

## Original Research Article

# Roving Survey of Panama wilt Disease (*Fusarium oxysporum* f. sp. *cubense*) of Banana in Bihar

## Abstract

A survey of Panama wilt of banana was conducted in different districts of Bihar ~~i.e. viz.,~~ Muzaffarpur, Vaishali, Samastipur, Darbhanga, Katihar, Purnea, Bhagalpur, Kishanganj and Saharsa. This disease was present in all districts with different levels of percent wilt index. In the Vaishali belt (Zone-I), the maximum percent wilt index was recorded in the Vaishali district (30-45 %) in cv. Malbhog (AAB) having sucker planting material in the year 2019-20. In the Koshi belt (Zone-II), the percent wilt index (external symptom) was highest in Purnea district (34-42%) in cv. Robusta (AAA) followed by district Saharsa (28-40%) and Kishanganj (25-38%). The lowest percent wilt index was found in districts Bhagalpur (22-38%) and Katihar (24-38%) in the year 2019 20. Panama wilt of banana ~~caused~~ ~~incited~~ by *Fusarium oxysporum* f. sp. *cubense* TR4 was recorded in the Koshi belt (Zone-II) having cv. Grand naine (AAA) and cv. Robusta (AAA) in Bihar only. While in Vaishali belt (Zone-I) was free from ~~the~~ incidence of *Fusarium* wilt of banana incited by *Fusarium oxysporum* f. sp. *cubense* TR4.

**Keywords:** *Fusarium oxysporum* f. sp. *cubense* (FOC), Panama wilt, Race, TR4.

## Introduction

Banana (*Musa paradisiacal* Linn.) is important perennial monocotyledonous fruit crop. ~~Which was It~~ belongs to family Musaceae. It produces ~~seed~~ ~~seedles~~ parthenocarpic fruit, ~~hence it is seedless~~. The cultivated hybrids are generally triploid  $2n=3x=33$ . The banana plant is a ~~tree-like~~ perennial herb, ~~which is tree-like~~. It has 9 to 15 leaves ~~measuring~~ ~~that are~~ up to 9 ft long and 2 ft wide. It is herb ~~hence~~, not having woody stem and pseudostem of parent plant ~~was dies~~ after every ~~cropping~~ ~~growing~~ season.

In India, bananas are prevailing and accepted fruits ~~erops~~ among the people, ~~which are liked both by poor and rich alike~~. It is ~~available~~ ~~accessible~~ around the year dissimilar to the occasional chance of ~~other~~ ~~different~~ ~~other~~ fruits. ~~Eighty seven percent~~ ~~87%~~ of the total bananas cultivated in subtropical and tropical areas are used for household utilization ~~just~~, while ~~only~~ ~~just~~ 13 % of the ~~complete~~ product is traded. ~~The B~~ banana yield is a critical crop at international markets ~~at a cost of fascinating US Doller~~ 4.7 Billion ~~USD~~ per year [1].

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Cultivated banana and plantain are ~~large herbaceous plants within the genus *Musa*, and~~ mostly propagated from ~~the mutants~~ found in the wild population. The major problem in achieving the high productivity of banana is its susceptibility to various fungal, bacterial, and viral diseases. ~~Thiese~~ diseases ~~reduces~~ ~~the~~ yield and degrades the marketability of banana fruits. Important diseases of banana are Panama wilt, bunchy top, bacterial wilt, Sigatoka and fruit rot. Among these, Panama wilt disease is considered to be very serious in banana-growing areas [2].

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The most important and economically destructive disease is "Panama wilt", ~~it is also~~ called as *Fusarium* wilt incited by *Fusarium oxysporum* f. sp. *cubense*. The Panama wilt disease is most destructive due to the emergence of new pathogenic races i.e. Tropical race (TR4). Incidence of Panama wilt disease ~~incidence~~ in the Dwarf Cavendish group (Grand naine) of bananas was known to occur in Bihar since 2015.

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## Materials and Methods

Intensive ~~roving~~ surveys were conducted in the major banana growing belt of Bihar i.e. Vaishali belt (Zone-I) including ~~comprises~~ Samistipur, Muzaffarpur, Vaishali and Darbhanga districts, and in the ~~while in~~ Koshi belt (Zone-II) including ~~ed~~ Katihar, Purnea, Bhagalpur, Kishananj and Saharsa districts. In each district, ~~many~~ banana orchards were surveyed ~~, where~~ and collected ~~wilt disease specimens were collected,~~ and calculated the percent wilt index.

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### Percent wilt index (PWI, external symptoms)

Percent wilt index (PWI) ~~per~~ ~~in each~~ plot was calculated as indicated by the ~~per~~ International Musa Testing Programme (IMTP rating scale) under the rating ~~in~~ 1-5 scale.

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Category	Reaction
1	Healthy
2	Little chlorosis and wilting with no petiole <u>bending</u> <del>buckling</del>
3	Moderate chlorosis and splitting of leaf base and wilting with some petiole <u>bending</u> <del>buckling</del>
4	Severe chlorosis and wilting, petiole <u>bending</u> <del>buckling</del> and stunting of newly emerged leaf
5	Dead

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Total sum of numerical rating

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—————  
Total number of plants observed × maximum category in the score

Percent Wilt index = \_\_\_\_\_ chart

### Percent Vascular Wilt Index (PVWI, Internal symptom)

For determination of internal symptom of Panama wilt using the percent vascular wilt index (PVWI) a-Affected plant was cut transversally and longitudinal section determined d the percent vascular wilt index (PVWI) as per IMTP rating in 1-6 scale.

Rating	Symptom
1	Corm completely clean
2	Discoloration of isolated point
3	1/3 parts of vascular tissue discoloration
4	Between 1/3 to 2/3 parts of vascular tissue discoloration
5	Greater than 2/3 parts of vascular tissue discoloration
6	Completely discoloration of vascular tissue

Percent vascular wilt index =  $\frac{\text{Total sum of numerical rating}}{\text{Total number of plants observed} \times \text{maximum category}} \times 100$   
in the score chart

### Collection of disease sample

During the survey sampling of the banana plants showing a typical external symptom of Panama wilt were collected from the farmer's fields. Each sample was placed in a paper towel and identified marked with the location and variety. The sample was brought at the Department of Plant Pathology, RPCAU, Pusa, laboratory, washed thoroughly in running tap water to remove soil particles and then kept in the refrigerator at 4 °C for further studies.

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### Results and Discussion

Panama wilt of banana incited by *Fusarium oxysporum* f. sp. *cubense* is a devastating disease in Bihar, due to the presence of new pathogenic race i.e. Tropical Race 4 (TR4). An intensive roving survey was conducted in October, November, and December of 2019-20 in all the major banana growing districts of Bihar. All the banana districts are categorized into two belts i.e. Vaishali belt (Zone-I) and Koshi belt (Zone-II). In Vaishali belt (Zone-I), includes four districts i.e. Samastipur, Muzaffarpur, Vaishali and Darbhanga. While in the Koshi-belt (Zone-II) includes five districts i.e. Bhagalpur, Katihar, Purnea, Saharsa, and Kishanganj. In the Vaishali belt, Panama wilt index percent was found highest in the Vaishali district in cv

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Malbhog(AAB) having sucker planting material (30-45 %) followed by Muzaffarpur (25-42 %), Samastipur (30-40 %) and Darbhanga (28-38 %) during 2019-20. Among the banana cultivars, highest percent of Panama wilt index was observed in cv Malbhog (AAB) (30-45%) and while lowest in cv Alpan (AAB) (12-18%). In the Dwarf Cavendish group of banana cultivars like Robusta (AAA) and Grand naine (AAA) were found free from Panama wilt disease during the survey.

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In the Koshi belt, the highest percent wilt index (External symptom) was found in cv. Robusta (AAA) in Purnea district (34-42 %) followed by Saharsa(28-40 %), Kishanganj(25-38 %), Bhagalpur (22-38 %) and Katihar(24-38 %). Panama wilt of banana incited by *Fusarium oxysporum* f. sp. *cubense* TR4 was only recorded in the Koshi belt (Zone-II) of Bihar only. While Zone-I was found free from the incidence of *Fusarium* wilt of banana incited by *Fusarium oxysporum* f. sp. *cubense* TR4. Data are presented in (Tables 1 and 2).

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Initial reports first time detects that of the presence of *Fusarium* wilt of banana are from Panama, Costa Rica, and Honduras [3].

The fungus *Fusarium oxysporum* f. sp. *cubense* was initially 1st time isolated in India from diseased affected banana plant tissue in Bengal. Panama wilt resistance cultivars were Amritsagar, Kabuli, Agnishwar and Chinchamapa found [4].

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Banana cultivars Chinnamondan plantains at Sholavandan and Arapalayam, Madras, were affected with Panama wilt nearly 30 % of the total plants were damaged. Later, Wollenweber found that the causal agent was as *Fusarium oxysporum* f. sp. *cubense* var Inodoratum [5].

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Poona was the major source of spreading of *Fusarium* wilt attacking the locally grown Son variety [6]. Panama wilt was extensively investigated in the agro-ecological conditions of Bihar [7].

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*Fusarium* wilt of banana spread with-in the country by infected planting material in the South African population. The availability of single planting material and narrow diversity of the pathogen fungus showed it unlikely to be reduced reduce through disease management practices, including inciples include genetic host resistance [8].

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Recent presence of profoundly destructive type virulent race of the fungus *Fusarium oxysporum* f. sp. *cubense* in Asia, was identified, recognized as the tropical race 4 (TR4). In the 1990s, it affected the Cavendish banana in Malaysia and Indonesia in year 1990s and in the Northern Territory of Australia it became epidemic in the years from 1997 to 1999. In the year 2004, serious infection in the banana crop by this race was reported in Guangdong province, South China due to TR4 [9].

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*Fusarium oxysporum* f. sp. *cabense* TR4, which affects banana crops in Asia, ~~which is~~ a major threat to the banana industry. In Latin America, ~~where is almost 100 % hundred percent~~ ~~is planted to~~ Cavendish subgroup of banana ~~which is highly susceptible~~ ~~is susceptible~~ to TR4 [10].

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In 2013, race TR4 was found in Jordan, the ~~first 1st~~ official report ~~of~~ the presence of TR4 in the Southeast Asia-Pacific region. In 2014 survey conducted ~~then~~ found another infected area ~~in the n~~North of the original outbreak [11-12]. ~~r-~~Reporting ~~ed~~ that TR4 is a ~~noteworthy serious problem~~ ~~issue~~ for the Cavendish group of banana developing zones in Pakistan ~~noting that~~ ~~and detailed that~~ cv. Basrai to be ~~affected~~ ~~influenced~~ by TR4 in specific ~~areas~~ ~~zones~~ in the Sindh territory ~~and creating~~ ~~e-~~devastation for the banana industry and ~~devastating~~ ~~seriously affecting the~~ ~~economically in~~ Pakistani economy.:-

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In 2018, tropical race 4 (TR4) as ~~identified~~ ~~confirming~~ in Myanmar. The samples were analyzed from the isolates ~~collected in~~ Laos, Vietnam and Myanmar, ~~providing ed~~ proof ~~that of~~ ~~particularthe~~ TR4 strain in these countries ~~could have been as may be~~ introduced from China [13].

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~~Detailed studies -determined that detailed~~ TR4 strain ~~was identified~~ in lower Carmel coastal plain (1,200 ha), Jordan valley (800 ha) of Israel and western Galilee (500 ha) [14].

Surveys ~~in -of~~ various districts ~~of~~ Sri Lanka (Rajanganaya, Kandy, Kegalle, Rambukkana, Warakapola, Matale, Dambulla, Attanagalla, Ratnapura, Hamabanthota and Udawalawe) ~~have determined~~ ~~to differentiated~~ banana developing regions infected by *Fusarium oxysporum* f. sp. *cabense* [15].

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Presence of *Fusarium oxysporum* f. sp. *cabense* TR4 ~~has been identified~~ in Barari village in Katihar, district of Bihar. The incidence of Panama wilt disease ranged from 2 to 26.6 % in Cavendish banana cvs. Robusta and Grand naine. There was a variation in percent wilt index ~~between banana cultivars,~~ ~~from cultivar to cultivar in banana.~~ ~~Presently,~~ ~~At present,~~ ~~bb~~ based on the surveys, the presence of new pathogenic race TR4 ~~is has~~ a serious threat to the banana industry in Bihar [16]. The first incidence of Panama wilt of banana ~~was reported at in~~ Bihar (Hazipur) ~~was reported~~ [17].

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Singh (2002) described the prevalence of *Fusarium oxysporum* f. sp. *cabense* (FOC) race 1 ~~and~~ 2 in banana-growing areas of Vaishali and Samastipur districts of Bihar, India. Race 1 of FOC ~~had been previously reported~~ ~~was already reported,~~ ~~but while~~ the existence of race 2 was ~~reported~~ probably ~~probably~~ for the first time.

Singh (2005) reported that Malbhog (AAB, silk) banana was becoming extinct in the Vaishali area of Bihar, due to wilt. The traditional growers have discarded Malbhog in favour of other cultivars like Chinia and Alpan.

Singh (2003) first reported a breakage of resistance in Alpan (AAB, Mysore group) to FOC race 1 ~~which was~~ earlier considered resistant to wilt. Its incidence varied from 0-16 % ~~percent.~~

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*Fusarium oxysporum* f. sp. *ubense* (FOC) ~~was~~ present in Uttar Pradesh in September 2017 [18].

Surveyed Panama wilt affected areas in Bihar during 2016-17 to 2018-19 ~~showed that~~ ~~the~~ highest percent wilt index was recorded in cv. Malbhog (AAB) from 36-40 % to 30-34 % during 2016-17 to 2018-19, while, in Samastipur districts, ~~and~~ lowest percent wilt index was found in cv. Alpan (AAB) from 21-23 % to 16-17 % during 2016-17 to 2018-19 in the Darbhanga district of Vaishali belt (Zone-I). In the Koshi belt (Zone-II), the highest percent wilt index was recorded in cv. Grand naine (AAA) from 23-25 % to 28-34 % during 2016-17 to 2018-19 of Bhagalpur district and lowest percent wilt index was found in cv. Basrai (AAA) from 9-11 % to 14-18 % during 2016-17 to 2018-19 of Kishanganj district [19].

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Plate-1. Panama wilt infected banana orchards at Dhamdaha village, ~~in~~ Purnia district of Bihar

**Table -1. Scenario of Panama wilt of banana in Vaishali belt (Zone I) of Bihar during 2019-20**

Districts	Variety	Genomic group	No. of orchards surveyed	Planting material	External symptoms (PWI 1-5 IMTP rating scale)
Samastipur	Malbhog	(AAB)	26	Sucker	30-40
	Alpan	(AAB)		Sucker	18-25
	Champa	(AAB)		Sucker	20-35
	Kothia	(ABB)		Sucker	25-30
	Robusta	(AAA)		Sucker	0
	Grand naine	(AAA)		Tissue Culture	0
Muzaffarpur	Malbhog	(AAB)	28	Sucker	25-42
	Alpan	(AAB)		Sucker	26-30
	Kanthali	(AAB)		Sucker	25-34
	Champa	(AAB)		Sucker	20-28
	Robusta	(AAA)		Sucker	0
	Kothia	(ABB)		Sucker	22-34
	Chinia	(AAB)		Sucker	22-25
	Grand naine	(AAA)		Tissue Culture	0
Vaishali	Chinia	(AAB)	24	Sucker	25-38
	Malbhog	(AAB)		Sucker	30-45
	Alpan	(AAB)		Sucker	14-18
	Grand naine	(AAA)		Tissue Culture	0
	Chini Champa	(AAB)		Sucker	20-24
	Kothia	(ABB)		Sucker	14-20
Darbhanga	Chinia	(AAB)	22	Sucker	22-30
	Malbhog	(AAB)		Sucker	28-38
	Robusta	(AAA)		Sucker	0
	Alpan	(AAB)		Sucker	12-18
	Grand naine	(AAA)		Tissue Culture	0

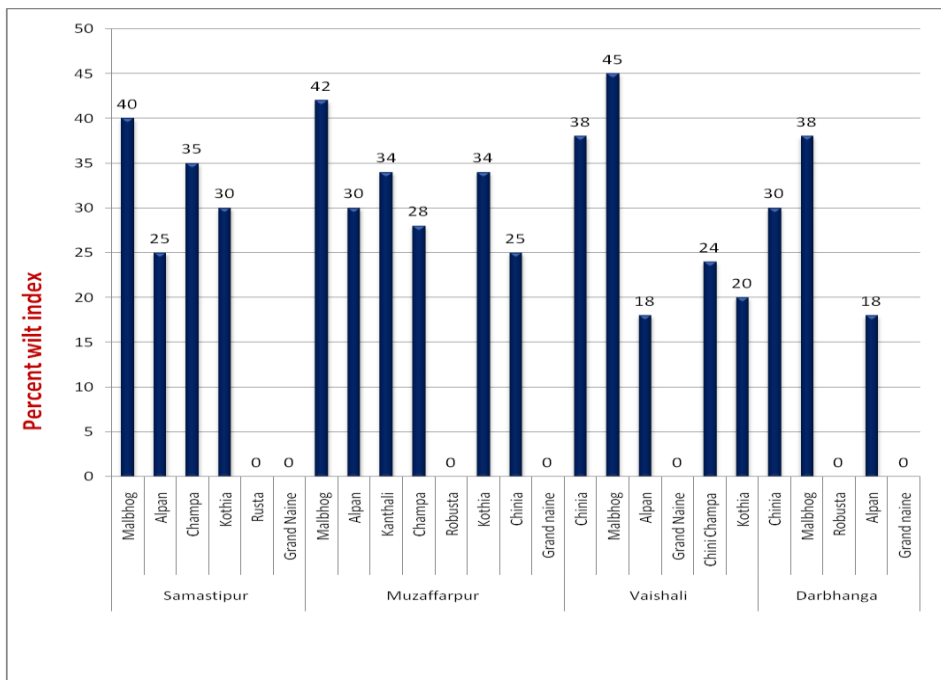


Fig. 1. Scenario of Panama wilt of banana in Vaishali belt (Zone I) of Bihar during 2019-2020

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Table -2. Scenario of Panama wilt of banana in Koshi belt (Zone- II) of Bihar during 2019-2020

Districts	Variety	Genomic group	No. of orchards surveyed	Planting material	External symptoms (PWI 1-5 IMTP rating scale)
Katihar	Robusta	(AAA)	25	Sucker	24-38
	Grand naine	(AAA)		Tissue culture	26-35
Purnea	Grand naine	(AAA)	30	Tissue culture	24-38
	Robusta	(AAA)		Sucker	34-42
Bhagalpur	Grand naine	(AAA)	28	Tissue culture	22-38
	Robusta	(AAA)		Sucker	26-36
Saharsa	Robusta	(AAA)	26	Sucker	26-38
	Grand naine	(AAA)		Tissue culture	28-40
Kishanganj	Robusta	(AAA)	15	Sucker	25-38
	Grand naine	(AAA)		Tissue culture	28-36

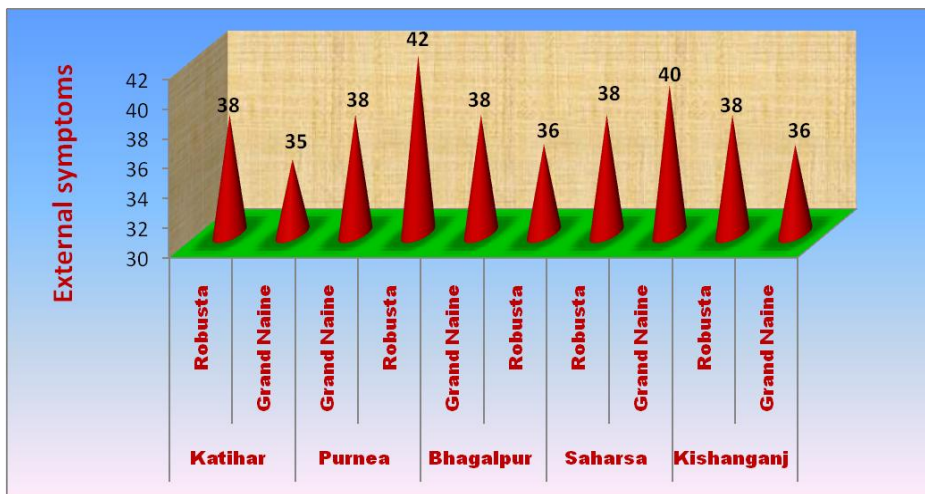


Fig.2. Scenario of Panama wilt of banana in Koshi belt (Zone II) of Bihar during 2019-20

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#### Literature cited

1. Tripathi L. Biotechnology in Musa improvement. In: Pillay M, Tenkouano A, editors. Banana breeding: progress and challenges. London: CRC press Taylor & Francis Group; p. 2011; 219-236.
2. Singh SK. Annual Report of AICRP. Tropical fruits, RAU, Pusa Centre. 2005; 63.
3. Reinking OA. Soil and *Fusarium* disease. 2bl. Bakt., Abt. II.1935; 91:11-15: 243-255.
4. Hector GP. Annual report of the first economic botanist, Bengal for the year 1926-27. Ann. Rept. Dept. Agric., Bengal. 1927; 1: 35-38.
5. Ayyangar CR. Study of a *Fusarium* isolate from wilted plantains. Madras. Agric. Dept. Year Book 1930 ; 16-21.
6. Uppal BN. India. Plant diseases in the Bombay presidency. *International Bulletin of Plant Protection*. 1933; 8 : 187.
7. Mallik PC, Mehta PP. Banana wilt in Bihar, *Sci. and Cult*. 1963; 29: 245.
8. Visser M, Gordon T, Fourie G and Viljoen A. Characterization of South African isolates of *Fusarium oxysporum* f. sp. *ubense*. *South African Journal of Science*.2009;106: 3/4:154-160.
9. Molina AB, Fabregar E, Snohin VG, Yi G, Viloen A. Recent occurrence of *Fusarium oxysporum* f. sp. *ubense* Tropical race 4 in Asia. *Acta Horti*. 2009; 828:109-116.

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10. Pocasangre LE, Ploetz RC, Molina AB, Vicente LP. Raising awareness of the threat of *Fusarium* wilt tropical race-4 in Latin America and the Caribbean. *Acta Horticulturae*. 2011; 897:331-337.
11. Ploetz R. Tropical race 4 of Panama disease in the Middle East. *Phytoparasitica*. 2015; 43:283-293.
12. Mushammad, Aish, Hussain, Khanzad, KA, mondo L, Ali M, Yasmin, T, Hyder MZ, Molecular characterization of *Fusarium oxysporum* f. sp. *ubense* Tropical race 4 causing Panama disease in Cavendish banana in *Pakista. Pak. J. Agri. Sci.* 2017; 54:1:1-8.
13. Zheng SJ. New Geographical Insights of the Latest Expansion of *Fusarium oxysporum* f. sp. *ubense* Tropical Race 4 Into the Greater Mekong Subregion. *Frontiers in Plant Science*. 2018;9:457.
14. Maymon M. First Report of *Fusarium oxysporum* f. sp. *ubense* Tropical Race 4 causing *Fusarium* Wilt of Cavendish Bananas in Israel. *Plant Disease* .2018; 59:348.
15. Rajapkse RG, Sakalasuriya SM, Kahawatta J, Sumanapala RV, Edirimanna SP. Identification of races of *Fusarium* wilt pathogen of banana in Sri Lanka and selection of resistant germplasm. *Annals of the Sri Lanka Department of Agriculture*. 2005; 7:225-232.
16. Thangavelu R, Mostert D, Gopi M, Ganga Devi P, Padmanaban B, Molina AB, Viljoen A. First detection of *Fusarium oxysporum* f. sp. *ubense* tropical race 4 (TR4) on Cavendish banana in India. *Eur J Plant Pathol*. 2019;154:777–786.
17. Roy RS, Sharma C. Diseases and pest of banana and their control, *Indian S. Hort.* 1952;9: 39-52.
18. Damodaran T, Mishra VK, Jha SK, Gopal R, Rajan S, Ahmed I. First Report of *Fusarium* wilt in banana caused by *Fusarium oxysporum* f. sp. *ubense* Tropical Race 4 in India. *Plant Disease "First Look"* paper.2019.
19. Shukla DN, Singh SK. First ever report of Tropical Race 4 of *Fusarium oxysporum* f. sp. *ubense* in dwarf cavendish group of bananas in Bihar state of India. National symposium on Recent challenges and opportunity in sustainable plant health management. organized by Indian Phyto pathological Society, New Delhi at Institute of Agricultural Sciences, BHU, Varanasi, UP. February26-28; 2019.

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