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Survival and host range of *Phytophthora capsici* Leon under Karnataka conditions

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ABSTRACT: *Phytophthora capsici* Leonian is a destructive pathogen of sweet pepper worldwide. In this study, survival and host range of *P. capsici* under Karnataka conditions was studied. Slender amaranth (*Amaranthus viridis*), black nightshade (*Solanum nigrum*) and spurge (*Euphorbia geniculata*) were found as weed hosts for the pathogen. The pathogen was infective on fruits and leaves of watermelon, cucumber, gherkin, squash, pumpkin, ridge gourd, round melon, snake gourd and sponge gourd. On bottle gourd, it was infective on fruits while non infective on leaves and root. Bitter gourd and ash gourd were not hosts without any foliar, fruit and root infection. Among solanaceous crops, tomato, chilli and potato leaves, fruits and root were infected. On brinjal, only fruit infection was recorded. The isolate was weakly pathogenic on cruciferous vegetables cabbage and cauliflower with only leaf infection. None of the leguminous vegetable tested showed root infection. Leaf and pod infection was observed on French bean and cowpea. On malvaceous vegetable crop okra, only fruit infection was recorded. In Piperaceae crops, only leaf infection was observed on black pepper and betel vine. Eight millets tested were found non-hosts for the Kadur isolate of *P. capsici*. The pathogen survived up to 90 days when infected fruit was buried in soil irrespective of three soil textures; sandy loam, sandy clay and sandy clay loam.The information on survival and host range generated would help in developing disease management strategy against *P. capsici* in Karnataka.

Keywords: *Phytophthora capsici*, soil survival, host range, Karnataka

INTRODUCTION

Phytophthora blight incited by *P. capsici* Leon is the most devastating field diseases of sweet peppers worldwide. *P. capsici* is an oomycete pathogen of vegetable crops worldwide, causing crop losses exceeding 50% (Sanogo and Ji, 2012). The pathogen has reportedly caused severe epidemics in Central and South America, Europe, Asia, and United States where susceptible vegetables are grown (Granke *et al*., 2012a). Globally the disease and pathogen is widely distributed and has been reported in all the major pepper production areas (CABI, 2022).

Phytophthora blight has been reported to be destructive disease causing marketable yield loss in hot and sweet pepper (*C. annuum* L) in India. In India, the disease is of economic interest on sweet pepper in Himachal Pradesh, Karnataka and Tamil Nadu (Sharma and Bhardwaj, 1976; Chaudhary and Banyal, 2013b; Chowdappa *et al*., 2014; Singh, 2015).

P. capsici is reported as a broad host pathogen infecting cultivated crops, ornamentals and native plants belonging to more than 15 plant families (Satour and Butler, 1967; Erwin and Ribeiro, 1996; Hausbeck and Lamour, 2004; Tian and Babadoost, 2004; French-Monar *et al*., 2006; Granke *et al*., 2012). In India, this pathogen has been reported on plantation crops, black pepper (Sharma and Anandaraj, 1997), cocoa (Chowdappa *et al*., 1993) and betel vine (Kumar *et al*., 2004), however there are no reports on pathogen city on different cultivated and weed hosts existing in sweet pepper agro ecosystem. This information is required as sound disease management strategies rely on knowledge of pathogen host range.

Review of research done in India on *P. capsici* points out to gaps in knowledge on survival and host range. Keeping in view the above knowledge and technology gaps, the present study was undertaken with an objective to determine the survival and experimental host range of *P. capsici* Kadur isolate.

MATERIALS AND METHODS

Source and maintenance of culture

A highly virulent, previously characterized isolate of *Phytophthora capsici* Leon (GenBank accession number MZ474494) maintained in fungal pathology laboratory was used in this work (Kumar G. M. S, 2022). The pathogen was isolated from infected fruit of sweet pepper sourced from Kadur region of Karnataka. Working culture of the isolate was maintained by periodical

culture on carrot agar medium with incubation at 25±2 ºC in dark for three to five days. For long term storage, agar plugs removed from the colony margin were placed in sterile water in 1.5 ml screw capped bottles and stored at room temperature in dark conditions. Virulence and aggressiveness of the isolate was maintained by inoculation and re isolation from sweet pepper fruits at regular intervals.

Survival of *P. capsici* in different soils

An experiment was conducted to study the survival of *P. capsici* in three soils of different textures in pots under glass house conditions. Soil samples for this study were obtained from different sweet pepper growing areas in Karnataka (Table 1). Three representative soil samples from Belgaum, Haveri and Bengaluru were selected based on soil colour (black soil, red soil and loamy soil) and texture by feel method.

Soil texture was determined by mechanical analysis using the international pipette method (Piper, 1966) at the soil testing laboratory of ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Regional centre, Bengaluru. After computing the relative percentage of different size groups namely clay, silt and sand, the textural class of the soils was determined using the triangular textural diagram given by the USDA.

Table 1. Source of soils used in the study

Sl. No.	Sample code	GPS coordinates	Place
	Haveri	14º36¹36.55''N 75 º 28¹01.32''E	Kollapur village, Byadagi taluk, Haveri district, Karnataka
	Belgaum	15º61¹01.75''N 74 º 63¹72.13''E	KadatanBagewadi village, Khanapur taluk, Belgaum district, Karnataka
	Bengaluru	13º08¹10.43''N 77 º 29¹53.79''E	Sixth block of Hesaraghatta farm of ICAR- IIHR, Bengaluru, Karnataka

The pathogen survival was studied in sterile soil at a moisture regime of 100% water holding capacity. One hundred gram of infected fruit with mycelium and sporangia was buried in soil as inoculum. Soil was sterilized before inoculation. Soil moisture was maintained at 100% WHC throughout the study period. The survival of the pathogen was assessed at monthly intervals up to six months by baiting with sweet pepper seedlings. The survival was confirmed by isolation of the pathogen from infected seedlings and morphological observations (Larkin *et al*., 1995).

Host range of *P. capsici*

In this study, the experimental host range of *P. capsici* Kadur isolate was determined by pathogenicity test on 8 weed plants and 36 crops commonly found in sweet pepper agro- ecosystem. The tested weeds are known to occur commonly in sweet pepper fields in Karnataka region of India. The crops tested are cultivated in rotation after sweet pepper crop / widely cultivated in fields adjacent to sweet pepper fields in Karnataka. Plants of 3-5 leaf stage were inoculated with zoospore suspension to test for root rot symptoms (Bosland and Lindsey, 1991). Pathogenicity on detached leaves and fruits were also tested by placing five mm diameter mycelia plug (Foster and Hausbeck, 2010; Chowdappa *et al.,* 2014).

RESULTS AND DISCUSSION

Survival of *P. capsici* in soil

The results of soil texture analysis of three representative soils used in the pathogen survival study are presented in the Table 2.

The results revealed that the three soils were of different texture with varied percentage of sand, clay and silt content. Soil from Belgaum belonged to sandy clay textural class with 45.86% sand, 35.40% clay and 18.74% silt. The texture of soil from Haveri was sandy loam with 68.96% sand, 19.50% clay and 11.54% silt. Bengaluru soil belonged to sandy clay loam texture with

Table 2.Texture of soils used in soil survival study*

Sample Code	Very course sand	Coarse Sand	Medium sand	Fine sand	Very fine sand	Sand	Clay	Silt	Coarse silt	Fine silt	Texture
Haveri	20.04	15.31	13.16	13.57	6.89	68.96	19.50	11.54	5.04	6.50	Sandy loam
Belgaum	5.84	9.13	10.51	13.16	7.22	45.86	35.40	18.74	7.75	10.99	Sandy clay
Bengaluru	7.47	15.47	14.42	11.68	7.26	56.32	26.63	17.05	6.76	10.29	Sandy clayloam

* All values are in %

Table 3. Survival of *P. capsici* in infected fruit tissue buried in soil of different textures

Soil texture	Duration (months)					
	1	2	3	4	5	6
Sandy loam	+	+	+	-	-	-
Sandy clay	+	+	+	-	-	-
Sandy clay loam	+	+	+	-	-	-

+ Detection, - No detection of *P. capsici* Kadur isolate with sweet pepper seedling baiting based on the re-isolation.

56.32% sand, 26.63% clay and 17.05% silt. Among the three soils, Haveri soil was moderately coarse textured whereas Belgaum and Bengaluru soils were moderately fine textured soils.

An experiment was conducted to study the survival of *P. capsici* in three different soils types. The result of the survival of *P. capsici* buried in soil is presented in the Table 3. In the current investigation, the pathogen was detected by baiting up to three months in all the three different textured soils assessed. The pathogen was not detected after third month irrespective of soil type.

The findings of present study are consistent with the observation of previous workers on soil survival of *P. capsici* in crop residue. It is reported that many *Phytophthora* species do not survive for extended period without their host. Mycelia, sporangia and zoospores of most *Phytophthora* species survive for few weeks (Ansani and Matsuoka, 1983; Schlub, 1983; Erwin

and Riberio, 1996; Roberts *et al*., 2005). Ansani and Matsuoka (1983) have reported that the mycelium of *P. capsici* survived less than 120 days in infected root tissue burried in soil, while zoospores and sporangia survived for fewer than 75 days. In a study by Roberts *et al*. (2005), sporangia, zoospores and mycelia of *P. capsici* were found to survive for 57 days in Florida at 30 °C and 100% soil moisture-holding capacity when buried inside soil. Contrary to these works, Schlub (1983) could not isolate *P. capsici* from inoculated leaf tissue two days after being placed on the soil surface in a field, but was easily isolated after 14 days if buried.

Oospores play an important role in the disease cycle of *P. capsici* as overwintering dormant spores. They are dormant in soil and plant tissue. Oospores survive in soil from few months up to several years in different types of soils (Turkensteen *et al.*, 2000; French-Monar *et al*., 2007; Babadoost and Pavon, 2013). In the present study, mycelial and sporangial survival on infected fruit tissue buried in soil was investigated. No work on oospore survival was carried out as the Kadur isolate used in the current study was heterothallic and was not able to produce oospore in the culture medium when paired with other available isolates on carrot agar medium. Pairing work indicated that the isolates tested belonged to one mating type, either A1 or A2. Further, reference tester isolates of known mating type was not available to induce oospore production. *P. capsici* of hot and sweet pepper isolates in Karnataka were reported to be of A1 mating type (Chowdappa *et al.*, 2014).

It can be concluded from the present findings that the pathogen survives for few months when buried in soil as infected fruit with mycelium and sporangia. Mechanical collection and destruction of crop residue or infected plant part has to be carried out as a good practice to prevent burial and soil survival of inoculum. Residue management should be recognized as a component in integrated management programme against *Phytophthora* blight of sweet pepper.

P. capsici host range

Weeds and native plants should be considered when endeavoring to manage and control plant pathogens of cultivated plants. Whether as a pest itself, vector of a pathogen, or reservoir of a pathogen or its vector, weeds could significantly influence disease incidence. The relationship between these factors plays a critical role in determining disease incidence and impact (Wisler and Norris, 2005). In this study, pathogenicity experiments were conducted to examine experimental host range of Kadur isolate of *P. capsici*. Pathogenicity of Kadur isolate was tested on eight weed hosts known to occur commonly in sweet pepper agroecosystem in Karnataka (Table 4).

Out of eight weeds tested (Table 4), slender amaranth (*Amaranthus viridis* L.), spurge (*Euphorbia geniculata* Ortega) and black nightshade (*Solanum nigrum* L.) were found as weed host for Kadur isolate of *P. capsici*. The isolate was infective on leaves of spurge, slender

Table 4. Pathogenicity on common weeds found in sweet pepper ecosystem

Common Name	Scientific Name	Pathogenicity	
		Leaf	Root
Slender amaranth	*Amaranthus viridis* L.	+	-
Lantana	*Lantana camara* L.	-	-
Spurge	*Euphorbia geniculata* Ortega	+	-
Congress grass	*Parthenium hysterophorus* L.	-	-
Black nightshade	*Solanum nigrum* L.	+	+
Goat weed	*Ageratum conyzoides* L.	-	-
Balloon vine	*Cardiospermum halicacabum*L.	-	-
Madras pea pumpkin	*Cucumis maderaspatanus* L.	-	-

amaranth and black nightshade. Root infection was observed only in black nightshade plant. Congress grass (*Parthenium hysterophorus* L.), lantana (*Lantana camara* L.), goat weed (*Ageratum conyzoides* L.), balloon vine (*Cardiospermum halicacabum* L.) and Madras pea pumpkin (*Cucumis maderaspatanus* L.) were not found to be host for this isolate of *P. capsici*.

In previous host range and characterization studies, black nightshade (*Solanum nigrum*) is reported as a weed host of *P. capsici* (Tamietti and Valentino, 2001; Tian and Babadoost, 2004; French-Monar *et al*., 2006). In literature other weeds that are reported to harbor *P. capsici* includes; common Carolina geranium (*Geranium carolinianum*), American black nightshade (*Solanum americanum*) and common purslane (*Portulaca oleracea*) (Ploetz and Haynes, 2000; Ploetz *et al*., 2002). In addition, slender amaranth (*Amaranthus viridis* L.) and spurge (*Euphorbia geniculata* Ortega) were found host for *P. capsici* in this study. These two weeds have not been previously reported as host of *P. capsici*.

The results of the present study validate that weeds can act as alternative host of *P. capsici* and contribute to its survival. Weeds as alternative hosts have epidemiological implications. In, sweet pepper growing regions of South India, oospores production of *P. capsici* in natural fields was not reported. This is due to non-existence of opposite mating types in the same field or geography. In the absence of oospore production, the pathogen has to over winter as mycelia, sporangia and zoospore propagules in infected plant debris buried in soil. However this survival is also for short duration. The identified weeds have the potential of serving as additional type of pathogen survival during offseason in addition to other survival strategies. Weed hosts and crop hosts should be considered when developing disease management strategy against *P. capsici*. Weed control should form essential component of *P. capsici* management strategy.

Strategies to manage plant disease from use of resistant varieties to crop rotation, elimination of reservoirs, landscape planning, surveillance, quarantine, risk modeling, and anticipation of disease emergences all rely on knowledge of pathogen host range (Morris and Moury, 2019). In this current study, pathogenicity of *P. capsici* Kadur isolate was tested on 36 crops commonly cultivated in sweet pepper agroecosystem in Karnataka. The results are presented in the Table 5.

The differential pathogenic response was observed in cucurbitaceous crops tested as experimental hosts (Table 5). The pathogen was infective on fruits and leaves of watermelon, cucumber, gherkin, squash, pumpkin, ridge gourd, round melon, snake gourd and sponge gourd. On

Table 5. Pathogenicity of *P. capsici* (Kadur isolate) on crops commonly cultivated in sweet pepper agroecosystem

Crop	Genotype	Scientific Name	Pathogenicity		
			Leaf	Fruit	Root
Leguminous vegetables					
Garden pea	Arka Karthik	*Pisum sativum* var. *hortense*Neilr.	-	-	-
Yard long bean	Arka Mangala	*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.	-	-	-
Cow pea	Arka Samrudhi	*Vigna unguiculata* (L.) Walp.	+	+	-
French bean	Arka Sharath	*Phaseolus vulgaris* L.	+	+	-
Velvet beans	Arka Shubra	*Mucuna pruriens* (L.) DC.	-	-	-
Solanaceous vegetables					
Tomato	NS501	*Solanum lycopersicum* L.	+	+	+
Chilli	Arka Lohith	*Capsicum annum* L.	+	+	+
Brinjal	Arka Anand	*Solanum melongena* L.	-	+	-
Potato	Kufri Jyoti	*Solanum tuberosum* L.	+	+	+

Cucurbitaceous vegetables						
	Cucumber	NS 404	*Cucumis sativus* L.	+	+	-
	Gherkin	Chandini RZF1	*Cucumis sativus* L.	+	+	-
	Bottle gourd	Arka Bahar	*Lagenaria siceraria* (Molina) Standl.	-	+	-
	Ash gourd	Local	*Benincasa hispida* (Thunb.) Cogn.	-	-	-
	Ridge gourd	Arka prasan	*Luffa acutangula* (L.) Roxb	+	+	-
	Sponge gourd	Local	*Luffa aegyptiaca* Mill.	+	+	-
	Snake gourd	Local	*Trichosanthescucumerina* L.	+	+	-
	Bittergourd	Arka Harit	*Momordica charanita* L.	-	-	-
	Pumpkin	Arka Suryamukhi	*Cucurbita moschata* Duchesne	+	+	-
	Squash	SQ-14	*Cucurbita pepo* L.	+	+	+
	Watermelon	Arka Muthu	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	+	+	+
	Musk melon	Arka Siri	*Cucumis melo* L.	-	-	-
	Round melon	Arka Tinda	*Praecitrullusfistulosus* (Stocks) Pangalo	+	+	-
Malvaceous vegetable						
	Okra	Arka Nikita	*Abelmoschus esculentus* (L.) Moench	-	+	-
Cruciferous vegetables						
	Cauliflower	White Wonder	*Brassica oleracea* var. *botrytis* L.	+		-
	Cabbage	Golden Acre	*Brassica oleracea* var. *capitata* L.	+		-
Piperaceae						
	Black pepper	Panniyur 1	*Piper nigrum* L.	+	-	-
	Betel vine	Mitha Paan	*Piper betle* L.	+	-	-
Millets						
	Foxtail millet	SiA 3156	*Setariaitalica*(L.) P.Beauv.	-	-	-
	Little millet	DHLM 36-3	*Panicum sumatrense* Roth ex Roem. & Schult.	-	-	-
	Finger millet	CFMV 1	*Eleusine coracana* (L.) Gaertn.	-	-	-
	Proso millet	TNAU 202	*Panicum miliaceum* L.	-	-	-
	Barnyard millet	DHBM 93-2	*Echinochloafrumentacea* (ROXB.) LINK	-	-	-

Kodo millet	RK 390-25	*Paspalum scrobiculatum* L.	-	-	-
Pearl millet	HHB67 Improved	*Pennisetum glaucum* (L.) R.Br.	-	-	-
Sorghum	CSV27	*Sorghum bicolor* (L.) Moench	-	-	-
Maize	Local	*Zea mays* L.	-	-	-

+ = Infective, - = Non infective

bottle gourd it was infective on fruits while non infective on leaves and root. Bitter gourd and ash gourd were not hosts without any foliar, fruit and root infection. Among 13 cucurbitaceous hosts tested, only watermelon and squash took root infection.

Among solanaceous crops tested, the isolate was pathogenic on tomato, chilli and potato with infection on leaves, fruits and root. On brinjal, it was not infective on leaves and root but infective on fruits. The isolate was weakly pathogenic on cruciferous vegetables cabbage and cauliflower where only leaf infection was observed. None of the leguminous vegetables tested showed root infection. Leaf and pod infection was observed on French bean and cowpea. On malvaceous vegetable crop okra, only fruit infection was recorded. In piperaceae crops, black pepper and betel vine, only leaf infection was observed. All the eight millets tested were found non-hosts for the Kadur isolate of *P. capsici*.

In other parts of the world, *P. capsici* is reported as a broad host range pathogen infecting cultivated crops, ornamentals and native plants belonging to more than 15 families with major threat to cultivated crop plant families cucurbitaceae, fabaceae and solanaceae (Satour and Butler, 1967; Erwin and Ribeiro, 1996; Hausbeck and Lamour, 2004; Tian and Babadoost, 2004; French-Monar *et al*., 2006; Granke *et al*., 2012b). In India, other than sweet pepper and hot pepper, black pepper, cocoa, betel vine and coconut are reported as cultivated hosts of *P. capsici* (Anandaraj *et al*., 1989; Chowdappa *et al*., 1993; Kumar and Kumar, 2004; Jonathan *et al*., 2006; Prathibha, *et al*., 2018).

Survival of plant pathogen inoculums determines the nature of disease initiation, dispersion and epiphytotics development. Knowledge on survival of plant pathogen on host and soil is required to break infection chain by devising suitable management interventions that reduce the source of inoculum and subsequent disease development. *Phytophthora* blight in sweet pepper is an emerging disease in India. The information on experimental host range generated in this study will help in risk analysis of further range expansion of this pathogen in the country. Crop sequence patterns should take in to account this host range information so as to reduce pathogen survival and perpetuation. Inter-cropping, mixed-cropping and sequence cropping of sweet pepper with solanaceous, cucurbitaceous, cruciferous and leguminous vegetables should be avoided. Cropping sequence with non-host crops like millets has to be practiced in areas where the disease is reported to be widely prevalent.

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