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Diseases of Seed Spices

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1. INTRODUCTION

The seed spices, viz., cumin, coriander, fennel, fenugreek, *ajwan* and soya are important for both internal consumption and exports. These are generally grown as *rabi* crops in cool and dry climate. Cumin, fennel and fenugreek are grown extensively in Rajasthan, Gujarat and Uttar Pradesh. Coriander is grown mostly in the southern states viz., Andhra Pradesh, Karnataka and Tamil Nadu apart from Rajasthan and Gujarat. Root rot, wilt and powdery mildew diseases cause severe crop losses in seed spices and have been identified as major production constraints. Vascular wilt of cumin, coriander and root rot of fenugreek are important soil borne diseases, and powdery mildew/leaf blight of cumin, coriander, fennel and fenugreek are important foliar diseases that affect these crops. Apart from these fungal diseases, losses caused by plant parasitic nematodes are on increase. Conducive climatic conditions, lack of resistant varieties and non-adoption of recommended package of practices by the farming community are the limiting factors for an effective disease management. Disease problems of seed spices have been reviewed earlier (Chattopadhyay, 1967; Suhag *et al.*, 1986; Agnihothri, 1990). The present status of diseases and future strategies for their management in seed spices in India are dealt in the present review.

2. CUMIN

Wilt, powdery mildew, and leaf blight are the major diseases of cumin (*Cuminum cyminum* L.) causing serious crop losses in Rajasthan, Gujarat and Haryana.

2.1 Cumin Wilt

Fusarium oxysporum f. sp. *cumini* Patel, Prasad, Mathur and Mathur has been identified as the causal agent of the disease. This was first reported from Kekri and Ajmer areas of Rajasthan. *Fusarium* sp. was found to be the causal agent (Gaur, 1949). Later, the correct identity of the fungus as *F. oxysporum* f. sp. *cumini* was established (Patel *et al.*, 1957). The problem has been reviewed recently (Siradhana and Shivpuri, 1990).

2.1.1 *Crop Losses*

About 5-25 per cent crop losses have been reported from North Gujarat and 5-60 per cent from Rajasthan (Patel *et al.*, 1957). Losses as high as 70 per cent have been reported from Gujarat (Gaur, 1949).

2.1.2 *Symptoms*

Plants at all stages of growth are susceptible to disease but younger plants are more vulnerable. Root infection results in varying degrees of foliar yellowing. Flaccidity and drooping of leaflets are the initial foliar symptoms. Later, the affected plants dry up. In older plants, foliar yellowing starts from the lower leaves and progresses upwards. Occasionally, only a portion of the plant is infected. Stunting of plant and yellowing of foliage are noticed in partially affected plants. When the infection occurs at flowering stage, seed set is affected. Seeds from such plants appear thin and shrivelled (Agnihothri, 1990). The affected plants can be pulled out easily.

2.1.3 *Biology of the Pathogen*

The fungus produces abundant aerial mycelium which consists of macro and micro conidia. Chlamydospores are spherical, smooth and terminal or intercalary. The fungus grows at wide range of temperatures, 24°C being optimum and 35°C is the maximum. The pH requirement for growth vary from 4.8-8.4 and 6.6 is the optimum (Anon., 1955). The fungus utilises glucose, fructose, sucrose, xylose, L-arabinose, L-mannose, sorbitol and mannitol as carbohydrate sources and ammonium salts as inorganic source, followed by d-alanine, L-glutamic acid, dl-aspartic acid L-leucine, L-asparagine as organic nitrogen sources. Among vitamins, biotin riboflavin and folic acid supported good growth and sporulation of the fungus (Mathur *et al.*, 1964). Growth regulators, viz., MA, NAA and IAA at low concentrations increased growth and sporulation (Sankhla *et al.*, 1965).

Production of pectin methyl esterase, pectin-trans-eliminase, polygalacturonase, polygalacturonaase-trans-eliminase and cellulase both *in vitro* and *in vivo* was reported (Champawat and Pathak, 1990). Considerable variation in growth, morphology and virulence in different isolates was reported (Mathur and Prasad, 1964; Sharma, 1982; Sharma *et al.*, 1985; Champawat and Pathak, 1989).

2.1.4 *Epidemiology*

The fungus is soil-borne and root infection is the primary cause resulting in different degrees of root rot leading to varying degrees of foliar yellowing. The disease is a typical vascular wilt and the presence of mycelium and chlamydospores in xylem elements was recorded (Anon., 1955; Patel *et al.*, 1957). The pathogen is highly host specific but seedling infection in coriander and carrot was noticed (Mathur and Prasad, 1964).

The disease appears in patches when the crop is about one month old. Disease incidence was more in light and poor soils and the soil temperature of 54.6-57.0°F in the morning and 61.0-66.7°F in the evening was found conducive for the disease development (Mathur and Mathur, 1966). However, critical studies are warranted on the adaphic factors particularly soil temperature and moisture in relation to the pathogen population and the disease outbreaks. Seed-borne nature of the disease was also established (Patel, 1968; Champawat and Pathak, 1990b). The fact that disease was noticed in the plots where previously the crop was not grown (Mathur and Prasad, 1964) supported further the possibilities of disease transmission through seeds. Presence of fungus between seed coat and endosperm was established and the seed infection might occur in the field or during storage (Singh *et al.*, 1972). Presence of sporodochia of the fungus on infected roots was reported (Gaur, 1949; Mathur and Mathur, 1970). The left over infected plant debris in the field and also contaminated or infected seed would serve as the primary source of inoculum.

2.1.5 *Disease Management*

Soil and seed-borne nature of the disease poses problems for an effective disease management. In the absence of high degree of host resistance, cultural, chemical and biocontrol methods of disease management appear promising.

2.1.6 *Cultural Practices*

Poor and late germination of seed appears to be a problem in cumin. Soaking the seed in potassium nitrate solution (100 ppm) gave highest germination (Maurya *et al.*, 1985). However, its effect on seed-borne inoculum is not known. Hot water treatment of seed at 54°C for 15 minutes checked seed-borne fungi and increased germination upto 85 per cent (Arjunan, 1993).

2.1.7 *Summer Ploughing*

Summer ploughing twice and thrice resulted in 55.5 and 69.1 per cent disease control and consequent increase in yield by 38 and 85.8 per cent respectively (Champawat and Pathak, 1990).

2.1.8 *Organic and Inorganic Amendments*

Soil amendments like organic oilcakes gave variable results on disease incidence. Soil application of neem, cotton, castor ad mustard cakes at 2t/ha in combination with seed treatment with bavistin/captan at 2g/kg seed did not check wilt incidence effectively (Jain *et al.*, 1990). However, oilcakes were superior in reducing the disease and increasing the yield compared to untreated control. Reduction of wilt incidence and increased yields were reported with soil application of castor and mustard cakes, and poultry manure at 2.5 t/ha before sowing (Champawat and Pathak, 1988b). Mustard cake application at 2t/ha gave lowest wilt incidence (13.3%) and a yield of 180 kg/ha compared to 41.1 per cent wilt incidence and an yield of 100 kg/ha in untreated control (Jain *et al.*, 1990).

2.1.9 *Crop Rotation*

Green manuring and crop rotation did not influence wilt incidence. Increased wilt incidence was noticed with crop rotation involving *bajra*-mustard, sorghum-castor *guar* and wheat (Mathur *et al.*, 1967). However, crop rotations like cluster bean-cumin, cluster bean-wheat and cluster-bean-mustard reduced wilt incidence (38.61%) and increased yield upto 248.2 kg/ha compared to 56.5 per cent wilt incidence and yield of 99.15 kg/ha in untreated control plots (Anon., 1993).

2.1.10 *Biocontrol*

Except for the report of presence of antagonistic bacteria and fungi in wilt sick soils of cumin (Mathur and Mathur, 1968), no serious efforts have been made on biocontrol approach of disease suppression. Isolation and identification of efficient biocontrol agents like *Trichoderma* spp., *Gliocladium* and other fungi, actinomycetes and bacteria antagonistic/hyperparasitic to *Fusarium* and agumentation of the same through cheap and efficient delivery systems need be intensified. Seed pelleting combined with soil application of these biocontrol agents need to be field tested. The studies on effect of soil solarisation and soil rabbing on wilt incidence were inconclusive (Anon.,1993).

2.1.11 *Chemical Control*

Varying degrees of success has been reported in checking wilt incidence through fungicidal treatments. Soil application of SMDC (Vapam) 100 and 50 per cent was found effective in checking wilt incidence, and increasing crop stand and vigour of plants (Mathur and Mathur, 1967). Seed treatment and foliar spray with bavistin or Benelate was found effective in reducing the wilt incidence (Agnihothri and Sharma, 1987). Seed dressing and soil drenching with captafol, captan, cheshunt compound in combination with bavistin did not check wilt (Jain *et al.*, 1990). Seed dressing and soil drenching with Emisan-6 (0.02%), Topsin (0.2%) and Bavistin (0.2%) decreased disease incidence and increased yield (Anon., 1990). Decreased disease incidence (29.5%) with Bavistin seed treatment and increased yield of 203 kg/ha was observed at Jobner compared to 47.9 per cent disease incidence and a yield of 103 kg/ha in untreated control (Anon., 1993). The inconsistency of Bavistin treatment need to be checked for possible resistance development to *Fusarium*. The reported disease suppression and increased yields of cumin with soil application of Temik, Phorate and carbofuran (Champawat and Pathak, 1988a) indicates the possible involvement of nematodes or other soil pests in the disease etiology. In general, cost-benefit ratio has to be taken into consideration in all the fungicidal control experiments to understand economic viability of the treatments.

2.1.12 *Host Resistance*

Development of host resistance ultimately would be the practical solution for the cumin wilt. The reported variable virulence of the pathogen and the variable reaction of the varieties to pathogen would render the development of host resistance more

complicated and hence breeding programmes need to be intensified. High degree of resistance has not been so far identified. Varieties UC-33, MC-43, UC-62 and UC-90 were found resistant, and UC-41, UC-60 and 5404 were reported tolerant (Prasad and Bhatnagar, 1980). An exotic type EC 109635 and UC-198 showed tolerance to wilt and are being used in breeding programme (Anon., 1991b). MC-43, Gujarat Cumin-1, RZ-19 (UC 19) and Gujarat Cumin-2 (Mc 43-73) were also reported tolerant (Edison *et al.*, 1991). In view of the available tolerant lines, it would be desirable to try varietal seed mixtures for their efficacy in disease reduction. The importance of multiline cultivars and varietal mixtures in disease resistance has been reviewed (Wolfe, 1985).

An integrated disease management programme need to be evolved involving efficient agronomical practices, chemical and biocontrol methods combining host resistance. Being a soil-borne problem, programmes on biocontrol need to be intensified and biocontrol agents compatible with agrochemicals need be identified.

2.2 Powdery Mildew

Powdery mildew is caused by *Erysiphe polygoni* DC. and is known to occur in Bombay province as early as 1921 (Burns, 1921) and is now reported to occur in all the tracts where cumin is grown extensively.

2.2.1 *Crop Losses*

On an average, crop loss of about 50 per cent has been reported if the disease occurs during flowering stage but losses would be minimum at 10-15 per cent if the disease occurs during late stage of seed formation (Chattopadhyay, 1967). Total crop loss would occur if the disease appears in epiphytotic form (Uppal and Desai, 1932). Yield losses of about 5-15 per cent have been reported from Rajasthan due to powdery mildew (Gaur, 1949; Mathur, 1949).

2.2.2 *Symptoms*

The disease appears as small white or greyish specks on the lower surface of the leaves which gradually spread to the entire lamina giving an ashy white appearance due to the mycelial growth and sporulation. It gradually spreads to the stem, flowers and fruits. Under favourable conditions, the severely infected fields appear to be dusted with white flour (Chattopadhyay, 1967). Fruit development is affected and they would be lighter in weight and shrivelled in appearance.

2.2.3 *Biology of the Pathogen*

Being an obligate parasite, the mycelium is superficial with haustorial development between the epidermal cells. The hyphae, which traverse along the epidermis, produce appresoria from which haustoria develop. These will penetrate the epidermal cells and swell into saccate lobed structures. The condiophores arise vertically from the surface of the mycelium giving off chains of conidia which are unicellular, hyaline, elliptical and barrel to cylindrical in shape. The conidia germinate in a drop of water and are very sensitive to dry conditions. Optimum temperature for conidial germination was found to be 20-22°C, the minimum and maximum being 16-18°C and 30°C respectively. (Chattopadhyay, 1967).

2.2.4 *Epidemiology*

The disease is noticed during December-January and is favoured by moist warm condition. Temperature appears to be the determining factor in rapid disease development. Disease appears in severe form under a temperature range of 26.5-35°C and temperatures below 26.5°C are not conducive for disease development. Occasional showers with warm condition during December would favour the disease. Irrigation of the field would ensure sufficient humidity for the disease development (Uppal and Desai, 1932). Studies are warranted on the micro-climatic conditions, the frequency of irrigation for disease development and also the collateral hosts, if any.

Hybernating dormant mycelium on the seed surface appears to be the mode of perennation from season to season (Uppal and Desai, 1932).

2.2.5 *Disease Management*

In general, chemical control appears to be the only method of disease management adopted.

2.2.5.1 *Cultural Methods* : Since the disease is known to perennate through infected seed, hot water and fungicidal seed treatment practised for cumin wilt might help in ensuring healthy seed. Maintenance of special disease-free seed plots was also suggested (Chattopadhyay, 1967). Agronomic practices on disease management need to be studied.

2.2.5.2 *Chemical Control* : Efficacy of sulphur dusting was recommended at 28 kg/ha once at the time of flowering and second time at 13.5 kg/ha, if favourable climatic conditions prevailed (Uppal and Desai, 1932). Efficacy of Prenox, a copper formulation, was reported to check the disease effectively (Joshi, 1955). On an average, about 70 per cent disease control has been reported with Karathane, Elosol and Thiovit (Mathur *et al.*, 1971). Efficacy of elosal, Karathane was further confirmed by Singh and Gupta (1976). Efficacy of two rounds of Bavistin with a disease control of 85.8 per cent followed by Sulfex and sulphur dust was reported by Sharma *et al.* (1981). Single Calixin application increased yield by 70.1 per cent although comparatively inferior, in reducing the disease with two rounds of Bavistin spray. Similarly, two rounds of spray with Karathane increased yield up to 75.6 per cent even though found inferior to Calixin and Bavistin in reducing disease severity (Gupta and Bhavaria, 1985). Three rounds of sulphur dust at 15 kg/ha effectively controlled the disease. (Gohil *et al.*, 1985). Studies on integrated spray schedule against blight, powdery mildew and aphids showed that four rounds of spray/dust, viz., captafol (0.2%) first round followed by captafol + karathane (0.1%) + dimethoate (0.01%) (second round), captafol + Karathane (third round) and sulphur dusting at 25 kg/ha (fourth round) gave an yield of 1107 kg/ha with 72 per cent blight control, 95 per

cent powdery mildew control and 46 per cent aphid control with cost-benefit ratio 6.21 : 1 (Rajpurohit *et al.*, 1990). There is a necessity for monitoring the pesticide residues in the produce, since this being an export oriented crop.

High degree of host resistance is not known in the available germplasm at present. However, MC-43, Gujarat cumin-1 and 2 were reported tolerant (Edison *et al.*, 1991).

2.3 Blight

The disease is caused by *Alternaria burnsii* Patel and Kamat. It was first reported from Bombay province to be caused by *Alternaria* sp. (Uppal, 1933) but later the correct identity of the fungus as *Alternaria burnsii* was established (Uppal *et al.*, 1938). It is wide spread in Rajasthan and West Bengal (Mathur, 1949; Joshi, 1955; Bandopadhyay *et al.*, 1980).

2.3.1 *Symptoms*

Infection starts as small isolated necrotic areas on the foliage specially on the tips of the young leaves. These lesions enlarge and later coalesce and finally turn dark. Infection spreads to stem, succulant leaves and blossoms. Severe infection affects the seed set and, if produced, such seed appear shrivelled, dark, light in weight and non-viable (Chattopadhyay, 1967).

2.3.2 *Biology of the Pathogen*

Conidiophores arise vertically from the aerial mycelium and also from mature lesions and give off conidia. Conidia germinate in distilled water. The optimum temperature for germination is 26-27°C while the minimum and maximum temperatures are 4.5 and 37.5°C respectively (Chattopadhyay, 1967). Fungus grows luxuriantly on potato dextrose agar, oat meal agar and cumin agar. It utilises sucrose, lactose, dextrose, maltose and dextran as carbon sources; sodium asparginate, ammonium tartrate, ammonium lactate, and potassium and sodium nitrates as nitrogen sources. Growth is optimum at pH 6 but grows at a wide range of pH 3-10. The optimum temperature for growth is 26-27°C, and minimum and maximum being 4.5 and 35°C respectively (Chattopadhyay. 1967).

2.3.3 *Epidemiology*

Disease development is governed by atmospheric humidity levels and the disease becomes serious if humid condition continue at the time of flowering (Uppal *et al.*, 1938). The plant becomes susceptible only after flowering stage. Rain, cloudy humid weather and temperature range of 23-28°C are highly favourable for disease development (Gemawat and Prasad, 1972). Under highly favourable conditions, yield loss to the tune of 70 per cent has been reported (Patel, 1968). Aerobiological studies carried out showed that conidial abundance in air was noticed during 09.00-12.00 h (Gemawat and Prasad, 1972). Physiological studies of the host during different phases of disease development indicated that it is a low sugar disease (Gemawat and Prasad, 1973). The reports of the effect of early planting in relation to disease development are contradictory and might be related to difference in prevailing weather condition of the particular season and year. While severity was less with early planting (Gemawat and Prasad, 1972), it was reported severe in early planting (Patel and Pillai, 1983). Infected seed (Uppal *et al.*, 1938; Patel and Desai, 1971) and infected plant debris left over in the fields might serve as the primary source of inoculum (Patil and Desai, 1971; Gemawat and Prasad 1972; Bandopadhyay *et al.*, 1988). This was further supported by the observations of the disease incidence in the fields where cumin was not grown earlier and also increased disease incidence with continuous cultivation. Extended sowing from October to December ensured availability of continuous susceptible host in the areas for longer periods (November-April). This resulted in disease spread to the adjoining area. (Gemawat and Prasad, 1972).

2.3.4 *Disease Management*

Fungicidal control has been the main strategy of the disease management. Earlier studies showed that copper fungicides, viz., Bordeaux mixture and Prenox were effective in checking the disease (Joshi 1955; Chattopadhyay, 1967). Subsequent studies showed that organic fungicides were more effective. Disease control of 72.6 and 61.7 per cent has been reported with Cuman (0.1%) and Dithane Z-78 (0.2%) with two rounds of spray at a monthly interval after flowering (Gemawat and Prasad, 1969). Efficacy of seed treatment with mercurial fungicide (Ceresan) and spraying with Dithane Z-78 gave better control (Patel and Desai, 1971). Difolatan, Ziram, Blitox, Aureofungin, Vitavax, Benelate and Brestanol applied thrice were found effective in checking the disease (Solanki *et al.*, 1973). Bavistin spray gave effective disease control and increased yield (Lakhtaria and Pillai, 1978; Gemawat, 1978; Sharma *et al.*, 1980). Seed dressing with Agrosan GN was reported to be effective in checking blight (Singh, 1977). Four rounds of spray with Dithane Z-78 (0.25%) gave good control with CBR of 1:3 (Patil, 1980). Under Gujarat condition, four rounds of spray with Dithane M-45 (0.2%) gave an effective control (Mehta and Solanki, 1990). Through an integrated control programme for blight, powdery mildew and aphids of cumin, 72 per cent of the blight control was obtained with four rounds of combination spray of captafol, karathane and dimethoate which gave yield of 1.1 t/ha and BC ratio of 6.2 : 1 (Rajapurohit *et al.*, 1990).

Seed dressing with Dithinon and Bengard at 1 g/kg seed, and Topsin M at 2 g/kg seed gave 6.7, 8.9, 9.8 per cent disease incidence with corresponding yield increase of 2.4, 2.1 and 2.2 q/ha compared to 38 per cent disease incidence and 0.932 q/ha yield in untreated control (Bhatnagar and Sharma, 1990).

2.3.5 *Host Resistance*

Though high degree of host resistance was not found, the varieties MC-43, Gujarat cumin-1, RZ-19 and Gujarat cumin-2 were found tolerant to blight (Edison *et al.*, 1990).

Standardising efficient agronomic practices that are effective against disease suppression and induction of host resistance are of high priority.

2.3.6 *Minor Diseases*

Leaf spot caused by *Elsinoe kamatii* (Tewari, 1974) and witches broom caused by MLO's (Jainarayan, 1987) have been reported, which at present, are not of economic importance.

3. CORIANDER

Like cumin, coriander (*Coriandrum sativum* L.) also suffers from three major diseases viz., wilt, powdery mildew and stem gall causing considerable crop losses.

3.1 Wilt

The disease is caused by *Fusarium oxysporum* f. sp. *corianderii* and was reported during 1936 (Anon., 1953). It is known from Gwalior and Guna districts of Madhya Pradesh and Kota area of Rajasthan.

3.1.1 *Crop Losses*

Precise crop loss figures are not available. About 25 per cent yield loss has been reported from Madhya Pradesh. In certain pockets of Madhya Pradesh like Guna district, the average losses were about 40-50 per cent. In Rajasthan, losses as high as 60 per cent have been reported (Chattopadhyay, 1967).

3.1.2 *Symptoms*

Plants are prone to infection at all stages of crop growth. Root infection leads to rooping of the terminal portion of the plants followed by withering and drying up of leaves are the major symptoms. The infected plants ultimately die. Partial infection of the plants results in growth retardation. The leaves of such plants exhibit pinkish yellow to yellow colour. Partial infection leads to sterility in some cases and, if seed set is noticed, such seed remained light and immature. When infection is noticed in entire field, wilting will be sudden. Early infection leads to total failure of the crop (Chathopadhyay, 1967). Pre-emergence death and damping off followed by wilt is also noticed (Mall, 1968).

3.1.3 *Biology of the Pathogen*

In culture, the mycelium appears whitish and the substrate shows pinkish colour on oat meal agar and old lilac colour on steamed rice. Microconidia are scattered and are hyaline, ovoid, ellipsoid or reniform. Macroconidia appear in sporodochia. The fungus grows at a temperature range of 12-35°C and best growth was observed at 19.5°C.

3.1.4 *Epidemiology*

Mortality of the plants as high as 37 per cent has been reported in irrigated fields compared to 14 per cent in unirrigated fields. The pathogen population correspondingly was high in irrigated soils compared to unirrigated soils (Srivastava, 1969).

Presence of hyphae was noticed both in the cortical tissues and vascular bundles of the infected plants in addition to vascular browning. Vascular plugging is noticed only in roots of older plants (Mall, 1968). For the disease development, optimum temperature range was 24-27°C, even though wilting was seen even at 20-29°C. Soil moisture content of 50-60 per cent was found favourable for the disease incidence (Chattopadhyay, 1967) and wilt increased with increase in soil moisture. Wilt incidence was high at a temperature range of 28-33°C and was low at 20-24°C. Mortality of the plants was high at soil pH range of 5.8-6.9. Symptom development was gradual in alkaline soils (Srivastava, 1972). The pathogen remained viable in the seed for five months and could survive for long in soil. Soil-borne inoculum appears to be the primary source of infection (Srivastava, 1967).

3.1.5 *Disease Management*

Application of organic amendments and fungicidal treatments were the adopted methods of disease management. Use of disease-free seed, crop rotation and summer ploughing have been suggested as disease management practices (Bhati *et al.*, 1985).

3.1.6 *Organic Amendments*

Organic soil amendments reduced the disease incidence. Disease incidence was less at higher concentration of amendments (Srivastava and Sinha, 1971). Soil temperature and pH affected the efficacy of organic amendments on disease suppression. At soil pH of 6.0 and 26°C, without addition of oil cake, wilt incidence was 100 per cent. However, with addition of oil cake, mortality reduced from 100 to 72 per cent at 28°C, from 55 to 33 per cent at 20°C at pH of 6.0 and from 5.0-27.7 per cent at pH 8.2 (Srivastava, 1972). Application of amendments with low N, and high P and K (40:80:80) gave the lowest wilt incidence of 8.3 per cent compared to high N and low and P and K (80-40:40) with wilt incidence of 59.7 per cent (Srivastava, 1967, 1972).

3.1.7 *Biocontrol*

Varying degrees of antagonistic activity of four strains of *Streptomyces* on *Fusarium* isolates of coriander was noticed (Mathur, 1963). However, their *in vivo* activities are not known. Biocontrol programmes are of great relevance and need be intensified.

3.1.8 *Chemical Control*

Seed treatment with Agrason G N was found effective in wilt control (Nikam *et al.*, 1959). Seed dressing and spraying twice with Bavistin or Benelate at the age of one and two months reduced wilt incidence upto 60 per cent (Jain and Agarwal, 1978).

3.1.9 *Host Resistance*

UD-20 has been reported resistant to wilt and varieties Sindhu, CS-287, CO-3, Swathi, Sadhana, RCr-41, RD44, Gujarat coriander-1 and 2 were reported tolerant (Edison *et al.*, 1990). Gwalior No.5365 has been reported resistant (Singh Banafar and Singh, 1985). Studies need be intensified to develop effective integrated disease management. Variety MS 5365 was found tolerant to five isolates of *Fusarium* (Mathur, 1963).

3.2 Powdery Mildew

The disease is caused by *Erysiphe polygoni* DC and is known to be severe in Rajasthan. It is also noticed in Andhra Pradesh and Tamil Nadu.

3.2.1 *Crop Losses*

Precise crop loss figures are not available. Yield losses of about 15-20 per cent have been reported from Rajasthan (Srivastava *et al.*, 1971).

3.2.2 *Symptoms*

Infection starts as small whitish circular patches on the leaves and stem, which gradually enlarge and coalesce covering the entire leaf surface (Chattopadhyay, 1967). Infection generally starts at the time of flowering and spreads from stems, leaves to inflorescence and seeds. In case of severe infection, the umbels dry up. Premature sterility and poor setting due to this disease have been recorded (Srivastava *et al.*, 1971).

3.2.3 *Epidemiology*

Infection is noticed during February-March. Dry season and high temperature favoured disease development (Butler, 1918). However, importance of humid condition for disease development in Rajasthan has been reported (Mathur, 1949).

3.2.4 *Disease Management*

Similar to powdery mildew of cumin, disease management so far adopted is mostly through agrochemicals.

3.2.5 *Cultural Practices*

Early sown crop during October showed less disease incidence compared to late sown crop (Keshwal *et al.*, 1979).

3.2.6 *Chemical Control*

Sulphur dusting once when the crop in about two months old and again after fruit setting was found effective (Nikam *et al.*, 1959). Two rounds of spray with the fungicides, viz., Cosan, Sultaf, Karathane, Elosal, Thiovit and Morocide were effective in checking the disease (Srivastava, 1971). Three rounds of spray with Sultaf (0.25%) was effective in checking the disease (Keshwal *et al.*, 1979). Sulphur fungicides, viz., wettable sulphur (0.6%) and Karathane gave maximum control of the disease and increased yield (Raju *et al.*, 1982; Vinayagamurthy *et al.*, 1985). A recent study in Gujarat showed the efficacy of disease suppression with sulphur dusting thrice at 25 kg/ha followed by three sprays of Dinocap (0.05%). The disease intensity was 21.1 and 37.4 per cent and yield was 1700 and 1600 kg/ha respectively, an incrase of 57 and 56 per cent respectively (Parkhia *et al.*, 1990).

3.2.7 *Host Resistance*

Varieties Gujarat Coriander 1 and 2, RCr-41, Sadhana, Co3, Sindhu and UD-20 were found tolerant while Swathi, an early maturing variety, escaped disease (Edison *et al.*, 1991).

Critical studies are needed on epidemiology to plan an effective disease management.

3.3 Stem Gall

This is a soil-borne disease caused by *Protomyces macrosporus* Unger. It was first reported in India by Butler (1918) but was not considered serious. However, it was later considered as important (Mundkar, 1949). It is noticed in all tracts where coriander is grown.

3.3.1 *Crop Losses*

In Gwalior (MP), the disease intensity was 23 per cent with an approximate loss of 23 per cent per plant (Gupta, 1954). In Uttar Pradesh, the disease intensity was 7.5-24.4 per cent causing a yield loss of 96-33.8 per cent (Singh *et al.*, 1984).

3.3.2 *Loss in Quality*

The hypertrophied leaves and fruits loose their flavour. The fat loss in fruit was about 15 per cent (Gupta, 1956a). The diseased fruits loose their flavour and also their fat, protein, carbohydrates and aminoacids (Gupta, 1964; Prasad, 1983). In diseased leaves and fruits, ash, magnesium, sodium and sillica contents increased, while calcium, manganese, phosphorus, potassium and iron content decreased (Gupta, 1975). Increased concentration of reducing sugar and aminoacids, and decreased content of non-reducing and total sugars in the diseased tissues was reported. Increased levels of invertase,

protease acid, phosphatase, peroxidase and polyphenols have also been reported (Goel *et al.*, 1983).

3.3.3 *Symptoms*

Infected plants exhibit tumour like swellings on stems, petioles, pedicels and veins of the leaves. The size of the tumour is 9-12 × 3.5 mm in diameter and vary according to the size of the part infected. The hyperplasy of the outer cortical cells restricted to those in the neighbourhood of inter-cellular hyphae results in tumour formation (Chattopadhyay, 1967).

3.3.4 *Biology of the Pathogen*

The organism could be cultured on potato dextrose agar (Mukhopadhyaya and Pavgi, 1964). The mycelium is intercellular and branched, producing thick walled, globose to ellipsoid chamydospores with three-layred membrane, a thick brownish exospore and thin meso and endospores. Chlamydospores germinate in water forming sporangia and spores. The released spores from the sporangium are connected in pairs and later they fuse (Gauman and Dodge, 1928). High acid phosphatase activity was noticed in chlamydospores (Maheswari and Chaturvedi, 1983). Considerable variability of the pathogen was noticed (Gupta and Sinha, 1963; Narula and Joshi, 1963). Chlamydospores showed 10 per cent germinatiion after 6 years and lost the viability after 7 years of storage (Mukhopadhyaya and Pavgi, 1971).

3.3.5 *Epidemiology*

Inoculum potential, microclimate and crop growth phase influenced the susceptibility of the plants. Chlamydospores germination and disease incidence was influenced by environmental condition prevailing (Mukhopadhyaya and Pavgi, 1975). The disease was severe in heavy and irrigated soils. Low temperature, abundant dew with higher day temperature have been reported to predispose the plant to infection. The disease was severe in low lying heavy and ill drained soils (Mukhopadhyaya and Pavgi, 1971). Infection was minimum (20.8%) at a soil pH of 4.6 and increased with rise in pH upto 7.4 with maximum infection (91.6%). Fruits showed maximum infection of 43.9 and 40.1 per cent at pH of 7.4 and 8.4 respectively (Mathur, 1962). Fertilizer application of N resulted in disease reduction and consequent nutritional status influenced the disease incidence. Increased levels of manganese increased disease. At lower dose of P disease reduction was noticed but increased with higher dose of P, (Gupta, 1[illegible]

3.3.6 *Disease Management*

Available information on the effect of fertilizer application, regulation of soil pH and drainage need to be adopted to reduce the disease incidence.

3.3.6.1 *Chemical control*: Prenox and Agrason GN inhibited the chlamydospore germination. The sulpha drugs, viz., sulphathiazole and sulphadiazine decreased chlamydospore germination at 0.025 and 0.05 per cent concentration but was completely inhibited at 0.1 per cent (Gupta, 1956b). However, their use in disease control are not known. Penicillin and Streptomycin spray (400 ppm) at three week's interval upto the age of 13 weeks reduced disease intensity by 85.4 and 87.9 per cent respectively (Gupta and Sinha, 1963). Seed and soil treatment with thiram at 250 g/100 kg seed gave better protection (Nene *et al.*, 1966). Foliar spay with thiram (0.2%), captafol (0.2%) or caxboxin (0.1%) at fortnightly intervals gave better protection (Bhardwaj and Shresta, 1985).

3.3.6.2 *Host resistance* : Cultures UD-48, UD-4, UD-46, UD-OZ were highly resistant at Jobner, (Naqvi, 1986). The variety NP-95 was least affected (Das, 1971). Shujalpur local, NP-92, NP-95, Delhi local, Synthetic North, Kota Local and P-107 were tolerant (Gupta and Sinha, 1973). Rajendra Swathi, Rcr-41 and UD-20 were found resistant (Edison *et al.*, 1991).

The available information should be utilised for development of an integrated disease management.

3.4 Minor Diseases

3.4.1 *Grain Moulds*

The disorder is noticed in Tamil Nadu and Andhra Pradesh. *Alternaria* sp. *Fusarium* sp. *Helminthosporum* sp. and *Curvularia* sp are the fungi associated with the affected seed (Anon., 1987). Grain discolouration was intense if flowering coincides with rain. Carbendazim (0.1%) spray 20 days after the seed set was found effective with mould incidence of 3.6 per cent and an yield of 643 kg/ha. This was followed by copper oxychloride (0.25%) spray at 20 days after the grain set that gave mould incidence of 4.7 per cent and 648 kg/ha yield, and carbendazim (0.1%) spray 10 days after the grain set, compared to 21.4 per cent mould incidence and 466 kg/ha yield in control (Rajan *et al.*, 1990). Disease incidence under irrigated crop ranged from 1.3-4.4 per cent compared to 5-10 per cent in rainfed condition. Cultures CS-287 followed by CO-1 showed lowest disease incidence (Anon., 1987).

3.5 Stem Rot

This is caused by *Sclerotinia sclerotiorum* (Lib) de Bary (Mehta *et al.*, 1946). Disease occurs sporadically and causes foot rot. High temperature (29-34°C) reduced disease incidence and lower temperatures (19-24°C) increased disease incidence (Gupta, 1963).

3.6 Anthracnose

This is caused by *Colletotrichum capsici* (Syd). Butler and Bisy and was reported from Kota region of Rajasthan (Sehagal *et al.*, 1965). This causes inflorescence blight and seen at the time of flowering. The disease also extends to foliage. Shrivelled and undeveloped seeds are seen when infection was delayed. *Glomerella cingulata* has been reported to cause similar malady in Anantapur district of Andhra Pradesh (Moses and Rao, 1969).

Damping-off caused by *Pythium irregulare* (Sharma and Chowdhury, 1981), wilt caused by *Macrophomina phaseolinia* (Mahor *et al.*, 1982), blights caused by *Alternaria poonensis* (Raghunath, 1968), *Alternaria alternata* (Khan and Kamal, 1984) and bacterial blight caused by *Xanthomonas corianderii* (Srinivasan *et al.*, 1961) are the other minor diseases reported.

4. FENNEL

Blight, leaf spot, sclerotinia root rot and powdery mildew are some of the known diseases of fennel (*Foeniculum vulgare* L.).

4.1 Powdery Mildew

This disease caused by *Leveillula taurica* (Lev.) Arnaud and *L. taurica* (Lev.) Arnaud var *languinosa* Salm is noticed in Rajasthan occasionally on fennel and it is seen generally during February-March. (Chattopadhyay, 1967). *L. taurica* var. *languinosa* differs from *L. taurica* in having cylindrical to irregular shaped conidia (Butler, 1918). Variety IS-171 was least affected (Gidanaver and Krishna Murthy, 1979).

4.2 Leaf Spot

The disease is caused by *Cercosporidium punctum*, (Syn. *Passalora foeniculi* Kamat and Khan. Syn. *Cercospora foeniculi* Magn.). It was first reported from Pusa, Kashmir and other parts of India (Sydow and Mc Rae, 1978). This caused widespread damage in Rajasthan resulting in substantial yield reduction due to destruction of the foliage (Chattopadhyay, 1967).

4.2.1 *Symptoms*

The fungus causes brown to black lesions on leaves, stems, peduncles and seeds. Severely infected plants give a blighted appearance. Severe epiphytotics were reported during 1955-56 in Ajmer due to prevailing warm temperature (78-95°F) and low rainfall (Joshi, 1958).

4.2.2 *Disease Management*

Bordeaux mixture spray at monthly intervals from January checked the disease (Joshi, 1958). Spraying with suspension of colloidal sulphur (0.25%) in water during February-March was recommended for the control of the disease (Chathopadhyay, 1967).

4.3 Blight

The disease is caused by *Ramularia foeniculi* and is known from Gujarat, Rajasthan, Uttar Pradesh, Punjab and Haryana.

4.3.1 *Symptoms*

It is known to appear as minute angular brown necrotic areas on the lower surface of the older leaves. This later shows whitish erupment growth. The infection spreads to stem, peduncle and fruits. Severe infection results in shrivelling and drying up of leaves, giving a blighted appearance. If the infection occurs in early stage of crop growth, seed set will be absent and, if it occurs at later stages, the seed appear shrivelled and dark (Prasad *et al.*, 1961).

Root rot caused by *Sclerotina sclerotiorum* (Sehagal and Agarwal, 1971) and *Fusarium solani* (Gupta and Srivastava, 1978), *Passalora krichneri* in association with *Phoma anethi* causing angular leaf spots (Pillai and Sarwar, 1970), blight caused by *Alternaria tenuis* (Deshpande and Sehagal, 1964) *A. umbelliferícola* (Raghunath, 1966) stem gall caused by *Protomyces macrosporus* (Awasthi *et al.*, 1978) and phyllody (Prakasam *et al.*, 1990) are the minor diseases known to affect fennel. In view of the sporadic nature of the disease, detailed studies have not been undertaken.

5. FENUGREEK

Powdery mildew, downy mildew, rust, root rot and leaf spot are some of the known diseases of fenugreek (*Trigonella foenum-graecum* L.).

5.1 Powdery Mildew

The disease is caused by *Erysiphe polygoni* DC. and *Leveillula taurica* (Lev) Arnand. It appears generally late in the season and is minor in nature. The infected plants show floury whitish fungal growth on leaves. *E. trifoli* has also been reported on fenugreek (Gupta *et al.*, 1982). Powdery mildew caused by *L. taurica* has been reported to be serious during December during which a relative humidity of 60-70 per cent and temperature of 15-25°C prevailed (Saxena, 1985).

Two applications of Cecosal, Cosan, Thiovit, Sultaf, Karathane-WD or Morestan controlled the disease and increased yield by 220-326 kg/ha. (Masih *et al.*, 1970). High volume spray with Gandhok gol (0.5%) or Cosan (0.2%) at 20 days intervals efficiently controlled the disease (Mathur *et al.*, 1972).

Collection No. 21-76-326 has been reported to be most resistant (Saxena *et al.*, 1984). Variety Prabha has been reported to be resistant (Sharma and Bhati, 1985). Varieties Rajendra Kanti, RMI-1 and Lam Selection-1 have been reported to be moderately resistant/tolerant (Edison *et al.*, 1991).

5.2 Root Rot

The disease caused by *Rhizoctonia solani* is soil-borne and was first reported from Karnataka (Hiremath *et al.*, 1978). This is also known from Rajasthan (Shuka, 1978) and Gujarat (Gupta, 1980) Tamil Nadu (Vinayagamurthy *et al.*, 1985). No details of crop loss due to this disease are available. However the disease is known to be serious in Tamil Nadu. Detailed investigations on crop loss and epidemiology are lacking.

5.2.1 *Symptoms*

The fungus causes varying degrees of root rot leading to foliar yellowing in 30-45 days old plants. The affected plants wither and dry up.

5.2.2 *Disease Management*

Carbendazim (0.1%), both as seed dressing and soil drenching twice, effectively controlled the disease and increased yield (Prasad and Hiremath. 1985; Prakasam *et al.*, 1990a; Rajan *et al.*, 1990a). Soil amendment with neem cake at 1t/ha and farm yard manure was also found effective in reducing the root rot and increasing the yield (Rajan *et al.*, 1990a). Soil application of neem cake at 1500 kg/ha alone or in combination with *Trichoderma* reduced root rot and increased yield (Anon., 1993). Neem cake alone showed 3.9 and 3.2 per cent disease incidence in *kharif* and *rabi* with a yield of 427 and 385 kg/ha. In combination with *T. viridae* seed treatment and soil application, the corresponding values of disease incidence were 3.2 and 3.4 per cent with yield of 424 and 360 kg/ha. Efficacy of captan as soil mix and soil drench in checking root rot has been reported (Hiremath *et al.*, 1978). Of the 10 lines tested in IET trial the Acc-464, 113 and 2310 showed lowest disease incidence (<5%). In a CYT trial involving 14 lines HM-57 showed disease incidence of 2.1 per cent in kharif and 1.8 per cent in *rabi* during 1992 (Anon., 1993). Leaf spot caused by *Cercospora traversiana*, downy mildew caused by *Perenospora trigonella* (Uppal, 1993), damping-off caused by *Humicola fuscoatra* (Pandey *et al.*, 1907) *Thanatephorus cucumeris* (Ali and Quershi, 1979) and *Fusarium oxysporum* (Shivpuri and Bansal 1987) are some of the other minor diseases of fenugreek.

Serious disease problems have not been identified on *Ajwain* (*Trachyspermum ammi* L.) Sprague ex Turrill, soya or dill (*Antheum graveolens* L.) and Indian soya or dill (*Anthium sowa* Kurz).

6. FUTURE STRATEGIES

Considerable work on disease problems of cumin and coriander has been done. However, there is a necessity for periodical surveillance for disease incidence and estimation of precise crop losses since this information is lacking for many of the major diseases. This should be coupled with monitoring of meteorological parameters and also microclimate for a better understanding of epidemiological implications that become pre-requisites for planning cheap and efficient disease management practices.

Specially in the case of soil-borne disease like cumin and coriander wilt and root rot of fenugreek, studies on biocontrol need be intensified since agrochemicals alone will not be sufficient for disease management. Isolation and identification of antagonistic/ hyperparasitic organisms like *Trichoderma* and *Gliocladium*, etc., which are efficient in disease suppression and development of efficient delivery systems for their augmentation in the field, should be receive priority. Disease-free seed, their better storage conditions, Cultural practices like irrigation frequency, phytosanitation and crop rotation schedules that reduce the build up of pathogen populations should be evolved.

Absence of high degree of host resistance to major diseases of seed spices renders the disease management more complex. High degree of variation of the pathogen like *Fusarium* makes it imperative to intensify breeding programmes to further develop varieties with durable resistance to major diseases and pests. Seed mixtures of tolerant lines also would be ideal for disease reduction. Introducing exotic germplasm is necessary for crop improvement, specially for disease resistance.

No effort appears to have been made on the biotechnological approaches to induce host resistance. Induction of somaclonal variation through callus cultures and regeneration, using toxins of *Fusarium* and *Alternaria* for *in vitro* screening of callus and cell cultures to identify toxin insensitive calli/cells, and regeneration of plants should be given a fair trial to induce host resistance. For each crop, aim should be to develop multiple resistant types to major diseases since host resistance would be major break through for an efficient disease management. It is also desirable to further improve the existing techniques for screening the germplasm for their reaction. Thus, a multipronged approach is called for to develop cheap and efficient integrated disease management technology to check the crop losses in seed spices.

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