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Diversity of *Phytophthora* species infecting spice crops

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Spices are of considerable importance to India and one or other spice crops is grown in almost all the states and union territories. There are 52 spices and among them the major share is occupied by black pepper and cardamom followed by chillies, ginger, turmeric, tree spices (nutmeg, clove, cinnamon), saffron, vanilla and seed spices (coriander, cumin, fennel, fenugreek etc.). The main production constraint of these crops is the diseases caused by plant pathogenic oomycetes, fungi, bacteria, viruses and phytoplasmas. Among them the disease caused by *Phytophthora* sp. are more destructive and of great economic importance.

Black pepper belongs to the family *Piperaceae* and is susceptible to the most damaging disease called foot rot (quick wilt) caused by *Phytophthora capsici*. Severe incidence of vine death was reported in the beginning of the nineteenth century and the causal organism was identified as *P. capsici, 'P. palmivora'* MF_4 (morphological form 4) which exhibits different degrees of morphological variation.

Foot rot of black pepper is a major problem in Vietnam. Nguyen *et al.* (2010) collected a large number of *P. capsici* isolates from black pepper and studied mating type, random amplified microsatellites (RAMS) and repetitive extragenic palindromic (REP) fingerprinting. They identified the two mating types A1 and A2 in four provinces in two climatic regions, with A1:A2 ratios ranging from 1:3 to 1:5. They also observed the co-existing of A1 and A2 mating types in the same farm suggesting the potential for sexual reproduction. RAMS and REP DNA fingerprinting analysis showed that the population was genetically diverse. The low diversity suggests that the *P. capsici* population may have originated from a single source. There was no genetic differentiation of isolates from different climatic regions. In addition to the large clonal group, they observed several isolates with unique RAMS/REP phenotypes and most of these unique phenotypes belonged to the A1 mating type. A comparative morphological and cultural study of 100 isolates of *P. capsici* revealed that the isolates fall into two taxa *viz.* *P. capsici* and *P. tropicalis*.

In betel vine (*Piper betle* L.) belonging to the same family of piperaceae, foot rot is caused by species of *Phytophthora viz.*, *P. parasitica* var. *piperina, P. nicotianae* var. *parasitica. P. capsici, P. nicotianae* var. *piperina, P. parasitica* and *P. palmivora.* Leaf rot is another problem reported to be caused by *P. parasitica* and *P. palmivora* (Dasgupta *et al.*, 2008). The disease has been reported from almost all betel vine growing countries in the world like Indonesia, Myanmar, Sri Lanka and Bangladesh. Dastur (1926) was the first to report *P. parasitica* infection on betel vine from India. Infection by *Phytophthora* sp. on stem portion of *P. betle* in Ceylon was reported as early as in 1928.

In India, the disease has been reported from all the betel vine growing areas. There was considerable confusion regarding the nomenclature of the species of betel vine *Phytophthora.* Mc-Rae (1928) established the parasitism of *Phytophthora* species. Later Mc Rae (1934) based on morphological characters identified *P. nicotianae* var. *parasitica*. Turner (1969) referred all isolates of *Phytophthora* from Southeast Asia as '*palmivora*' type. This was stated to be true for the Indian isolates as reported by Maiti and Sen (1977) as *P. parasitica* and *P. palmivora.* Based on existing keys to *Phytophthora* sp. all the isolates from Assam were identified as *P. palmivora* (Butl.) Butl. However, ITS sequencing of *Phytophthora* isolates from betel vine and many other crops such as brinjal, guava roselle, black pepper, sesame, taro, chilli, pointed gourd and papaya

(Roy *et al*., 2009) revealed that both *P. nicotianae* and *P. capsici* are present in betel vine but not *P. palmivora.*

Capsicum and chillies (*Capsicum* sp.), belongs to the family *Solanaceae* along with other *Phytophthora* prone crops like tobacco, potato, tomato and chillies. Out of 34 different diseases reported on chillies (Black *et al.*, 1991), the root and collar rot caused by *P. capsici* is of great importance globally (Sherf and Macnab, 1986; Stamps, 1985). *P. capsici* is also well established in Punjab and causes root and collar rot epidemic each year in the main chilli growing areas (Saleem *et al*., 1989). In chillies and capsicum foot rot symptoms are produced by *P. parasitica* var. *piperina* and *P. nicotianae* var. *parasitica* whereas the leaf blight is caused by *P. parasitica* and *P. palmivora.* Root rot and *Phytophthora* blight due to *P. capsici* occurs in almost all chilly growing areas. But in Peru, the disease is caused by *P. citrophthora.*

The family Zingiberaceae includes 47 genera of which the most important spice crops are Cardamom (*Elettaria cardamomum* Maton), ginger (*Zingiber officinale* Rosc) and turmeric (*Curcuma longa*). In cardamom, capsule rot (Azhukal) caused by *P. meadii* is a serious soil borne disease causing severe damage in almost all the cardamom growing tracts of the high ranges of Kerala. The disease was earlier reported from Idukki district of Kerala as caused by *Phytophthora* species *viz*. *P. palmivora* and *P. meadii*. Later another disease called leaf blight due to *Phytophthora* was also identified. This disease appears during the post monsoon period from November to February. Studies on the etiology of the disease clearly confirmed that two species of *Phytophthora viz. P. meadii* and *P. nicotianae* var. *nicotianae* are involved in initiating capsule rot occurring during the monsoon season and A_2 mating type of *P. meadii* being the predominant pathogen. Foliar infection by the same pathogen was also noticed during the season. The leaf blight is due to *P. nicotianae* var. *nicotianae.* However, there is certain amount of overlapping of these in initiating the disease in cardamom.

Though ginger and turmeric are prone to infection by *Pythium* species, no *Phytophthora* infection is reported.

The genus *Cinnamomum*, belonging to the family Lauraceae is highly prone to infection by *Phytophthora* sp. The most important disease of cinnamon is stripe canker caused by *P. cinnamomi*, which causes severe damage to forest trees. Rands (1922) first reported *P. cinnamomi* as causal agent of stripe canker of *C. verum*. This disease is reported to be severe in poorly drained soils and causes up to 42 per cent damage. The pathogen was reported from other species of cinnamon *viz. C. camphora*, *C. culitlawan* and *C. sintok* (Rands, 1922; Ciferri and Fragoso, 1927). *P. cinnamomi*, from pineapple is also pathogenic to cinnamon, but with reduced virulence. Stripe canker is found on the trunks and branches, particularly of young trees of *C. verum* and *C. baumannii* in Indonesia. Vertical stripes are seen on the stems with amber colour exudates that harden later at the advancing margins. Vertical stripes of dead bark are most numerous near ground level.

The genus Laurus of the family *Lauraceae* has two members *Lnobilis* known as bay laurel and *L. azorica.* Both the species are susceptible to the most damaging root rot caused by *P. cinnamomi* which can damage plants at all growth stages. The symptoms in young plants are general yellowing and wilting leading to death of the plant. On more mature plants leaves turn yellow and fall and twigs may show die back symptoms, while a severe infection causes general defoliation and death.

Nutmeg (*Myristica fragrans*) of family Myristicaceae is one of the major tree spices. It is cultivated as an intercrop in coconut and arecanut gardens. The plant is susceptible to a number of diseases of which fruit rot (fruit drop) caused by *Phytophthora* species is a severe problem. The disease appears during the monsoon season when there is heavy and continuous rain fall. Symptoms are expressed only on half matured or unripe fruits which later turn brown in colour followed by premature splitting of the pericarp and rotting of the mace and seed. The infection on the fruit stalk results in dropping of the fruit.

In clove (*Syzygium aromaticum* L.) of family *Myrtaceae*, *Phytophthora* is also reported to be associated with Sumatra disease besides species of *Endothia* and *Phymatotrichum*. Another seedling wilt caused by *Phytophthora* species along with *Colletotrichum*, *Fusarium* and *Rhizoctonia bataticola* is also reported.

The seed spice fennel (*Foeniculum vulgare*) is reported to be affected by brown rot and wilt caused by *P. megasperma* in Italy. Another leaf blight caused by *P. syringae is also reported.* Disease can appear on leaves at any time during their development. Damping off of coriander is also reported to be caused by species of *Pythium* and *Phytophthora.* In Parsley (*Petroselinum crispum*) root and crown rot caused by *P. primulae* is the most common pathogen.

The *Phytophthora* rot of crucifers *viz. Brassica oleracea* is due *to P. megasperma var. sojae*. The symptom of the disease is manifested by the withering of the foliage followed by collapse and death of the plants. All leaves of the infected plants droop down and drop finally leaving the stump bare. *Phytophthora* sp. also cause damping off and foot rot besides *Pythium* and *Thanetophorus* sp. The degree of damage caused by a particular pathogen varies regionally The main symptoms are dark brown or black rot on the stem base of seedlings, sometimes causing a constriction of the stem.

Vanilla is also not an exception to *Phytophthora* infection. Bean rot is a severe disease in vanilla incited by *P. meadii* Mc Rae. It has also been isolated from infected leaves, stem and roots. In India the disease was noticed in many vanilla plantations of Karnataka and Kerala. The disease appears during the onset of south west monsoon rains causing rotting of beans beginning from the bean tips and extending to the stalk and then to all the beans in a bunch. The fully infected bunch falls off in 10-15 days emitting a foul smell. In advanced stages of infection, the rotting extends to the stem and leaves also (Bhai and Thomas, 2000). The pathogen could be 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. The disease was also reported from other vanilla growing regions of the world *viz.* Tahiti, Morrea, Tahaa, Raiatea, Huahine in French Polynesia and Puerto Rico. Occasionally, species of *Phytophthora* was also found associated with shoot tip rot and die back disease. Stem blight caused by *P. palmivora*, *P. capsici*, and *P. parasitica* was earlier reported from French Polynesia.

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