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Survey on Panama Wilt Disease (*Fusarium oxysporum* f.sp. *cubense*) of Banana in Mysuru, Mandya and Chamarajanagar Districts of Karnataka

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Abstract

The roving survey was carried to find out the prevalence of *Fusarium* wilt disease incidence in banana cultivars during 2016-17 to 2017-18 in different places of Mysuru, Mandya and Chamarajanagar districts of Karnataka. During the survey, the average disease incidence of *Fusarium* wilt was ranged from 6.54 to 25.47%. The mean disease incidence in Mysuru district was 15.00% during 2016-17 and 25.47% in 2017-18, Mandya district recorded the average disease incidence of 6.54% during 2016-17 and 7.88% in 2017-18 and Chamarajanagar district showed the average disease incidence of 13.24% during 2016-17 and 10.56% in 2017-18. Among districts, Mysuru recorded the highest average disease incidence followed by Chamarajanagar. While the severe form of disease was observed in the cultivar Nanjanagudu Rasabale (60.57%) in Krishnapura village of Nanjangud taluk. However, among all the locations surveyed the highest disease incidence recorded was 60.57 % and lowest incidence was 0.00%. The maximum wilt incidence (%) was recorded in cultivar Nanjangud Rasabale followed by Ney Poovan 28.00 %. Nanjangud taluk of Mysuru district reported severe incidence level of panama wilt disease when compared to other taluks and districts. The wilt incidence (%) was higher during 2017-18 showing the consecutive increase in the disease incidence compare to 2016-17. The increased wilt incidence (%) was due to virulence of the pathogen and susceptibility of the cultivars.

Keywords: Banana, disease incidence, *Fusarium wilt,* Nanjangud, Rasabale

1. Introduction

Banana (*Musa paradisiaca*) is an important ancient tropical fruit in the world. It belongs to family Musaceae and native to tropical region of Southeast Asia. Banana is cultivated throughout the warm tropical regions of the world and extensively cultivated in Brazil, Ecuador, China, Philippines, Indonesia, Cost Arica, Mexico, Thailand, Colombia and India. It is grown as monoculture or mixed cropping system. The total annual global production of banana is estimated around 113.9 million tonnes (agriexchange.apeda.gov.in). India stands first in the World banana production (26.5% of the World production). In India, it is regarded as "fruit of the wise men" and it is grown in an area of 8.74 lakh ha with an annual production of 30 million tones and the average productivity is 35.88 MT ha^{1} (http://agricoop.nic.in). Tamil Nadu state has the largest area under cultivation in India, followed by Maharashtra, Gujarat, Andhra Pradesh, and Karnataka. The average yield ha^{-1} is very low, due to abiotic stressors, such as salinity (Willadino et al., 2017) and drought (Said et al., 2015; Nansamba et al., 2020). Another biotic stressor, represented by their primary pests, the banana root borer (*Cosmopolites sordidus*) and the nematodes *Meloidogyne* spp., *Pratylenchus coffeae*, and *Radopholus similis* (Monteiro et al., 2020) and disease-causing pathogens, including banana bunchy top virus (BBTV) (Galvez et al., 2020; Sairam et al., 2020), *Xanthomonas vasicola* p.v. *musacearum* causing bacterial wilt (Studholme et al., 2020), *Pseudocercospora fijiensis* causing black Sig Sigatoka (Timm et., 2016; Nascimento et al., 2020) and *Fusarium oxysporum* f. sp. *cubense* (FOC) causing Fusarium wilt (Dita et al., 2018; Goncalves et al., 2019). Among, Panama disease also known as *Fusarium* wilt or vascular wilt incited by *Fusarium oxysporum* f.sp. *cubense* (E.F. Smith) Snyd. and Hans. is one of the world's most disastrous plant diseases (Ploetz and Pegg., 2000; Siamak and Zheng, 2018; Butler, 2013) and the disease was believed to have originated in Southeast Asia (Stover, 1962; Vakili, 1965). The latest outbreak of FocTR4 has been confirmed in the Americas affecting the most popular commercial variety which could have jeopardized banana production for decades (Lambert, 2019). *Fusarium oxysporum* f.sp. *cubense* (Foc) causes a typical wilt syndrome on the infected banana plants accompanied by the necrosis

and rotting of roots, rhizome, and pseudostem vessels. These symptoms occur between 2 and 5 months after infection of roots (Stover, 1962). The first internal symptom of the disease occurs in the hair roots which are the initial sites of infection. The infection later progresses to the rhizome and pathogen passes through the affected vessels to the new growing shoot (Li et al., 2017).

Presently, the disease is widespread in all the regions of India and varieties like Nanjanagud Rasabale (AAB), Rasthali (AAB), Ney Poovan (AB) and Virupakshi (AAB) were found highly susceptible, some of the local cultivars were in-danger of extinction (Thangavelu et al., 2001) and these cultivars are no-longer profitable to grow because of the damage caused by the pathogen. Among, Nanjanagud Rasabale is top ranked due to their inviting aroma and bright yellow peel with fluffy white delicious pulp. Choice table variety "Nanjangud Rasabale" is commercially grown in southern dry zone (Zone-6) of Karnataka at Nanjanagud taluk of Mysuru district (Stover and Malo,1972). This variety is highly susceptible to wilt diseases and area under cultivation is declining for many successive years, earlier data shows the cultivation was more than 500 hectares in the year 1990. The build-up of *Fusarium oxysporum* f. sp. *cubense* to aggressive levels with new races resulted in the decline of cultivation to 30 acres (Guranna et al., 2018). The pathogen lives in soil and penetrates the roots by colonizing rapidly in the xylem vessels (Ploetz, 2006). The internal symptoms of *Fusarium* wilt develop in the feeder roots, which are the initial sites of fungal infection (Ploetz, 1990). The fungus spreads to the rhizome, but the symptoms are most prominent where the stele joins the cortex (Ploetz et al., 1994). Later, the pseudostem is colonized and then the dim brown streaks or flecks become more evident on and within the older leaf sheaths (Ploetz, 2006). Consequently, an extensive area of the xylem turns brick red to brown colour. The internal spread of disease makes one's way towards the first appearance of external symptoms like leaf yellowing pseudostem splitting and rotting (Ploetz et al., 1994). To know the status of the disease the roving survey was conducted in three districts of Karnataka. During survey the emphasis was made on the cultivar Nanjangud Rasabale to know the existence of the cultivar.

2. Materials and Methods

Extensive survey work was carried out during 2016-17 to 2018-19 in different places of Mysuru, Mandya and Chamarajanagar districts of Karnataka, India. During survey observations were recorded with respect to cultivar, planting material used, GPS co-ordinates and wilt incidence based on the external symptoms. Samples were collected for isolation of pathogens and isolated pathogens were identified using PCR method and further confirmed by sequencing. In each district, major banana growing taluks were selected and in each village five fields were randomly selected. Observations were recorded with respect to the incidence of wilt. In each plot random samples were drawn, from which the number of plants affected over the total number of plants were counted and expressed as % disease incidence as described in the formula given by Vernell and Hecloud (1975).

% disease incidence=(No.of plants showing wilting symptom/ Total number of plants)×100

The survey maps were prepared by using latitude and longitude of the field in Google Earth software 2016.

3. Results and Discussion

All the isolated pathogens were identified as *Fusarium oxysporum*, these fungal strains showed 100% sequence similarity in nucleotide blast search for *Fusarium oxysporum* f.sp. *cubense* with accession number MW214723.1. The data on roving survey of Panama wilt diseases incidence during 2016-17 to 2018-19 is presented in Table 1 and Table 2. The roving survey were conducted during September, October and November 2016-17 to 2018-19. The survey data revealed that the disease was prominent and present in all the surveyed districts and the survey maps were prepared and presented in Figure 1. During 2016-2017 the mean incidence of *Fusarium* wilt was 15.00% in Mysore district. Among taluks, the highest average incidence of 28.62% was observed in Nanjangud taluk followed by Mysuru taluk (10.66%). In Nanjangud taluk, Nandigunda village recorded the highest *Fusarium* wilt of 57.14% in the cv. Nanjangud Rasabale followed by Devarasanahalli village (51.69%) and the lowest disease incidence was noticed in Chikkahomma village (0.00%). In Mandya district, the average disease incidence was 6.54%. Maximum incidence of 7.2% was observed in Maddur taluk followed by Nagamangala taluk (7.05%). Among villages, Sompura village of Maddur taluk recorded highest incidence (12.71%) in the cv. Ney Poovan followed by H. Kodihalli

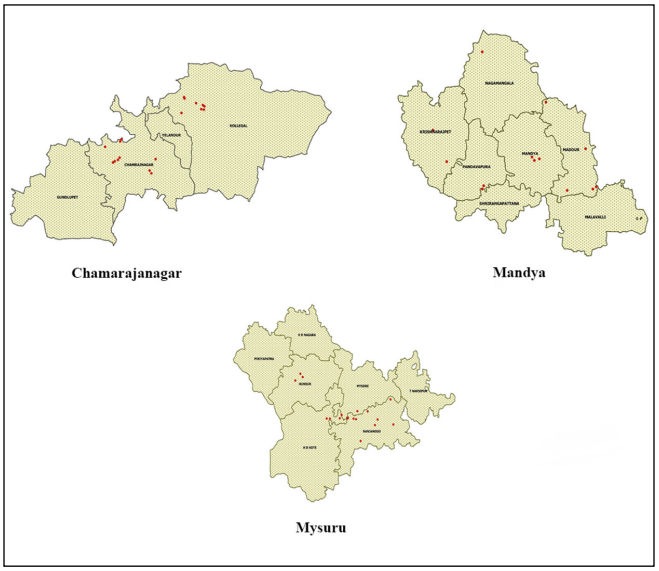

Figure 1: Red points on the maps indicate the GPS locations of the banana fields visited during the survey

Table 1: Roving survey for incidence of Panama disease (*Fusarium wilt*) of banana during 2016–2017

Sl. No.	Name of the place			Latitude	Longitude	Stage of the crop (Months)	Variety or Cultivar	Planting material used	% disease incidence	Average disease incidence
	District	Taluk	Village							
1.	Mysuru	H D Kote	Beechanahalli	11.989219	76.356405	9	Nendran (AAB)	Tissue culture	6.67	5.73
			Lingenahalli	11.97179	76.360589	8	Grand Naine (AAA)	Tissue culture	0.00	
			Holehundi	12.1252616	76.4260557	7	Ney Poovan (AB)	Tissue culture	16.25	
			Karigala	12.1246624	76.4436841	9	Grand Naine (AAA)	Tissue culture	0.00	
		Mysore	Belthur	12.333752	76.280056	9	Grand Naine (AAA)	Tissue culture	11.00	10.66
			Doddakaturu	12.1594122	76.5951793	8	Ney Poovan (AB)	Suckers	11.60	
			Kadanahalli	12.1283586	76.5385445	9	Ney Poovan (AB)	Tissue culture	9.38	
		Nanjangud	Chikkahomma	12.017016	76.893718	7	Grand Naine (AAA)	Tissue culture	0.00	28.62
			Devarasanahalli	12.094338	76.692257	8	Rasthali (N. Rasabale AAB)	Suckers	51.69	
			Hallididdi	12.166186	76.664212	9	Ney Poovan (AB)	Tissue culture	13.50	
			Hebya	12.180999	76.694879	9	Rasthali (N. Rasabale AAB)	Suckers	46.51	
			Hullahalli	12.094323	76.547893	8	Rasthali (N. Rasabale AAB)	Suckers	38.89	
			Kalale	12.07296	76.668513	4	Rasthali (N. Rasabale AAB)	Tissue culture	2.50	
			Kugalur	12.020128	76.61312	8	Rasthali (N. Rasabale AAB)	Suckers	18.75	
			Nandigunda	12.213976	76.777878	9	Rasthali (N. Rasabale AAB)	Suckers	57.14	
% average incidence in Mysuru district										15.00
2.	Mandya	Maddur	Chikkonahalli	12.683345	76.471923	9	Ney Poovan (AB)	Suckers	0.00	7.21
			S. Hagalahalli	12.465563	77.112971	8	Ney Poovan (AB)	Suckers	6.67	
			Sompura	12.547354	77.058264	9	Ney Poovan (AB)	Suckers	12.71	

Table 1: Continue...

Sl. No.	Name of the place			Latitude	Longitude	Stage of the crop (Months)	Variety or Cultivar	Planting material used	% disease incidence	Average disease incidence
	District	Taluk	Village							
	Mandya		Halasahalli	12.481896	77.21754	9	Ney Poovan (AB)	Tissue culture	7.80	
			H. Kodihalli	12.5714132	76.8782999	8	Ney Poovan (AB)	Tissue culture	8.89	
		Nagamangala	Alisandra	12.973022	76.669236	9	Ney Poovan (AB)	Suckers	12.40	7.05
			Mella Hally	12.933048	76.723406	7	Ney Poovan (AB)	Suckers	8.74	
			Begamangala	12.913714	76.751895	8	Grand Naine (AAA)	Tissue culture	0.00	
		Pandavapura	Aralakuppe	12.450416	76.610166	9	Grand Naine(AAA)	Tissue culture	0.00	5.3
			JagateMallenahalli	12.479312	76.602716	8	Ney Poovan (AB)	Tissue culture	8.67	
			Malligere	12.787007	76.925109	10	Ney Poovan (AB)	Tissue culture	12.80	
			Kadathanalu	12.4658295	76.6693441	9	Grand Naine (AAA)	Tissue culture	0.00	
% average incidence in Mandya district										6.54
3.	Chamarajanagar	Chamarajanagar	Badanaguppe	11.998872	76.876032	8	Grand Naine (AAA)	Tissue culture	0.00	12.53
			Dollipura	11.871808	77.009339	8	Ney Poovan (AB)	Suckers	27.09	
			Kerehalli	11.977181	76.811303	7	Ney Poovan (AB)	Suckers	23.03	
			Somasamudra	11.933909	76.873547	8	Grand Naine (AAA)	Tissue culture	0.00	
		Kollegala	Jinakanahalli	12.169738	77.151465	8	Ney Poovan (AB)	Tissue culture	26.00	13.94
			Haravanapura	12.143167	77.229826	9	Grand Naine (AAA)	Tissue culture	0.00	
			Kongarahalli	12.12535	77.234184	8	Ney Poovan (AB)	Suckers	29.77	
			Thimmarajipura	12.111829	77.138052	9	Grand Naine (AAA)	Tissue culture	0.00	
% average incidence in Chamarajanagar district										13.24

village (8.89%) and lowest disease incidence was noticed in Chikkonahalli village (0.00%). Chamarajanagar is one of Nanjangud Rasabale growing district which is also well known for growing various other banana cultivars, in this district the average *Fusarium* wilt incidence was 13.24%. The maximum average incidence of 13.94% was observed in Kollegala taluk followed by Chamarajanagar taluk (12.53%). Kongarahalli village of Kollegala taluk noticed the highest incidence of wilt (29.77%) in the cv. Ney Poovan.

During 2017-2018, average incidence of *Fusarium* wilt was 25.57% in Mysore district. The highest average incidence was observed in Nanjangud taluk of 45.39% followed by H D Kote taluk (19.30%). Among the villages in Nanjangud taluk, Krishnapura village recorded the highest *Fusarium* wilt incidence (60.57%) in the cv. Nanjangud Rasabale. The mean disease incidence of 7.88% was observed in Mandya

Table 2: Roving survey for incidence of Panama disease (*Fusarium wilt*) of banana during 2017–2018

Sl. No.	Name of the place			Latitude	Longitude	Stage of the crop (Months)	Variety or Cultivar	Planting material used	% disease incidence	Average disease incidence
	District	Taluk	Village							
1	Mysuru	H D Kote	Beechanahalli	11.966986	76.358326	8	Ney Poovan (AB)	Suckers	22.20	19.30
			Halasur	11.986062	76.457599	9	Rasthali (N. Rasabale AAB)	Suckers	12.29	
			Hampapura	12.1260401	76.4978782	8	Ney Poovan (AB)	Tissue culture	23.42	
		Mysuru	Angatahalli	12.301937	76.252679	12	Ney Poovan (AB)	Suckers	20.00	11.71
			Belthur	12.318152	76.293404	10	Ney Poovan (AB)	Tissue culture	10.00	
			Kadanahalli	12.1414303	76.5082945	9	Grand Naine (AAA)	Tissue culture	0.00	
			Nanagalli	12.1270559	76.5429674	8	Ney Poovan (AB)	Tissue culture	16.86	
		Nanjangud	Golur	12.119497	76.701742	9	Rasthali (N. Rasabale AAB)	Suckers	58.33	45.39
			Heggadahalli	12.1247486	76.5734625	8	Rasthali (N. Rasabale AAB)	Suckers	30.00	
			Horalavadi	12.12075	76.706465	8	Rasthali (N. Rasabale AAB)	Suckers	41.00	
			Hullahalli	12.099637	76.562076	6	Rasthali (N. Rasabale AAB)	Suckers	43.25	
			Krishnapura	11.991083	76.631333	7	Rasthali (N. Rasabale AAB)	Suckers	60.57	
			Maraluru	12.1218387	76.5876762	8	Ney Poovan (AB)	Tissue culture	26.25	
			Tandavapura	12.172882	76.676111	7	Rasthali (N. Rasabale AAB)	Suckers	47.89	
			Tagadur	12.097229	76.793422	8	Rasthali (N. Rasabale AAB)	Tissue culture	41.20	
			Yechagalli	12.158502	76.651608	8	Rasthali (N. Rasabale AAB)	Suckers	60.00	
% average incidence in Mysuru District										25.47
2	Mandya	Maddur	Bookanakere	12.567102	76.527125	10	Ney Poovan (AB)	Suckers	8.33	6.14
			Madanaikanahalli	12.6147922	77.0834621	9	Ney Poovan (AB)	Tissue culture	10.00	
			S. hagalahalli	12.473492	77.126396	9	Grand Naine (AAA)	Tissue culture	0.00	
			Yaladahalli	12.460585	77.0101057	8	Ney Poovan (AB)	Tissue culture	6.25	
		Mandya	Halaguru	12.4818637	77.1431043	7	Ney Poovan (AB)	Suckers	13.50	8.05

Table 2: Continue...

Sl. No.	Name of the place			Latitude	Longitude	Stage of the crop (Months)	Variety or Cultivar	Planting material used	% disease incidence	Average disease incidence
	District	Taluk	Village							
			H. malligere	12.583901	76.869085	10	Ney Poovan (AB)	Tissue culture	10.67	
			Honaganahalli	12.577257	76.898479	9	Grand Naine (AAA)	Tissue culture	0.00	
		Nagamangala	Chandanahalli	12.816441	76.932197	8	Ney Poovan (AB)	Suckers	15.33	13.27
			Devalapura	12.823304	76.861193	7	Ney Poovan (AB)	Tissue culture	11.20	
		Pandavapura	Hiremarali	12.521849	76.702094	7	Ney Poovan (AB)	Tissue culture	12.25	4.08
			Kennalu	12.477869	76.675241	9	Grand Naine (AAA)	Tissue culture	0.00	
			Aladahalli	12.47505	76.86893	8	Grand Naine (AAA)	Tissue culture	0.00	
% average incidence in Mandya district										7.88
3		Chamarajanagar	Byadamudlu	11.883133	77.001676	9	Grand Naine (AAA)	Tissue culture	0.00	14.82
			Kaggalipura	11.914545	76.84515	9	Grand Naine (AAA)	Tissue culture	0.00	
			Kalanahundi	11.925369	76.86614	8	Ney Poovan (AB)	Suckers	28.00	
			Nanjedevanapura	11.919644	76.852627	7	Ney Poovan (AB)	Suckers	26.33	
	Chamarajanagar		Vagarapura	11.928253	77.027601	9	Ney Poovan (AB)	Tissue culture	19.78	
		Gundlupet	Madahalli	12.415201	77.01748	8	Grand Naine (AAA)	Tissue culture	0.00	6.67
			Vijayapura	11.815167	76.674722	8	Rasthali (N. Rasabale AAB)	Suckers	13.33	
		Kollegala	Chikkinduvadi	12.15124	77.200722	7	Ney Poovan (AB)	Suckers	14.50	10.20
			Jinakanahalli	12.175027	77.149365	9	Grand Naine (AAA)	Tissue culture	0.00	
			Kongarahalli	12.138362	77.236601	8	Grand Naine (AAA)	Tissue culture	0.00	
			Modahalli	12.127011	77.222911	9	Ney Poovan (AB)	Suckers	26.32	
% average incidence in Chamarajanagar district										10.56

district. Maximum average incidence of 13.27% was recorded in Nagamangala taluk followed by Mandya taluk (8.05%). Among the villages, Chandanahalli village of Nagamangala recorded highest incidence (15.33%). In Chamarajanagar district the disease incidence was 10.56%. The maximum average incidence recorded in Chamarajanagar taluk (14.82%) followed by Kollegala taluk (10.20%). Kalanahundi village of Chamarajanagar taluk noticed the highest wilt incidence (28.00%) in the cv. Ney Poovan.

The disease was present in all the districts with various levels of wilt incidence. The two-year data showed the average disease incidence ranging from 6.54 to 25.47%. Mysuru district recorded the highest average disease incidence of 15.00 and 25.47%. Cultivar Nanjangud Rasabale was severely infected and highest disease incidence was found in this cultivar. The wilt incidence was higher during 2017-18 showing the consecutive increase in the disease incidence compare to 2016-17. Nanjangud taluk of Mysuru district reported severe incidence level of panama wilt disease when compared to other places surveyed because of continuous growing of susceptible cultivar every year and the disease spread is more compared to other districts. The increased wilt incidence in this was also due to virulence of the pathogen. This highly virulent pathogenic form was more contagious and devastative due to lack of effective management practices. The incidence was confirmative with results of Narendrappa and Gowda(1995). In 1890 to 1960, about 40,000 ha of banana cv. Gros Michel were destroyed or abandoned in Latin America and Caribbean because of *Fusarium* wilt (Moore et al., 1999). Similar incidence level of 2-10% in Tamil Nadu was observed by Sivamani and Ganamanickam (1987). Prasadji (2006) surveyed different regions of Andhra Pradesh and reported that the disease incidence was highest in Silk group cultivars viz., Amritapani and Rashthali grown mainly in the coastal districts of Andhra Pradesh. Panama wilt disease has become most serious threat to banana cultivation because of TR4 strain in India. All the varieties of banana are susceptible to Foc race TR4. In this survey the spread or incidence of TR4 was not found in the surveyed districts.

4. Conclusion

The average *Fusarium wilt* disease incidence ranged from 6.54 to 25.47% and the highest disease incidence was 60.57%. The maximum disease incidence was found in Mysuru district. In Mysuru district, Nanjangud taluk had the highest disease incidence in the cultivar Nanjangud Rasabale followed by the cultivar Ney Poovan. The incidence was more predominant in the year 2017-18 because of the spread of the diseases and continuous growing of susceptible cultivar which led to the increased virulence of the pathogen.

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