger (1883) gave the first binomial name to the causal agent of stem gall as Protomyces macrosporus, but the taxonomic position of this fungus has remained uncertain. De Bary (1887) treated them as a group alongside the Ustilaginaceae. The first work on the cytology and development of Protomyces was done by Trouffy (1897) and Popta (1899). However, it was Buren (1915) who proposed the first concept regarding the nature of the vesicle. The concept of ascospore formation and the nature of the vesicle have been confirmed by Pavgi and Mukhopadyay (1972). A natural rest period or dormancy prerequisite to chlamydopsore germination was indicated by Butler (1918).

P. macrosporus was first described by Unger (1833) belonging to family Protomycetaceae. Previously, this pathogen was placed in Chytridiales (Heim, 1967). But this pathogen was placed in class Ascomycetes and order Protomycetales by Kramer (1973). Preece and Hick (2001) described *P. macrosporus* as the first member of the Protomycetaceae. Presently, *P. macrosporus* has been placed in Kingdom: Fungi, Division: Ascomycota, Class: Archiascomycetes, Order: Taphrinales, Family: Protomycetaceae, Genus: Protomyces and species: macrosporus (Alexopoulus *et al*., 2002).

The genus *P. macrosporus* Unger has been reported to be obligate parasite within the Apiaceae family causing galls on stems, leaves, flowers, and fruits by various workers (Lakra, 2001, Khare *et al*., 2014; Mishra *et al*., 2017). However, Pavgi and Mukhopadhyay (1969a) isolated this fungus from the infected parts of the coriander plant on different cultural media such as malt agar, Richard's agar, Lilly and Barnett's semi-synthetic medium, and potato dextrose agar media. In these media, two differentially pigmented cultures i.e., salmon red (SR) and creamy white (CW) were isolated. Growth was moderate and pigment bright salmon red in salmon red culture; colony attained a diameter of 4–5.5 mm after 7 days of incubation at room temperature (22–24°C) and resembled that of yeast or species of *Taphrina*. Its texture was pasty and not slimy, form convex, smooth on the surface and surrounded by zonate rings having a smooth broadly crenate margin. A gradual paling in pigmentation occurred after a month, and the older central portion became pinkish to dull buff. New growth accumulated in successive layer forming a deep mass. The entire colony lost its pasty appearance and seemed coarsely granular with aging after 2 months (Pavgi and Mukhopadhyay, 1969a). The colonies in creamy white culture showed a slow restricted growth on PDA attaining a diameter of 3–4 mm after 7 days incubation at room temperature (22–24°C). This colony also resembled one of yeast or *Taphrina* species but was dull creamy white in the young stage of growth. The texture of the colony was pasty as well as slimy, lobed in appearance with plicate surface and surrounded by an uneven margin. A gradual change in pigmentation occurred after 15 days of growth; an older portion in the center turned yellowish brown. The colonies became raised in the , and successive new growth piled up in a deep mass on aging (Pavgi and Mukhopadhyay, 1969a).

Lodder and Kregervan (1952) reported that the culture of *P. macrospores* resembled much with the culture of yeast in the young stage. Tubaki (1957) isolated the culture of three species of *Protomyces* such as *P. inouyei, P. lactucae-debilis* and *P. pachydermus* by spore fall method on malt agar medium and incubated, not inverted, at 20°C until the colonies can be counted. In a second method, the expelled mass of spores or spore-sacs containing spores is picked up from the water with a pasteur pipette and transferred to the medium. Colonies are dull, flat, sometimes wrinkled, pasty and restricted with a smooth margin and cream to pale orange or pinkish in color. Growth was good at 20°C, very slow at 25°C, no growth at 27°C and cultures died in 120 hours at 30°C. Lakra and Parkash (1993) developed a technique for isolation of *P. macrosporus* in short period (10-12 days). One-year-old stem bits of coriander infected with *P. macrosporus* were washed with sterilized distilled water, dipped in 0.2 percent mercuric chloride solution for one minute and again washed 2-3 times with water. After washing in water it was crushed in sterilized distilled water and droplets was transferred to PDA slants and incubated at 22°C. After 12 days, medium yielded dull creamy white, wrinkled colony on PDA which was similar to spore fall method of Mukhopadhyay and Pavgi (1964).

Use of PCR-based molecular markers provides an efficient reproducible and reliable approach to characterize plant pathogen population particularly for the assessment of genetic diversity and phylogenetic relationships. Internal transcribed spacer (ITS) sequence data have been used to study the phylogenetic relationships of many Protomyces spp. (Nishida et al., 1993). Molecular tools used in phylogenetic studies of Ascomycota (Sugiyama et al., 2006) have included large and small subunits of ribosomal RNA genes and sequence analysis of the Internal Transcribed Spacer (ITS) regions of the *rRNA* genes (Bacigalova et al., 2003).

Host Range

The pathogen *P. macrosporus* has also been found to develop galls on stems and leaves on a number of hosts. Reddy and Kramer (1975) reported some members of the family Umbelliferae which are susceptible to *Protomyces* spp. such as *Aegopodium, Ammi, Angelica, Anthriscus, Archangezica, Athamanta, Canopodium, Carum, Caucazis, Chaerophyzzum, Coriandrum, Feruza, Heraczeum, Hydrocotyze, Laserpitiwn, Ligusticum, Meum, Onanthe, Pancicia, Parum, Peucedanum, Pimpineua, Seseli, Silaus, Thapsia* and *Trinia*. Similarly, Preece and Hick (2001) have observed this fungus on 27 genera of Umbelliferae and 14 genera of Compositae throughout the world. Other hosts of this pathogen as reported by various workers include *Aegopodium podagraria* (Baumler, 1890), *Torilis japonica* (Valverde and Templeton, 1984), *Foeniculum vulgare* Mill. (Khare *et al*., 2014) and *Boerhaavia diffusa* (Verma *et al*., 2014). Bacigalova *et al*. (2008) found the association of the different *Protomyces* spp. causing galls in different families. They found the association of *P. macrosporus* on family Apiaceae and *P. pachydermus* Thüm on Asteraceae (*Taraxacum*), *P. kriegerianus* Büren on *Leontodon*, *P. buerenianus* Buhr on *Galinsoga* and *P. cirsii-oleracei* on Cirsium.

Disease Perpetuation

Relative success or failure of the pathogen to infect a new crop is partly determined by its survival and transmission from season to season. Recurrence of the stem gall of coriander is also indicated through the infected plant debris over-summering in the field soil providing a source of primary inoculum in the following crop season (Butler, 1918; Mundkur, 1959). Abundant chlamydospore development in the non-vascular tissues of the host takes place in a maturing crop.

The chlamydospores are carried to the soil through the debris, host trash during harvest and uncleaned seed contaminated with fruit galls. The resting spores released from the decayed host tissues after the monsoon rains provide the primary inoculum. Possibility of survival of free chlamydospores in the soil has not hitherto been indicated due to the high temperature prevailing during the summer months. Survival of endo- or blastospores from the germinated chlamydospores in the previous cropping season over the soil surface through the summer months would provide an additional source of primary inoculum as in the species of *Taphrina* (Mix, 1925; Upadhyay and Pavgi, 1967).

Epidemiology

The infection process and epidemiology of stem gall of coriander is influenced by some important and critical factors such as the host plant, tissue specificity, asexual form, and dormant mycelium of the fungus and environmental conditions.

Weather conditions play a predominant role in determining the course and severity of epidemics, however, information on this aspect of stem gall disease is limited. Hawker (1950) observed that the chlamydospore germination was hastened by exposure to high or low temperature; however, Gupta (1959) reported the chlamydospore germination in double distilled water after 7–8 days at 18-20°C temperature. Mukhopadhyay and Pavgi (1971) found that the primary inoculum of the disease is carried to the field with the seed drawn from an infected crop, crop debris and/or uncleaned seed mixed with fruit galls. The pathogen persists from year to year in the chlamydospore stage and the latter germinates to initiate fresh infection in the following season. The thick-walled chlamydospore resists the effect of high temperature and desiccation during the high-temperature summer months (May-June) and survives the unfavorable environment over prolonged periods in the absence of the host crop. The chlamydospores hibernating in the crop debris and/or hypertrophied fruit galls are released after the monsoon period (July-September) in the former case and the richly irrigated fields with heavy soil in the latter. The chlamydospores from fruit galls are induced to germinate on the soil surface late in January at cool time. The ability of the pathogen to build up chlamydospores *in vitro* in the soil further adds to the inoculum potential. The concentration of the inoculum thus remains at a high level. Infection of the seedlings takes place through the endospores and subsequent blastospores during January-February.

Gupta (1973) found 37 percent chlamydospores germination after one year and 27 percent after 2 years with material stored at room temperature. Lakra (2000) tested the ratios of irrigation water (IW) to cumulative pan evaporation (CPE) [It is the ratio of the amount of irrigation water (IW) applied to cumulative pan evaporation (CPE)] on diseases incidence and found that at (IW:CPE 1.33) resulted in 46 per cent disease, while IW:CPE 0.7 resulted in 22 percent disease, with 57.2 and 10.4 percent yield losses. Saxena *et al*. (2002) observed that stem gall disease appears continuously every year in the field of coriander grown on high soil pH, moisture and adverse ecological and adapted factors. Minimum/maximum atmospheric temperature and relative humidity play an important role in the development of stem gall. The disease appeared on the plants sown when the minimum and maximum temperatures were 13.2 and 30.9°C, respectively, and relative humidity was 57.2 percent. Maximum disease intensity was recorded in the plants sown when the minimum and maximum temperature was 8.1 and 22.6°C, respectively, and relative humidity of 65.8 percent. Maximum germination of chlamydospores of *P. macrosporus* was found at 22–24°C (Tripathi *et al*., 2003).

Bacigalova (2004) confirmed the occurrence of *P. macrosporus* fungus mainly on the humid places along the brooks and streams during the whole vegetation season (spring, summer, and autumn). Malhotra *et al*. (2016) observed that presence of excess soil moisture, low sunshine hours due to cloudy weather in winter season fuels the spread of stem gall and damages the crop up to 100 percent. Leharwan *et al*. (2018) reported that stem gall development was maximum (77.50%) at 25°C soil temperature followed by 30°C temperature giving 52.50 percent disease incidence and 30.00 percent disease severity, while very low and the high temperature was not favorable for the development of the disease. In another experiment on different moisture regimes, 45 percent of soil moisture level was favorable for disease development and resulted in 70.25 percent disease incidence and 35.25 percent disease severity. Very low and very high soil moisture levels were not favorable for disease development.

Disease Management

The yield losses by stem gall of coriander can be minimized through the use of some cultural practices, biological control, nutrition, bio-product, chemical control and by use of host resistance.

Cultural Control

Early sown a crop in mid-September and late sown crop around the first week of December have less disease severity, however, the crop sown in mid-November had the least intensity of the disease and high seed yield (Tripathi, 2003). The plastic covering is an effective practice to restrict weed growth, conserve moisture, and reduce the effect of soil-borne diseases through soil solarization. Dabbas *et al*. (2009) also confirmed the control of stem gall through soil solarization and a mean 50.91 percent control of the disease was found by them after 30 days of treatment. The mulching is found beneficial in a state like Rajasthan and UP as the proper solarization could be done due to high temperature prevailing in the area resulting in higher yields as compared to the non-mulched field (Singh *et al*., 2016). The integration of soil solarization and plastic mulching are a foolproof method to suppress weed growth, prevents leaching of fertilizers, act as a physical barrier to rainfall, and conserving

the fertility of the soil. Mishra and Tiwari (2018) reported that the change of microclimate through plastic mulching in the vicinity around the host plant significantly influenced both the host and pathogen because increasing temperature and moisture adversely affect the survivals of chlamydospores and blastospores of *P. macrosporus* and it also enhanced the plant growth.

Biological Control

Biological control agents are successfully used by several workers in their experiment such as *Trichoderma viride* and *Pseudomonas fluorescens* as a seed treatment, soil treatment and as foliar sprays. Dabbas *et al*. (2009) recommended seed treatment with *T. viride* 4 g/kg seed + soil treatment by *T. viride* 2 kg/ha for the management of stem gall of coriander. Similarly, Kumar *et al*. (2014) found that the seed treatment of bio-fungicides like *T. viride* and *Pseudomonas* at the rate of (0.4%) and foliar spray of *Trichoderma* spp. and *Pseudomonas* spp. at the rate of (0.4%) after 40,60 and 75 days of sowing decreased the percentage incidence of disease by 24.50 and 32.65, respectively.

Nutrition

Tripathi *et al*. (2002) found that the potassium and nitrogen fertilizers reduced stem gall incidence while phosphorous fertilizers increased the disease. Organic nutrition for spices is especially important as they provide quality food. Malhotra *et al*. (2006) studied the influence of *Azospirillium* spp., nitrogen fertilizer, farmyard manure and their combinations on seed yield and incidence of stem gall of coriander. They observed that *Azosprillium* spp., 50 percent nitrogen and 5 tonnes of FYM were the most economical treatment in increasing the seed yield and reducing the incidence of stem gall disease.

Bio Product

A large quantity of chemicals is being used to reduce the ravages of various diseases. Which are not only detrimental to the environment but are also hazardous to human health and need to be replaced by less detrimental compounds preferably from natural sources. Mishra and Tiwari (2018) concluded that the seed treatment and three foliar spray applications with 1.0% neem oil at 45, 60 and 90 days after sowing greatly reduced the disease severity of stem gall. Tripathi (2005) recorded the minimum disease intensity in soil treated with neem cake which reduces the disease by 50 percent and increased yield by 36 percent and also gave a significant reduction in disease up to 27 percent.

Chemical Control

A large number of fungicides have been used against the disease in almost all the coriander growing countries of the world since the first record of stem gall of coriander. Though the application of fungicides has lowered the disease incidence but has not given satisfactory control. Nene *et al*. (1966) reported partial field control of this disease through seed treatment with thiram at the dose of 0.25 kg per 100 kg of seed. They further indicated that better control is possible by combining seed and soil treatments with thiram @8 kg/acre in the soil. Seed treatment with ceresan and soil application of omnamycin was effective in reducing gall development on the stem as well as invasion of fruits by the pathogen *P. macrosporus* Unger (Pavgi and Mukhopadhyay, 1970).

Paul (1992) tested eight fungicides and their combinations as seed dresser against stem gall disease and observed that seed treatment with captafol (@2 g/kg seed) was most effective in inhibiting chlamydospores germination of *P. macrosporus*. Lakra (2000) treated seeds with carbendazim, captan, thiram and vitavax (carboxin) at the rate of 2 and 4 g a.i./kg seed before sowing. Carbendazim (0.2%), carboxin (0.1%), copper oxychloride (0.3%), mancozeb (0.25%), streptomycin (500 ppm) and tridemorph (0.1%) were applied to foliage, 30, 45, 60 and 75 days after sowing. Control by seed treatments with thiram, vitavax, Bavistin and captan at 4 g/kg seed was 53.5, 50.0, 35.7 and 32.1 percent, respectively, and 66.6, 62.5 and 58.3 percent control were obtained with streptomycin, carboxin, and tridemorph, respectively, 30 days after sowing.

Shukla *et al*. (2006) found that seed treatment with carbendazium (1g/kg) + foliar spray with Bayleton (0.04%) was the most effective and reduced 57.66 percent disease severity followed by seed treatment with carbendazim+ foliar spray with karathane (0.04%) and foliar spray with Bayleton (0.4%). Kumar *et al*. (2014) reported that minimum disease incidence of 44.16 percent was recorded by treatment of seeds with hexaconazole (0.2%) and foliar spray of hexaconazole (0.2%) after 40, 60 and 75 days of sowing. This treatment controlled stem gall disease by 45.92 percent over control. This was followed by plant disease incidence of 48.33 by seed treatment of propiconazole (0.2%) and foliar spray of propiconazole (0.2%) after 40, 60 and 75 days after sowing and controlled the disease by 40.82 percent over control.

Bhardwaj and Shrestha (1985) reported that four sprayings with thiram, captafol or carboxin, when given at fortnightly intervals from the time of disease manifestation, were far more effective than seed treatment or combined seed and soil treatment in controlling stem gall and increasing the yield of coriander. Thiram gave the highest fruit yield followed by carboxin and captafol.

Host Resistance

Host plant resistance is an effective, economic and environmentally safe component to keep stem gall disease below the threshold level. Studies conducted in different countries indicate that the coriander varieties are variably susceptible or differ slightly to greatly in their reaction to stem gall.

Mishra and Pandey (2017) evaluated coriander genotypes for resistance against stem gall disease and powdery mildew under natural conditions and data revealed that genotype K. Selection showed lowest disease severity of stem gall 6.4 per cent in 2002–2003, 6.7 per cent in 2003–2004 and 6.8 per cent in 2004–2005, whereas, pooled disease severity of stem gall

in K.Selection during 2005–08 was 8.62 percent as compared to Pant Haritma (11.78%), UD-118 (18.78%), RD-154 (33.33%) and LCC-174 (37.46%). The yield performance of K.Selection was also significantly higher over the national check Pant Haritma. Khan and Parveen (2016) also evaluated 27 varieties of coriander against stem gall pathogen, and only four were found to be resistant. Kumar *et al*. (2016) screened a total of 102 germplasm against stem gall disease under natural field conditions and found that 35 varieties showed a moderately susceptible reaction, whereas, 67 varieties were observed to be susceptible to the disease. None of the genotypes was found to be resistant or moderately resistant against the disease.

Conclusion

Stem gall of coriander is emerging as one of the most common, widespread and serious diseases throughout the world and causes significant yield losses. The most serious losses occur during flowering and fruit formation, and on the severe incidence of stem gall, no fruits are produced. A minimum temperature range of 13–15°C and a maximum of 25–30°C along with 45–75% RH are the most conducive for disease development. In spite of a large number of fungicides in use, substantial incidences of stem gall are still encountered, and inoculum potential of the pathogen is substantially building up in the soil and in seed material. The causal fungus perennates in the form of chlamydospores in soil and in seed material for which soil solarization and seed treatment with effective fungicides or with bioagents is adequate. The flowering stage appears to be the most critical for infection; therefore, fungicidal treatment must start before flowering or when 20-30% of inflorescences have appeared and during fruit set. There is evidence that the stem gall fungus is somewhat obligate pathogen and in future developing resistance against some fungicides especially systemic ones. Therefore, the fungicides of the same group should not be used. A mixture of non-systemic and systemic fungicide as seed and foliar treatment, which is very promising; must be emphasized. Coriander varieties vary considerably in their susceptibility to stem gall throughout the globe. So, the use of only the latest resistance varieties for a particular area is the best strategies for economic control of the disease.

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