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Status of ginger rhizome rot complex disease in major growing tracts of Karnataka

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Abstract
Ginger is an economically important cash crop grown for its aromatic underground rhizomes. Crop is highly succulent in nature and its rhizomes are highly susceptible to different abiotic and biotic stresses. Rhizome rot or soft rot is the most destructive diseases of ginger worldwide. To know the status of rhizome rot complex disease and pathogens associated with disease complex during two cropping season 2016 and 2017. The maximum mean rhizome rot incidence was observed in Uttara Kannada district (33.20%) and least (18.84%) was in Mysore during 2016. Whereas in 2017, maximum rhizome rot disease incidence (44.66%) was noticed in Sagara taluk of Shivamogga district and least (22.67%) was recorded in Piriyapatna taluk of Mysore district. Among the different cultivated varieties maximum mean rhizome rot incidence was observed in Reo-de-Janeiro (28.33%), whereas the least incidence recorded in Himachal (22.46%). The incidence of disease was more in low land black soil as compared well drained red loamy soils. In both the year, frequency of occurrence of *Pythium* was more as compared to other pathogens but the severity of the rotting was more when bacterium (*R. solanacearum*) is associated.

Keywords: rhizome rot, *Pythium aphanidermatum* and *Ralstonia solanacearum*

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) [4]. Ginger is one important spice crop grown throughout the world. 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.

Currently our country occupies the 2nd largest producer of ginger globally with 168 thousand hectares under its cultivation with production potential of 10.70 lakh tones (Anon, 2018) [2]. The average productivity of ginger in India is around 6.5 tonnes/ha. In India, it is cultivated in all most all tropical and subtropical parts. 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.

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) [3]. 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. The correct diagnosis of the disease in a given location and involvement of one or more pathogens should be clearly understood to plan effective integrated management measures, which would be location specific. Hence the effort was made to know the status of rhizome rot complex disease and pathogens associated with disease complex during two cropping season 2016 and 2017.

Material and Methods
An intensive roving survey was conducted for incidence of rhizome rot complex disease in ginger during cropping season (in the month of August, September and October) of 2016 and 2017 in major ginger growing areas of Karnataka *viz.*, Uttara Kannada, Haveri, Shivamogga, Hassan, Kodagu and Mysore. During survey different observations such as variety grown, crop growth stage, soil type, pathogen associated and disease incidence were recorded.

Disease incidence was calculated by following formula.

$$\text{Per cent disease incidence:} \quad \frac{\text{No. of plant infected}}{\text{Total no. of plant observed}} \times 100$$

Result and Discussion
Survey and surveillance aid in identifying the disease prone hotspots and disease-free areas in different districts of Karnataka. During *Kharif* 2016, rhizome rot disease incidence was noticed in all the surveyed locations, with a range from 3.33 to 53.33 per cent. Among the surveyed villages, Yadiyurbail village of Uttara Kannada district was recorded maximum mean disease incidence of rhizome rot (53.33%) and least mean rhizome rot incidence of (3.33%) was observed in Puttanahalli village of Shivamogga district (Table 1a). Among the surveyed taluks, mean maximum rhizome rot incidence of 36.11 per cent was recorded in Sirsi

taluk of Uttara Kannada district and least disease incidence (17.67%) was observed in Hunsur taluk of Mysore district (Table 2). Among the surveyed districts, the maximum mean rhizome rot incidence was observed in Uttara Kannada district (33.20%) followed by Kodagu (26.67%), Haveri (25.25%) and least (18.84%) was in Mysore (Table 2). The incidence of rhizome rot complex disease of ginger was ranged from 8.33 to 60.00 per cent during *Kharif* 2017. Among the villages surveyed, maximum of 60.00 per cent rhizome rot incidence was recorded in Ikkeri village of Shivamogga districts and the lowest incidence of disease (8.33%) was reported from Kanchenegaluru village of Haveri district (Table 1b). Among the surveyed taluks, maximum rhizome rot disease incidence (44.66%) was noticed in Sagara taluk of Shivamogga district, followed by Sirsi taluk of Uttara Kannada district (40.56%) and least (22.67%) was recorded in Piriyapatna taluk of Mysore district. The incidence of rhizome rot complex disease of ginger was more during 2017 (31.00%) than 2016 (25.14%). These results were supported findings of Kulkarni *et al.* (2004) observed that, the ginger rhizome rot incidence was observed in all the surveyed locations of northern parts of Karnataka, incidence was ranges from 2.00 to 47.28 per cent and maximum incidence of disease was noticed in Korlakatta village (47.28%) of Uttara Kannada district and least incidence was recorded in Haveri district Markoppa village (2.00%) during 2004.

In 2016, maximum mean rhizome rot incidence was observed in Reo-de-Janeiro (28.33%) followed by Humnabhad local (26.51%), whereas the least incidence recorded in Himachal (22.46%) followed by Varadha (23.86%). The disease incidence during 2017, the maximum disease incidence was observed in Sirsi local (37.29%) and least was in Varadha (25.32%) (Table 3a). According to Karthikeyan *et al.* (2018) [5], ginger varieties like Reo-de-Janeiro and Varadha were susceptible, whereas Mahima, Athira and Acc-581 were moderately resistant to soft rot disease in Tamil Nadu.

Himachal and Varadha varieties of ginger showed moderately resistance against bacterial wilt disease under both glasshouse and field condition as reported by Anand (2014) [1].

Ginger is cultivated in a variety of soils, but mainly grown in black, red and red loamy soils. The maximum incidence of rhizome rot disease was recorded in crop grown in black soil (34.68%) and least incidence was recorded in red loamy soils (22.62 per cent). The incidence of disease was more in low land black soil as compared well drained red loamy soils (Table 3b). Similar findings were observed by Suryanarayana (2005) [11] and Kulkarni *et al.* (2003) [7] that the incidence and development of rhizome rot complex disease in ginger was maximum in the months of July and August, due to coincidence heavy rainfall and cool weather. The disease was observed first time in Australia and Fiji during hot, wet conditions in 2007, which leads to more than 50 per cent loss in seed rhizomes (Stirling *et al.,* 2009) [10].

The data in Table 4 indicated that, *Pythium aphanidermatum* was reported from 19 locations with 28.79 per cent recovery from the collected samples, followed by *P. aphanidermatum* + *Ralstonia solanacearum* both in combination was recovered from samples collected from 15 locations (22.73%).

R. solanacearum was found in 13 places with 19.70 per cent recovery from the infected samples. During 2017, *P. aphanidermatum* was recovered from eighteen fields (28.12%) followed by *R. solanacearum* and *P. aphanidermatum* + *R. solanacearum* were found sixteen locations with 25.00 per cent recovery. The combination of three pathogens i.e., *P. aphanidermatum* + *R. solanacearum*+ *F. solani* was found in three fields with 4.68 per cent recovery. Similar finding was reported by Savitha *et al.* (2009) [9].

Pythium aphanidermatum was recovered from maximum samples as compared to *F. oxysporum* f. sp. *zingiberi* and *R. solanacearum* from rhizome rot infected samples in Ranchi. *R. solanacearum* was most predominant, followed by *F. oxysporum, P. aphanidermatum* and *S. rolfsii* and was due to use of metalaxyl fungicide in rhizome rot management (Rekha, 2013) [8].

Table 1: Incidence of rhizome rot complex disease of ginger and their associated pathogens in major growing districts of Karnataka during 2016

District	Taluk/ Village	Variety	Crop stage	Soil type	Per cent disease incidence	Pathogen/s noticed
Uttara Kannada	Mundgod					
	Kavalakoppa	Sirsi local	Tillering	Red	20.00	R
	Hirehalli	Humnabad local	Seedling	Red	26.50	P
	Katur	Reo-de-Janeiro	Tillering	Black	41.66	P,R,F
	Nandipur	Himachal	Seedling	Red	25.00	P
	Bachanki	Humnabad local	Seedling	Black	38.33	P,R
	Sirsi					
	Banavasi	Himachal	Seedling	Black	41.67	P,R
	Madhuravalli	Humnabhad local	Tillering	Red	28.33	R
	Yadiyurbail	Sirsi local	Seedling	Red	36.67	P,F
	Andagi	Reo-de-Janeiro	Seedling	Black	46.67	P,R,F
	Bilur	Himachal	Tillering	Red	8.33	S
	Kerekoppa	Reo-de-Janeiro	Seedling	Black	53.33	P,R
Haveri	Hanagal					
	Akkialur	Himachal	Tillering	Red	23.33	P,F
	Anwati	Humnabad local	Tillering	Red	26.67	P
	Konkana	Sirsi local	Seedling	Red	35.00	P,R
	Balur	Himachal	Seedling	Red	21.67	R
	Tivali	Sirsi local	Tillering	Red	5.0	M
	Hirekerur					
	Kachavi	Sirsi local	Seedling	Red	33.33	P,R
	Purapundikoppa	Reo-de-Janeiro	Tillering	Red	11.67	S

	Yogikoppa	Humnabad local	Tillering	Red	21.67	R
	Muddinakoppa	Humnabad local	Seedling	Red	25.00	R
	Vadenapura	Reo-de-Janeiro	Seedling	Red	40.00	P
	Byadgi					
	Nellikoppa	Humnabad local	Seedling	Red	26.67	P,F
	Kadaramandalagi	Himachal	Tillering	Red	28.33	P
	Dollikoppa	Himachal	Tillering	Red	20.00	R
	Gudad Malapura	Reo-de-Janeiro	Tillering	Red	33.33	P,R,F
Shivamogga	Shivamogga					
	Ayanur	Himachal	Seedling	Red	18.33	R
	Kumsi	Himachal	Tillering	Black	5.00	P
	Harnahalli	Humnabad local	Seedling	Black	48.33	P,R
	Channanahalli	Humnabad local	Seedling	Red	30.00	R
	Sagara					
	Narasipura	Himachal	Tillering	Red loamy	21.66	P
	Gowthamapura	Himachal	Seedling	Red loamy	28.33	P,R
	Thyagarthi	Reo-de-Janeiro	Tillering	Red loamy	6.67	F
	Arasalu	Varadha	Seedling	Black	36.67	P,R
	Sampalli	Humnabad local	Seedling	Black	15.00	P
	Soraba					
	Anawatti	Himachal	Tillering	Red loamy	33.33	P
	Puttanahalli	Reo-de-Janeiro	Tillering	Red sandy	3.33	M
	Devanahalli	Humnabad local	Tillering	Red loamy	16.67	P,F
	Gendala Hosuru	Himachal	Tillering	Red loamy	36.67	P,R
	Gudavi	Reo-de-Janeiro	Seedling	Black	20.00	P
Hassan	Alur					
	Haluvalli	Reo-de-Janeiro	Seedling	Black	28.33	P
	Taruru	Humnabad local	Seedling	Black	11.67	R
	Madagere	Himachal	Tillering	Red loamy	22.50	P
	Kanathur	Reo-de-Janeiro	Seedling	Red loamy	26.67	P,R,F
	Beerakanahalli	Varadha	Tillering	Red loamy	15.00	P,F
	Arkalgud					
	Mallipatna	Humnabad local	Rhizome formation	Red	18.33	P
	Aladahalli	Humnabad local	Tillering	Red loamy	29.0	P,R
	Shiradanahalli	Reo-de-Janeiro	Tillering	Red loamy	36.67	R
	Konanur	Varadha	Rhizome formation	Red loamy	23.50	P,F
Kodagu	Madikeri					
	Panane	Reo-de-Janeiro	Rhizome formation	Black	26.67	P,R
	Kakkabe	Reo-de-Janeiro	Tillering	Black	40.00	P,R
	Ballananatti	Himachal	Rhizome formation	Black	15.00	P,F
	Rothur	Mahima	Rhizome formation	Black	28.33	P
	Virajpet					
	Hathur	Reo-de-Janeiro	Tillering	Black	50.00	P,R
	Bittahongal	Varadha	Rhizome formation	Black	28.33	R
	Karnadu	Humnabad local	Tillering	Black	18.33	P,F
	Hudikeri	Himachal	Rhizome formation	Black	6.67	F
Mysore	Piriyapatna					
	Bekya	Varada	Seedling	Black	8.33	S
	Kirangooru	Reo-de-Janeiro	Tillering	Black	11.67	P
	Basalapura	Humnabad local	Tillering	Black	38.33	P,R
	Mellahalli	Humnabad local	Seedling	Red	18.35	P
	Mallinathapura	Reo-de-Janeiro	Tillering	Red	23.33	R
	Hunsur					
	Udduru	Reo-de-Janeiro	Seedling	Red sandy	16.67	P
	Vaddaragudi	Reo-de-Janeiro	Tillering	Red sandy	10.00	P
	Gowripura	Varadha	Seedling	Red sandy	13.33	P
	Kallahalli	Himachal	Tillering	Red sandy	28.33	P,R
	Dharmapura	Humnabad local	Seedling	Red sandy	20.00	R

P-*Pythium aphanidermatum*, R- *Ralstonia solanacearum*, F- *Fusarium solani*, S- *Sclerotium rolfsii* and M- *Meloidogyne sp.*

Table 2: Incidence of rhizome rot complex disease of ginger and their associated pathogens in major growing districts of Karnataka during 2017

District	Taluk/ Village	Variety	Crop stage	Soil type	Disease incidence (%)	Pathogen/s noticed
Uttara Kannada	Mundgod					
	KaraginaKoppa	Sirsi local	Tillering	Black	60.00	P
	Salgav	Humnabad local	Seedling	Black	27.77	P,F
	Marigunda	Sirsi local	Tillering	Black	45.00	P,R,F
	Bachanaki	Sirsi local	Seedling	Red	26.67	R
	Kanakapura	Rio-de-Janeiro	Seedling	Red	28.33	P,F
	Sirsi					
	Navanagere	Humnabad local	Seedling	Black	41.67	P,R
	Banavasi	Humnabad local	Seedling	Black	61.67	P,R
	Vadla	Sirsi local	Tillering	Red	35.00	P,R
	Kalangi	Himachal	Tillering	Black	53.33	P,R
	Badanagudda	Himachal	Tillering	Red	11.67	F
	Kalangi	Reo-de-Janeiro	Seedling	Black	40.00	R
Haveri	Hanagal					
	Konkana	Sirsi local	Tillering	Red loamy	20.0	P,F
	Makaravalli	Varadha	Tillering	Red	10.00	M
	Kanchenegaluru	Himachal	Tillering	Red	8.33	S
	Veerapura	Humnabad local	Tillering	Red loamy	18.88	P
	Kallapura	Sirsi local	Tillering	Red	51.67	R
	Malgunda	Reo-de-Janeiro	Seedling	Red	38.33	P,R
	Akkihalur	Humnabad local	Tillering	Red loamy	36.67	P
	Hirekerur					
	Ningapura	Himachal	Seedling	Red loamy	25.55	P,F
	Hirekonati	Humnabad local	Tillering	Red loamy	14.45	P
	Appinkoppa	Sirsi local	Tillering	Red	36.63	R
	Chikkerur	Reo-de-Janeiro	Seedling	Red	47.77	R
	Byadgi					
	Bannihalli	Himachal	Tillering	Red	41.67	P,R
	Hirehalli	Himachal	Seedling	Red	31.11	P
	Kummalli	Sirsi local	Tillering	Red	23.33	R
	Timkapura	Reo-de-Janeiro	Seedling	Red	10.00	P
Shivamogga	Soraba					
	Kuppakatti	Humnabhad local	Tillering	Red	27.78	R
	Hittakki	Reo-de-Janeiro	Tillering	Red loamy	41.11	P,R
	Bommanahalli	Humnabad local	Seedling	Red	20.00	P
	Jade	Varadha	Tillering	Red	31.67	R
	Mangapura	Himachal	Tillering	Red	43.33	R
	Sagara					
	Anandapura	Reo-de-Janeiro	Seedling	Black	48.33	R
	Ambligola	Himachal	Tillering	Black	23.33	R
	Ripponpet	Humnabad local	Seedling	Black	53.33	P,F
	Ikkeri	Reo-de-Janeiro	Tillering	Black	60.00	P,R
	Keladi	Himachal	Tillering	Black	38.33	P,F,R
	Shivamogga					
	Hubnahalli	Himachal	Seedling	Red	13.33	M
	Choradi	Varadha	Seedling	Red	18.33	P,F
	Sakrebailu	Reo-de-Janeiro	Tillering	Black	41.11	P,R
	Hosahalli	Himachal	Tillering	Red	26.67	P
Hassan	Alur					
	Bhairapura	Reo-de-Janeiro	Tillering	Red	30.00	R
	Ajjenahalli	Varadha	Tillering	Red sandy	24.44	P
	Kallakere	Humnabad local	Tillering	Red loamy	38.33	P,R
	Honnavalli	Himachal	Tillering	Red loamy	10.00	P
	Arkalgud					
	Maagodu	Humnabad local	Rhizome formation	Red	35.55	R
	Shiradanahalli	Reo-de-Janeiro	Tillering	Red loamy	33.33	R
	Kelagalale	Himachal	Tillering	Red loamy	16.67	P
Kodagu	Madikeri					
	Napoklu	Varadha	Rhizome formation	Black	18.33	P,R
	Cherambane	Reo-de-Janeiro	Tillering	Black	44.45	P,F,R

	Hakathuru	Himachal	Rhizome formation	Black	34.16	R
	Chettimani	Humnabhad local	Rhizome formation	Black	23.33	P
	Virajpet					
	Moornadu	Varadha	Tillering	Black	40.00	P,R
	Sri mangala	Mahima	Rhizome formation	Black	28.50	P,R
	Birunani	Reo-de-Janeiro	Rhizome initiation	Black	43.33	P
Mysore	Piriyapatna					
	Hittanahebbagilu	Reo-de-Janeiro	Rhizome initiation	Red	18.33	P,F
	Kaggundi	Himachal	Tillering	Red	21.67	P
	Hemige	Reo-de-Janeiro	Tillering	Red	26.66	R
	Chittanahalli	Varadha	Seedling	Red	23.33	P
	Mallinathapura	Reo-de-Janeiro	Tillering	Slightly Red	11.67	P
	Chowthi	Humnabad local	Seedling	Black	35.00	P,R
	Hunsur					
	Halepura	Reo-de-janeiro	Seedling	Red	15.00	F
	Gadige	Himachal	Tillering	Black	13.33	P
	Karimuddanahalli	Reo-de-Janeiro	Tillering	Black	46.67	P,R
	Ratnapuri	Humnabad local	Tillering	Red	26.67	P

P-*Pythium aphanidermatum*, R- *Ralstonia solanacearum*, F- *Fusarium solani*, S- *Sclerotium rolfsii* and M- *Meloidogyne sp.*

Table 3: Year wise incidence of rhizome rot complex disease of ginger in different taluk and districts of Karnataka

District	Taluk	Mean disease incidence (%)		
		2016	2017	Pooled mean
Uttara Kannada	Mundgod	30.30	37.55	33.92
	Sirsi	36.11	40.56	38.34
	Mean	33.20	39.05	36.13
Haveri	Hanagal	22.33	26.27	24.30
	Byadgi	27.08	26.53	26.81
	Hirekerur	26.33	31.10	28.72
	Mean	25.25	27.97	26.61
Shivamogga	Shivamogga	25.41	24.86	25.14
	Sagara	21.67	44.66	33.17
	Soraba	22.00	32.78	27.39
	Mean	23.02	34.11	28.57
Hassan	Alur	20.83	25.69	23.26
	Arkalgud	26.87	28.52	27.69
	Mean	23.85	27.11	25.48
Kodagu	Madikeri	27.50	30.07	28.78
	Virajpet	25.83	37.28	31.56
	Mean	26.67	33.68	30.17
Mysore	Piriyapatna	20.00	22.76	21.38
	Hunsur	17.67	25.42	21.54
	Mean	18.84	24.10	21.47
Grand mean		25.14	31.00	28.07

Table 4: Incidence of rhizome rot disease in different cultivars on ginger

Cultivar	Per cent disease incidence		
	2016	2017	Pooled mean
Himachal	22.46	25.71	24.08
Reo-de-Janeiro	28.33	34.69	31.51
Sirsi local	24.33	37.29	30.81
Varadha	23.86	25.32	24.59
Humnabhad local	26.51	31.86	29.19
Mean	25.09	30.97	28.03

Table 5: Influence of soil type on incidence of rhizome rot disease in ginger

Soil type	Per cent disease incidence		
	2016	2017	Pooled mean
Black	28.83	40.54	34.68
Red loamy	21.25	24.00	22.62
Red	24.13	28.28	26.20
Mean	24.73	30.94	27.83

Table 6: Frequency of pathogens associated with ginger rhizome rot complex disease in different surveyed area

Pathogens detected	2016			2017			Pooled mean per cent disease incidence
	No. of fields infected with respective pathogen	Per cent share of pathogen associated	Mean per cent disease incidence	No. of fields infected with respective pathogen	Per cent share of pathogen associated	Mean per cent disease incidence	
Pythium aphanidermatum	19	28.79	21.52	18	28.12	25.21	23.36
Ralstonia solanacearum	13	19.70	23.46	16	25.00	28.29	25.87
Fusarium solani	2	3.03	6.67	2	3.12	13.33	10.00
Sclerotium rolfsii	3	4.55	9.44	1	1.56	8.33	8.88
Meloidogyne arenaria	2	3.03	4.16	1	1.56	10.00	7.08
P. aphanidermatum + R. solanacearum	15	22.73	37.59	16	25.00	41.36	39.47
P. aphanidermatum + F. solani	8	12.12	21.89	7	10.93	25.23	23.56
P. aphanidermatum + R. solanacearum + F. solani	4	6.06	37.08	3	4.68	42.59	39.83
Total fields visited	66	100		64	100		

Conclusion

In conclusion, the incidence of ginger rhizome rot complex disease in different districts like Uttara Kannada, Kodagu, Haveri and Shivamogga were identified as hotspot for the disease. They highlighted, improper planting material selection, poor soil, low lying area, wrong diagnosis of pathogen, spurious fungicide and indiscriminating use of fertilizer, unfavorable weather conditions and higher rainfall could be the reasons for higher rhizome rot disease in different parts of Karnataka.

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