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Management strategies for *Phytophthora* diseases of spices

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INTRODUCTION

India is the home of spices and a sizable area is under spice crops cultivation. Spices are cultivated in an area of 5.98 million ha globally with a total production of 7.31 million tonnes (FAO, 2008). The total area under spices in India is 2.89 million ha with a total production of 3.33 million tonnes. The major spice crops cultivated in India are black pepper (*Piper nigrum* L.), cardamom (*Elettaria cardamomum* Maton.), ginger (*Zingiber officinale* Rosc.), turmeric (*Curcuma longa* L.) and vanilla (*Vanilla planifolia* Andrews). The production constraints are mainly due to diseases caused by Oomycetes such as *Phytophthora* and *Pythium* besides nematodes and viruses. Most of these diseases are of both soil and air-borne nature and occur during south-west monsoon season. Virus diseases are a recent threat to crops like black pepper, cardamom and vanilla. Strategies adopted for managing the major diseases of important spice crops are dealt here.

1. Black pepper (*Piper nigrum* L.)

Foot rot disease

Black pepper is susceptible to a number of diseases of which foot rot or quick wilt caused by the Oomycete pathogen *Phytophthora capsici* and slow decline caused by plant parasitic nematodes along with *P. capsici* are of great importance. These diseases cause huge crop loss if timely and proper plant protection measures are not adopted. On a global scale, an annual crop loss of around 4.5-7.5 million tonnes has been reported due to foot rot alone (De waard, 1979). A crop loss of 5-10 per cent has been reported from Malaysia with up to 95 per cent loss in individual black pepper gardens (Kueh and Sim, 1992). In India 9.4 per cent of vines are destroyed annually in major black pepper growing areas (Anandaraj, 2000). A crop loss of 2000 tonnes valued at ₹ 320 million was reported in Kerala due to foot rot (Sarma and Anandaraj, 1988).

Phytophthora infection occur both in nurseries as well as main fields and all the plant parts namely root, stem, leaves and spikes are susceptible. The disease breaks out coinciding with the onset of south-west monsoon and the wet weather conditions prevailing during this period highly favour spread of disease.

In nurseries, the primary infections are caused due to soil-borne inoculum. The symptoms appear on the leaves as black spots with fimbriate margins which enlarge and cause defoliation. Soil contamination results in collar as well as root infections. The root infection sometimes culminates in collar infection leading to death of the plants (Anandaraj *et al.,* 1994).

In plantations, the tender leaves and succulent shoot tips of freshly emerging runner shoots trailing on the ground turn black when infected. The disease spreads to the entire vine due to rain splash. When the main stem at the collar region is infected, the entire vine wilts followed by shedding of leaves and spikes with or without any lesion on them. The branches break up at nodes and thereafter the entire vine collapses within a month. When the damage is confined to the feeder roots the expression of the symptom is delayed till the cessation of rain and thereafter the infected vines start showing declining symptoms such as yellowing, wilting, defoliation and drying up. This may occur during October-November. These vines may recover after the rain and survive for more than two seasons till the root infection culminates in collar rot and death of the vine (Anandaraj and Sarma, 1995).

Disease management

Phytosanitation

In perennial cropping system involving black pepper and betel vine, the initially infected vines serve both as inoculum source and focus of secondary spread. Removal and destruction of dead vines along with root system from the garden is necessary to reduce the buildup of inoculum. The pathogen is soil-borne and the propagules are passively carried along with soil particles. So planting materials must be collected from disease free gardens and nurseries raised using disinfested soil.

Cultural practices

Soil moisture plays an important role in the buildup of inoculum of *Phytophthora*, besides predisposing the plant to infection. So water stagnation must be prevented at all times. Providing adequate drainage reduces the chance of multiplication of *Phytophthora*.

The live supports produce lot of foliage and contributes to low temperature and increased humidity favorable to the pathogen. Shade lopping greatly alters the micro-climate of the canopy and helps in reducing the primary disease incidence. Injury to the root system due to cultural practices such as digging should be avoided. The freshly emerging runner shoots should be pruned prior to the onset of monsoon and shade should be regulated in order to avoid build up of humidity and for better penetration of sunlight in the plantation.

Host resistance

The resistance to *P. capsici* is limited as none of the cultivars is resistant. But the seedling progenies from susceptible parents showed varying levels of resistance and the mapping population showed a modified dihybrid ratio in segregation suggesting the involvement of more than one gene. "IISR Shakti", an open pollinated seedling progeny of the cultivar "Perambramundi" was found moderately resistant to *P. capsici* (Bhai *et al*., 2007). Another seedling progeny of" IISR Shakti" is also resistant to *P. capsici* (Bhai *et al.,* 2010) and is in the process of field evaluation. Among germplasm of *Piper*, some related species *P. colubrinum* and *P. arboreum* are found resistant to both *P. capsici* and nematodes, *Radopholus similis* and *Meloidogyne incognita*. *P. colubrinum* was identified to be the most promising species for grafting with rooted stem cuttings. Grafting at 50 cm height has been reported to be ideal as the rootstock produces several adventitious roots that penetrate the ground and facilitate vigorous growth of vines. Though there were initial problems due to late incompatibility due to the presence of anomalous secondary thickening in black pepper, the modified double rootstock method recorded better success and survival. It is reported that scions with single nodes took more time for sprouting than two or three node scions. The grafted top shoots started bearing in the first year itself.

Chemical control

Being a wet weather pathogen a compact fungicide schedule that includes spraying of Bordeaux mixture (BM) (1 per cent), pasting collar with 10 per cent BM and drenching the basin with either BM or copper oxychloride is recommended (Ramachandran *et al.,* 1991). In place of copper fungicides, the use of systemic fungicide metalaxyl (0.125 per cent at 5-10 L/vine) both as spray and soil drench after the receipt of a few monsoon showers are also recommended. Application of the metalaxyl six months prior to harvest was recommended to prevent traces of metalaxyl residues in the final product

In disease prone areas, prophylactic spraying of 1 per cent BM to all the vines with the onset of south-west monsoon and drenching the plant basins at a radius of 45-50 cm with 0.2 per cent copper oxychloride at 5-8 L/vine and repeating this after about 45 days are suggested. As an alternative, first round with copper fungicides and a second time drenching and spraying with 0.3 per cent potassium phosphonate during August-September is also recommended. A third round of drenching during October is preferable to check the proliferation of the soil borne inoculum in severely disease prone areas. Potassium phosphonate is reported to move fast in black pepper plant from the site of application reaching the tip and downwards to the root system showing its ambimobile nature and leaves no residue in the soil (Anilkumar *et al*., 2006).

Biological control

Several strains of bio-control agents effective in protecting pepper against *P. capsici* have been isolated, screened and mass multiplied on inexpensive carrier media and applied in the field with promising results (Rajan *et al.,* 2002) Fluorescent pseudomonads and *Trichoderma* sp. were isolated from black pepper roots and rhizosphere soil collected from different places in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Sikkim. Studies on the rejuvenative capacity of fluorescent pseudomonads in black pepper indicated the potential of these strains for nursery management of black pepper, especially to protect the plants from *P. capsici* infection (Diby *et al.,* 2005)

In order to ensure that the antagonistic fungus *Trichoderma* proliferates in the rhizosphere of black pepper, it is recommended to apply the commercial product of *T. harzianum* around the base of the vine at 50 g/vine along with organic manure such as neem cake, farmyard manure, decomposed coffee pulp or coir pith with the onset of monsoon (May-June). A second application of *Trichoderma* is to be given during August-September. This has to be repeated for 2-3 consecutive years to check the pathogen spread.

Integrated management of nursery diseases

In black pepper planting materials are produced as rooted cuttings. Since the disease affecting the nursery occur in a short span of 3-4 months, an integrated management strategy is followed to prevent plants from infection caused by various types of pathogens. The infection may occur from contaminated soil or potting mixture besides the air borne or splash borne inoculum like *Colletotrichum* sp. or other foliar pathogens. The management strategies that can control the nursery diseases are listed below.

(a) Use of certified planting material

Use of pathogen free material is the foremost requirement for the production of disease free planting material. Good agricultural practices and phytosanitation helps to reduce nematode spread to a great extent.

(b) Disinfestation of nursery mixture

Earlier, fumigation with chemicals used to be done with methyl bromide and formalin (Ramana *et al*., 1994). This is now replaced with either solarization or steam sterilization (Sarma *et al*., 1996; Mammootty *et al*., 2007) followed by fortification with biological control agents. Incorporation of vesicular arbuscular mycorrhizae *viz*., *Glomus mossae*, *G. fasciculatum*, *Acaulospora laevis*, *Gigaspora margarita*, which are suppressive to nematodes on black pepper (Anandaraj *et al*., 1991; 1996) is recommended. A combination of VAM and other biocontrol agents like *T. harzianum* and *Pseudomonas fluorescens* is reported to give healthy robust planting material (Anandaraj and Sarma 2003; Kandiannan *et al*., 2000, Thankamani *et al*., 2005).

(c) Chemical control

As a preventive measure, black pepper planting materials can be treated with granular nematicides like phorate or carbofuran at 0.1 g a.i./plant once in two months (Mohandas and Ramana, 1987). This will ensure eradication of nematodes and production of healthy roots. After the establishment of plants in the polybags, spraying 1 per cent Bordeaux mixture or 0.2 per cent carbendazim on the aerial portion and drenching the soil with 0.2 per cent copper oxychloride or 0.125 per cent Metalaxyl–mancozeb or 0.3 per cent potassium phosphonate at monthly intervals is recommended.

2. Cardamom (*Elettaria cardamomum* Maton)

Cardamom, the "queen of spices" is the most important spice crop grown on a large scale in the Western Ghats of Kerala, Karnataka and Tamil Nadu states of India. Apart from mosaic or 'katte' disease, *Phytophthora* infection is a serious problem and is a major constraint in the successful cultivation and production of crop in India. Menon *et al.* (1972) observed widespread incidence of capsule rot in cardamom hills of Idukki district in Kerala. The disease is locally known as 'Azhukal' meaning rotting. Occurrence of the disease is noticed with the onset of south-west-monsoon, becoming severe during August-September and continues to prevail up to November, depending on rainfall conditions. Azhukal disease is frequently observed in Idukki and Wynad districts of Kerala and in isolated pockets of Anamalai hills in Tamil Nadu. Phytophthora rot has not yet been observed in plantations of Karnataka area. A crop loss of 30 per cent was estimated by Nambiar and Sarma (1976). However, during years of heavy and continuous rainfall, severe disease incidence and crop losses as high as up to 40 per cent had been reported.

Capsule rot ('Azhukal')

Disease symptoms appear on young leaves as water-soaked lesions during monsoon season. These later form patches of dead areas surrounded by yellow halo. At a later stage, leaves dry and shred along the veins. Infection of inflorescence and capsules resulting in rotting and shedding of capsules are the common symptoms noticed. Nair (1979) studied symptomatology in detail and reported similar types of symptoms on the foliage, capsules, tillers and roots. Infection starts as water soaked lesions on capsules which enlarge to cover the entire surface. Infected capsules show dull green discolouration which develop into rotting. Usually immature capsules are infected first, which shed within 3-5 days. Mature capsules when infected become shriveled on drying and the epidermis is peeled off exposing the fibrous tissues.

Infection gradually spreads from capsules to panicle and such infected panicles fail to develop to maturity but dry up. Rotten capsules are shed from the panicle emitting a foul

smell. Infection takes place on tender leaves or capsules independently. Visible symptoms of rotting appear simultaneously on capsules and leaves or first on capsules followed by lesions on leaves. Generally plants of all age groups are susceptible to Azhukal disease. However, under field conditions, natural disease incidence is noticed in plants that reached the age of bearing. In severe cases, symptoms are expressed on all plant parts in the form of rotting and shredding of leaves and such plants completely rot and perish.

Post-monsoon infection of *Phytophthora* sp. has been reported to cause leaf blight disease in cardamom during winter season. All the three major cultivars namely "Mysore", "Malabar" and "Vazhukka" are reported to be equally susceptible to Azhukal disease (Nair, 1979). However, a certain extent of tolerance is noticed in "Mysore" type cultivars while "Malabar" is more vulnerable.

Disease management

Chemical control

Early detection of the disease and timely application of adequate plant protection measures are important in managing Azhukal disease. As the incidence of disease is closely associated with monsoon rains, plant protection operation has to be initiated prior to initiation of primary infection. Thomas *et al*. (1989; 1991) evaluated a number of systemic and contact fungicides over a period of six years under field conditions and found that three rounds of spraying with one per cent Bordeaux mixture or 0.3 per cent Fosetyl Aluminium (Aliette 80 WP) could effectively control the spread of the disease. They also stressed the importance of plant sanitation operations prior to monsoon and timely spraying of fungicides. Application of fungicides after the commencement and spread of disease is not very effective in reducing disease severity. Significant disease control has been reported with three foliar sprays of either 0.3 per cent Aliette 80 WP or one per cent Bordeaux mixture concentration or spraying alternate rounds of Bordeaux mixture and metalaxyl formulations.

Biological control

The antagonistic activity of *Trichoderma* sp., *Laetisaria arvalis*, an exotic genus and *Bacillus subtilis* on *P. meadii* is well studied. It has been reported that these antagonists interacted with the pathogens causing growth inhibition and hyphal lysis (Bhai *et al*., 1993). Significant levels of field control of *P. meadii* could be achieved by soil application of *Trichoderma viride*, *T. harzianam* and *B. subtilis* in disease prone soils (Bhai *et al*., 1992). Soil amendments with neem cake is reported to reduce Azhukal incidence (Nair, 1979) by activating the growth of native *Aspergillus* sp. *Trichoderma* sp. and actinomycetes.

The more economical and frequently used method in the biological control of soil borne plant pathogens is to incorporate plant residues and organic amendments to the soil which support high level of microbial activity. Farm yard manure, poultry manure, coffee husk and neem cake were used as soil amendments with and without *Trichoderma* sp. to evaluate their efficacy in controlling *P. meadii* under *in vitro* conditions and found that neem cake was a suitable soil amendment for enhancing the population level of *Trichoderma* as well as reducing the buildup of *P. meadii* population. Poultry manure will also be as efficient as FYM, while the crop residue such as coffee husk or neem cake enhances other saprophytic fungi like *Penicillium* sp., *Rhizopus* sp., *Aspergillus* sp., *Mucor* sp. *etc*.

Disease resistance

As all types of cultivars are susceptible to *P. meadii*, identification of resistant/tolerant lines is of high priority. Among the 123 accessions evaluated, two cultivars each of "Mysore" and "Malabar" types were found moderately tolerant to Azhukal disease (Bhai *et al*., 1990).

In an approach towards integrated management of capsule rot it was found that application of Bordeaux mixture and copper oxychloride alone or in combination with *Trichodema* sp. reduced the disease potential index of the soil. Efficient and economical control was achieved when fungicides were applied as initial rounds followed by subsequent treatment with *Trichoderma sp*.

3. Vanilla (*Vanilla planifolia* Andrews)

Vanilla (*Vanilla planifolia* Andrews syn. *V. fragrans*), a native to the humid tropical rainforests, is widely cultivated in India for its aromatic vanillin. It is grown as an intercrop along with arecanut, coconut, coffee and black pepper, in homestead gardens and as a main crop supported on standards such as glyricidia, plumeria, dadaps and concrete or stone poles. During initial years of cultivation diseases were not common. But as the extent of area under cultivation increased, the crop became susceptible to a number of diseases of which that caused by *Phytophthora* sp. resulted in total destruction of vines.

The vanilla crop is highly susceptible to the changing climatic conditions that lead to a number of diseases. Close planting, excess shade, intensive crop management with manures, frequent irrigation and lack of phytosanitory measures are the factors that predispose the plant to infection by Oomycetes.

The pathogens affect almost all the plant parts of vanilla like roots, stem, leaves and beans and occasionally inflorescence also. Fungal infections often lead to rotting of affected parts or wilting of the entire vine. Fungal species belonging to the general *Phytophthora, Fusarium, Sclerotium, Calospora, Colletotrichum and Cylindrocladium* are the main pathogens that cause serious damage to the crop.

Vanilla diseases have been reported as early as in 1953 from various countries such as Brazil, Columbia, Java, Mauritius, Puerto Rico, Republic of Malagasy, Sri Lanka and Tahiti. In India vanilla is grown largely in Karnataka, Kerala and Tamil Nadu. Among the fungal diseases, infections caused by *P. meadii* (Bhai and Thomas, 2000) as well as stem and root infection by *Fusarium oxysporum* and *F.* sp. *vanillae* are very destructive.

***Phytophthora* bean rot**

Extensive cultivation and intensive production technology paved the way for heavy disease incidences that lead to the destruction of the crop. In India, the disease was noticed in many vanilla plantations in Karnataka and Kerala. Disease appears during the onset of south-west monsoon rains.

The symptom of the disease mainly appears as rotting of beans. Rotting usually begins from the bean tips and extends to the stalk. Rotting starts on individual beans or among all beans in a bunch. In some cases rotting starts from the pedicel region and progresses towards to the tip. The infected portions of the beans are water soaked, soft and dark brown. In moist weather, the affected beans are shed from the vines but in dry weather the rotten beans are shriveled and may remain attached to the bunch. Small dull white pinhead like pustules are seen on the surface of the infected beans during this stage. Fully infected bunches fall off in 10 to 15 days emitting a foul smell. In advanced stages of infection, the rotting extends to the stem and leaves also (Bhai and Thomas, 2000).

The disease is caused by *P. meadii*. The pathogen was isolated from affected beans, stems, leaves and aerial roots. Cornell (1953) reported a similar type of fruit rot disease of vanilla caused by *P. parasitica* Dast. Blight or mildew attack in developing fruits of vanilla caused by *P. jatrophae* Jens. was reported by Bouriquest (1954) from Malagasy Republic. Excess shade in the plantations, continuous and heavy rains, overcrowding of vines, water logged conditions and presence of *Phytophthora* sp. as source of inoculum in the field predisposes the plants to infection.

Disease Management

Phytosanitation

The disease can be managed by adopting phytosanitary measures such as (1) removal and destruction of infected plant parts to reduce the inoculum build up; (2) lopping of shade tree branches during monsoon season in order to prevent excess shade (to allow at least 30-50 per cent light to fall on the vines).

Chemical control

Spraying the foliage with 1 per cent Bordeaux mixture and drenching the base of the plant with 0.25 per cent copper oxychloride twice depending on the severity of infection and as prophylactic measure are practiced.

Biological control

Rhizobacterial isolates, *P. fluorescens* (five isolates), *Enterobacter agglomerans* (one isolate) and *Bacillus* spp. (14 isolates), were screened against pathogens of vanilla including *P. meadii*. All the isolates tested except *Bacillus polymixa* (isolate IISR909) and one *Bacillus* sp. (isolate IISR915) were inhibitory to *P. meadii* (Bhai and Kumar 2008). Vijayan *et al*. (2009) found that basal application of *Trichoderma* along with foliar spray with *Pseudomonas* sp. were effective in reducing the diseases caused by *P. meadii and F. oxysporum.*

SUMMARY

In perennial cropping systems integrated management strategy along with rigorous phytosanitation is crucial in reducing the initial inoculum of *Phytophthora* sp. and preventing its secondary spread. Soil health management has to be undertaken to maintain the pH and organic carbon at optimum levels so that sustained availability of nutrition is assured and the survival of biological control agents such as *Trichoderma* and *Pseudomonas* is ensured. Since major diseases are soil borne and often inadvertently carried from the nursery to main field, introduction of pathogen through the planting material has to be avoided by using disease free planting material.

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