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Interaction of Pathogens Associated with Rhizome Rot Complex Disease in Ginger

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A B S T R A C T

India is renowned throughout the world as "spice bowl" due to production and export of spices. Ginger is an economically important cash crop grown for its aromatic underground rhizomes. Rhizome rot or soft rot is the most destructive diseases of ginger worldwide. The pathogen associated with rhizome rot complex disease of ginger in Karnataka includes *Pythium aphanidermatum* (causes soft rot), *Ralstonia solanacearum* (bacterial wilt), *Fusarium solani* (yellows), *Sclerotium rolfsii* (*Sclerotium* rot) and *Meloidogyne arenaria* (root knot). In the interaction study, *R. solanacearum* took 16 days to express the symptoms in individual inoculation with highest rot incidence (55.56 %). In case of *P. aphanidermatum*, the symptoms were expressed within 19 days after inoculation with 43.55 per cent disease incidence. The symptoms were seen within 10 DAI with all pathogens (P + F + R + S + M). In sequential inoculation of *M. arenaria* followed by *R. solanacearum* after 15 days, recorded maximum incidence of disease (91.67 %). The disease was expressed in 21 DAI of pathogens.

Introduction

India is renowned throughout the world as "spice bowl" due to production and export of spices. The spices contribute 1.24 per cent to total export and 8.50 per cent to agriculture export (Karthick *et al.*, 2015). The major spices crops include black pepper, chilli, cardamom, coriander, ginger, turmeric *etc.* Among them ginger is important one. Ginger is botanically known as *Zingiber officinale*, belongs to family Zingiberaceae. It's an economically important cash crop grown for its aromatic underground rhizomes, which is used as a both spice and medicine purpose. Spicy aroma in ginger is due to the presence of principle component ketones (Bode and Dong, 2011). Refreshing pleasant aroma, carminative and biting taste of ginger made it indispensable ingredient in food preparation throughout the world.

Currently our country is the largest producer of ginger globally with 168 thousand hectares

under its cultivation with production potential of 10.70 lakh tones. The average productivity of ginger in India is around 6.5 tonnes/ha. Karnataka stands 4th in area and production of ginger and the growing districts are *viz.*, Uttara Kannada, Shivamogga, Haveri, Bidar, Hassan, Kodagu and Mysuru. Around 29.3 thousand ha. is under ginger with annual production of 109.3 thousand tonnes. This has wide usage in ayurvedic possessing anti-fungal, anti-bacterial, anti-tumorigenic, anti-inflammatory, anti-apoptotic, anti-hyperglycemic, anti-oxidant, anti-emetic and immune-modulatory property that too without any side effects (Badredin *et al.,* 2008). Ginger is a highly succulent herb and its rhizomes are highly susceptible to different abiotic and biotic stresses. Among them major constraint in ginger production is rhizome rot complex disease. Rhizome rot or soft rot is the most destructive diseases of ginger worldwide caused by the association of fungi, bacterium and plant parasitic nematode (Dohroo, 2005).The pathogen associated with rhizome rot complex disease of ginger in Karnataka includes *Pythium aphanidermatum* (causes soft rot), *Ralstonia solanacearum* (E. F. Smith) Yabuuchi *et al.,* 1995 (bacterial wilt), *Fusarium solani* (yellows), *Sclerotium rolfsii* (*Sclerotium* rot) and *Meloidogyne arenaria* (root knot) as reported by Anand (2014). The rhizome rot disease is complex in nature and also organisms associated with the disease vary with different growth stages of crop and different geographical area. Hence there is a need to study the association between different pathogens associated with rhizome rot complex disease of ginger.

Materials and Methods

Green house experiment was conducted to study the interaction among the different rhizome rot pathogens of ginger *viz., P. aphanidermatum, F. solani, S. rolfsii, R. solanacearum* and *M. arenaria*. For each treatment three replications were maintained. The experimental details are presented here under.

Sl. No	Treatments
1	*Pythium aphanidermatum* alone (P) (6% Inoculum)
2	*Fusarium solani* alone (F) (6% Inoculum)
3	*Ralstonia solanacearum* alone (1X10^{-7} cfu/ml)
4	*Sclerotium rolfsii* (S) (4% Inoculum)
5	*Meloidogyne arenaria* alone (M) (2juveniles per gram of soil)
6	P + F (Simultaneous inoculation)
7	P + R (Simultaneous inoculation)
8	P + S (Simultaneous inoculation)
9	P + M (Simultaneous inoculation)
10	P + F + M (Simultaneous inoculation)
11	P + R + M (Simultaneous inoculation)
12	P + S + M (Simultaneous inoculation)
13	P + F + R + M (Simultaneous inoculation)
14	P + F + R + S + M (Simultaneous inoculation)
15	P followed by F inoculation after 15 days
16	P followed by R inoculation after 15 days
17	P followed by S inoculation after 15 days
18	P followed by M inoculation after 15 days

19	F followed by P inoculation after 15 days
20	F followed by R inoculation after 15 days
21	F followed by S inoculation after 15 days
22	F followed by M inoculation after 15 days
23	M followed by P inoculation after 15 days
24	M followed by F inoculation after 15 days
25	M followed by R inoculation after 15 days
26	M followed by S inoculation after 15 days
27	P followed by M inoculation after 15 days
28	F followed by M inoculation after 15 days
29	R followed by M inoculation after 15 days
30	S followed by M inoculation after 15 days
31	Uninoculated control

Fungal pathogens were multiplied in corn sand agar and inoculum was added to pot containing 40 days old plants of susceptible variety of ginger (Cv. Reo-de-janeiro) was planted in pot and the soil moisture was maintained to field capacity level. Observations on germination, disease incidence and death of plants were recorded periodically. Finally reisolation of pathogens was made to confirm the association.

Results and Discussion

Interaction study of different pathogens were carried out in glass house condition Pathogens were inoculated individually and in combination by using giant culture as mentioned in section. Observations such as per cent rot incidence, number of days taken to appear symptoms and pathogen detected were recorded (Table 1).

All inoculated plants induced rhizome rot disease symptoms except in uninoculated control. When individual pathogens were inoculated, plants produced varying symptoms in different days. When *R. solanacearum* alone was inoculated, plants induced within 16 days after inoculation. The inoculated plant produced symptoms such as bronzing of lower leaves followed by inward rolling, which proceeds upwards. Later plant showed wilting symptoms and finally rotting of rhizomes with foul smell. *R. solanacearum* alone inoculated plants were recorded 55.56 per cent disease incidence.

In case of *P. aphanidermatum*, the symptoms were expressed within 19 days after inoculation with the symptoms likes foliar yellowing, pseudostem as well as rhizome rotting with foul smell. In case of soft rot 43.55 per cent disease incidence was recorded. In case of single inoculation of *F. solani* exhibited symptoms 40 days after inoculation with 33.33 per cent rot incidence. When plants were inoculated with *S. rolfsii* alone, the symptoms was observed 28 days after inoculation with rot incidence of 31.67 per cent. The plants inoculated with *M. arenaria* exhibited symptoms 55 days after inoculation with incidence of 16.67 per cent.

The pathogens took 10-21 days to express symptoms during combined inoculation of rhizome rot pathogens. The incidence of disease ranges from 45.00 to 73.33 per cent. When the plants were simultaneous inoculation with the all pathogens (P + F + R + S + M), the symptoms were seen within 10 DAI with rhizome rot incidence of 73.33 per cent. In case of P + F + R + M combination

recorded 70.00 per cent rot incidence, this was statistically on par with the combined inoculation of P + R + M (72.22 %) and P + F + R + S + M (73.33 %). When the pathogens were reisolated from the rotted rhizome, it was found that most of the combination *S. rolfsii* and *Meloidogyne* were not recovered. The incidence of rhizome rot disease was more in combined inoculation of pathogens as compared to individual inoculation except in P + S (49.44 %) and P + M (45.00 %).

In case of sequential inoculation of pathogens, when the nematode was inoculated first and followed by other pathogen recorded highest per cent rhizome rot incidence as compared to other treatments. In sequential inoculation of *M. arenaria* followed by *R. solanacearum* after 15 days was recorded maximum incidence of disease (91.67 %). The disease was expressed within 21 DAI of pathogens. The results indicated that, *F. solani* and *S. rolfsii* were weak pathogens as compared to other pathogens of rhizome rot of ginger.

Table.1 Interaction of different pathogens associated with rhizome rot complex disease in ginger

Sl. No.	Treatments	Rot incidence (PDI)	Appearance of symptoms (DAI)**	Pathogen reisolated
1	*Pythium aphanidermatum* alone (P)	44.44 (41.75)*	19	*P. aphanidermatum*
2	*Fusarium solani* alone (F)	33.33 (34.79)	40	*F. solani*
3	*Ralstonia solanacearum* alone	55.56 (48.23)	16	*R. solanacearum*
4	*Sclerotium rolfsii* (S)	31.67 (33.86)	28	*S. rolfsii*
5	*Meloidogyne arenaria* alone (M)	16.67 (24.09)	55	*M. arenaria*
6	P + F (Simultaneous inoculation)	54.60 (47.69)	20	*P. aphanidermatum* + *F. solani*
7	P + R (Simultaneous inoculation)	74.67 (59.79)	12	*P. aphanidermatum* + *R. solanacearum*
8	P + S (Simultaneous inoculation)	49.44 (44.83)	21	*P. aphanidermatum* + *S. rolfsii*
9	P + M (Simultaneous inoculation)	45.00 (41.92)	20	*P. aphanidermatum*
10	P + F + M (Simultaneous inoculation)	53.33 (46.92)	18	*P. aphanidermatum* + *F. solani*
11	P + R + M (Simultaneous inoculation)	72.22 (58.25)	12	*P. aphanidermatum* + *R. solanacearum*
12	P + S + M (Simultaneous inoculation)	57.38 (49.45)	18	*P. aphanidermatum* + *S. rolfsii*
13	P + F + R + M (Simultaneous inoculation)	70.00 (61.92)	10	*P. aphanidermatum* + *F. solani* + *R. solanacearum*
14	P + F + R + S + M (Simultaneous inoculation)	73.33 (63.85)	10	*P. aphanidermatum* + *F. solani* + *R. solanacearum*
15	P followed by F inoculation after 15 days	47.22 (43.51)	24	*P. aphanidermatum*
16	P followed by R inoculation after 15 days	58.89 (50.10)	18	*P. aphanidermatum* + *R. solanacearum*
17	P followed by S inoculation after 15 days	50.00	20	*P. aphanidermatum*

		(44.98)		
18	P followed by M inoculation after 15 days	44.44 (41.78)	22	*P. aphanidermatum*
19	F followed by P inoculation after 15 days	52.78 (46.58)	32	*P. aphanidermatum + F. solani*
20	F followed by R inoculation after 15 days	62.22 (52.07)	24	*F. solani + R. solanacearum*
21	F followed by S inoculation after 15 days	52.22 (46.27)	35	*F. solani + S. rolfsii*
22	F followed by M inoculation after 15 days	38.89 (38.56)	35	*F. solani*
23	M followed by P inoculation after 15 days	75.00 (60.21)	26	*P. aphanidermatum*
24	M followed by F inoculation after 15 days	67.22 (55.17)	35	*M. arenaria + F. solani*
25	M followed by R inoculation after 15 days	91.67 (80.00)	21	*R. solanacearum*
26	M followed by S inoculation after 15 days	44.44 (41.75)	30	*M. arenaria + S. rolfsii*
27	P followed by M inoculation after 15 days	55.00 (47.86)	20	*P. aphanidermatum*
28	F followed by M inoculation after 15 days	38.89 (38.53)	35	*M. arenaria + F. solani*
29	R followed by M inoculation after 15 days	69.44 (56.47)	16	*R. solanacearum*
30	S followed by M inoculation after 15 days	33.33 (35.25)	30	*M. arenaria + S. rolfsii*
31	Uninoculated control	00.00 (00.00)		
S. Em. ±		**1.39**		
C.D. @ 1 %		**5.42**		

These interaction studies results were similar with the findings of Shalini (2006) reported that the *P. aphanidermatum* and *F. solani* complex in ginger and turmeric rhizome rot disease. *F. solani* and *S. rolfsii* were weak pathogens as compared to other pathogens of rhizome rot of ginger. Association of *Pythium* spp. especially *F. solani* and *F. equiseti* has been demonstrated (Bhardwaj *et al.,* 1988) and interaction of *Ceratocystis fimbriata* and *Meloidogyne incognita* in Pomegranate was reported by Sonyal *et al.,* (2016). In artificial inoculation tests it has been demonstrated that maximum rotting occurred only when *P. aphanidermatum* was inoculated first followed by *F. solani* (Doshi and Mathur, 1987). The individual and interactive effects of *M. incognita* with *P. aphanidermatum* and *R. solanacearum* in ginger were demonstrated by Ramana *et al.,* (1998).

When the plants were simultaneous inoculation with the all pathogens (P + F + R + S + M), the symptoms were seen within 10 DAI with rhizome rot incidence of 73.33 per cent. The incidence of rhizome rot disease was more in combined inoculation of pathogens as compared to individual inoculation. This result were similar with the observation of Chauhan and Patel, 1990, independent infection and interaction between *Pythium* spp. and *F. solani* leading to synergy. Vadhera *et al.,* (1992) reported synergy of *P. aphanidermatum* and *M. javanica* in ginger from Madhya Pradesh. Gogoi *et al.,* (2008) identify the association of

R. solanacearum + *F. oxysporum* f. sp. *zingiberi* and *R. solanacearum* + *P. myriotylum*.

In sequential inoculation of *M. arenaria* followed by *R. solanacearum* after 15 days was recorded maximum incidence of disease (91.67 %). The disease was expressed within 21 DAI of pathogens. Similar trend was observed by Ateka *et al.,* (2001) reported the interaction nature of *R. solanacearum* and *M. incognita*. The presence of *M. incognita* increases the severity of the disease in potato (Siddiqui *et al.,* 2014), Tomato (Sundaresh *et al.,* 2017).

In the interaction study, *R. solanacearum* took 16 days to express the symptoms in individual inoculation with highest rot incidence (55.56 %). In case of *P. aphanidermatum*, the symptoms were expressed within 19 days after inoculation with 43.55 per cent disease incidence. The symptoms were seen within 10 DAI with all pathogens (P + F + R + S + M). In sequential inoculation of *M. arenaria* followed by *R. solanacearum* after 15 days, recorded maximum incidence of disease (91.67 %). The disease was expressed in 21 DAI of pathogens.

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