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Survey for fusarium wilt disease incidence of tomato in Andhra Pradesh state

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Abstract
Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family and is the second most important fruit or vegetable crop next to potato (*Solanum tuberosum* L.). It is cultivated for fresh fruit and processed products. Tomatoes contain many health-promoting compounds including vitamins, carotenoids, and phenolic compounds. In addition to its economic and nutritional importance, tomatoes have become the model for the study of fleshy fruit development. In this article a total of 27 fields from three districts were surveyed during kharif and Rabi 2017-2018, and recorded with wide spread occurrence of fusarium wilt disease of tomato. List of districts surveyed with mandals and villages along with GPS were presented. Different types of symptoms *viz*, wilting, yellowing, initial yellowing on one side of the plant at lower leaves and branches, drooping of leaves, stunted in growth, loss of leaf turgidity, browning and dead of whole plant on advanced stage of infection were observed during the survey.

Keywords: *Solanum tuberosum*, fusarium wilt, *Fusarium oxysporum*, yield

Introduction

Tomatoes belong to a large family of plants called Solanaceae, which contain many important food crops [1]. Tomatoes were born in the Andes Mountains of South America. Cultural forms were first introduced to Europe by the Spaniards in the 16th century and then introduced to South and East Asia, Africa and the Middle East, and around the world [1]. Global tomato production in 2001 ranged from an estimated 3.9 million hectares to approximately 4,444,105 million tonnes of fresh fruit. Due to the short-lived crops, high yields and economical attractiveness of the cultivated area of is increasing daily [1]. Since local tomato varieties have not been developed or developed in Ethiopia, all cultivars have been imported [2]. Tomatoes are cultivated in many parts of the country and are also the main vegetable, their production since becoming the most profitable crop, which brings high incomes to smallholders compared to other vegetables [3].

Tomato belongs to a large family of plants called the Solanaceae which contains many important food crops tomato [1]. Tomato was originated in South America Andes. The cultivated form first taken to Europe by Spanish in the 16th century and from there introduced into southern and eastern Asia, Africa and the Middle East and distributed throughout the world [1]. World tomato production in 2001 was about 105 million tons of fresh fruit from an estimated 3.9 million hectare. As it is a short duration crop, gives a high yield and economically attractive, the area under cultivation is increasing daily [1]. In Ethiopia, no local cultivars of tomato have evolved or been developed and hence all cultivars grown are introduced [2]. Tomato grows in many parts of the country and also among the most important vegetable crops and its production has shown a marked increase since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops [3].

The main tomato producing states in the country are are Madhya Pradesh, Andhra Pradesh, Karnataka, Gujarat, Odisha, Chhattisgarh, West Bengal, Tamil Nadu, Bihar, Maharashtra, Uttar Pradesh, Haryana and Telangana. These states account for about 90% of the country's total production. Table 1 details the seasonality and harvest time of domestic tomato harvests. According to the Second Extended Estimate, total tomato production across India in 2019-20 is estimated to be 205.72 lactones, 8% higher than normal and last year's production (Table 2). Rabi tomato harvest continues in the major Rabi growing states Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Gujarat, Chhattisgarh, Maharashtra. Sowing of Kharif Tomato has just begun in the southern states (Karnataka, Andhra Pradesh, Tamil Nadu, Telangana). Rabi / summer harvest ends in the second to third weeks of June, and early Harif products are just on the market, so July offers may be lower and prices may be higher as a result. By end of July/August, more produce/supplies are expected. Table 3 shows the monthly market arrivals and average wholesale prices of tomatoes in the states in June 2020, May 2020 (previous month), and June 2019 (corresponding month of the previous year). Arrivals in June 2020 were 21% higher than in June 2019 and higher than in May 2020 (25.70%). Prices were kept low due to increased production this year [Prices in June 2020 were 37% lower than in June 2019]. Table 4-6 shows all monthly market arrivals in India, average wholesale prices from January 2016 to June 2020, and the market in Delhi.

Plant diseases cause serious crop loss, and *Fusarium oxysporum* makes agriculture heavily dependent on proper pest control. Wilt disease in tomatoes can be caused by fungi, bacteria, viruses, nematode pathogens, and biological factors. Determining which agent is responsible can be important in defining an appropriate management strategy. Wilt describes the external and internal symptoms caused by each pathogen on the host. Tomato wilt disease such as growth patterns in the field and environmental conditions such as temperature and humidity contribute to the progression of the disease [1]. Symptoms of Fusarium wilt

disease, wilting of the oldest leaves, and ultimately the entire dry plant were particularly pronounced in dry, hot weather. Initially, the first signs of the disease were found in individual seedlings, then spots of dead tissue on the entire surface of the tomato variety. Young plants are more susceptible to diseases exacerbated by poor rooting of seedlings. Disease is a major cause of crop loss and damage that can be caused by many phytopathogenic (causes of disease) organisms. Plant pathogens are specific to a particular plant host and are called special forms. *Fusarium oxysporum* has more than 100 special forms, most of which have specific hosts that can cause disease through *Fusarium oxysporum*. The fungus is the soil borne hyphomycete and is one of more than 100 *F. oxysporum* that causes vascular wilts of flowering plants

Fusarium wilt is caused by soil-borne fungus *Fusarium oxysporum* was the most common and harmful disease of field tomatoes. The most common symptom of Fusarium wilt disease is the fungal *Fusarium oxysporum*, a fungal disease that affects tomatoes, which destroys the blood vessels that carry plant water through the roots. When the infection spreads to the stems and leaves, the flow of water is restricted and the leaves die and turn yellow. Symptoms often appear in the second half of the growing season, first in the lower (older) leaves. As the disease progresses, the young leaves are also affected and the plant eventually dies. Often, only one branch or one side of the plant is symptomatic. Symptoms of the disease appear as yellow spots on the lower lobes, wilting and eventually falling [1]. The pathogen is soil-borne and is found in most tomato-growing areas, where infected leaves begin to sag, bend, and turn yellow. Symptoms of the disease occur during flowering and fruiting, and due to the specific vascular tissue infected with the pathogen, the leaves on one side of the plant are usually more severe than the leaves on the other side [2].

Multiple roving surveys were carried out at *kharif* and *rabi* of 2017-18, in major tomato growing districts of Andhra Pradesh State, to assess the fusarium wilt disease incidence of tomato and to collect diseased samples infected by *Fol*, under field conditions. Per cent wilt disease incidence and characteristic symptoms were recorded during different stages of the tomato crop *i.e.*, growth stage, flower initiation, fruit set and at harvesting stage. Tomato hybrids (US 440, PHS 448, Arka raksha, sahoo) and local varieties (laxmi, ranjit, kapila) were popularly grown in the surveyed areas. Field transplantations were usually done in the surveyed areas between last week of May to first week of June for *kharif* season and third week of November to first week of December for *rabi* season in the surveyed areas depending on irrigation sources.

A total of 27 fields from three districts were surveyed during kharif and Rabi 2017-2018, and recorded with wide spread occurrence of fusarium wilt disease of tomato. List of districts surveyed with mandals and villages along with GPS were presented (Table 7). Different types of symptoms *viz*, wilting, yellowing, initial yellowing on one side of the plant at lower leaves and branches, drooping of leaves, stunted in growth, loss of leaf turgidity, browning and dead of whole plant on advanced stage of infection were observed during the survey.

The survey results (Table 7) revealed that overall fusarium wilt disease incidence during *kharif* 2018-19in State ranged from 5.13 per cent (Seethampeta mandal), West Godavari district to 14.55 per cent (Amalapuram mandal), East Godavari district and, in *rabi* 2018-19, disease incidence ranged from 10.98 per cent (Jharasanagm mandal), West Godavari district to 29.00 per cent (Ibrahimpatnam mandal), Krishna district. In present investigation it is observed that highest fusarium wilt disease incidence was observed during *rabi*, 2018-19 compared to *kharif*, 2018-19as warm climatic conditions favours the disease development which is usually @ 28ºC.

Table 1: Seasons, transplanting & harvesting period and production (Agriculture Year: July-June, Production in Lakh Tonnes)

Season	Transplanting	Harvesting Period	Production	
			2018-19 (Final)	2019-20 (2nd Ad. Est.)
Kharif	May-July	July-November	51.04	49.62
Rabi	October-February	December-June	139.03	154.86
Total			190.07	205.72

Source: As reported by State Directorates of Horticulture for 2018-19 and 2019-20

Table 2: State-wise tomato production in the country (Production in '000 Tonnes)

State/Uts	Five year Average (2014-15 to 2018-19)		2018-19		2019-20 (2nd Ad. Est.)	
	Production	% Share	Production	% Share	Production	% Share
Andhra Pradesh	2687.78	14.21	2503.49	13.17	2667.43	12.96
Madhya Pradesh	2423.57	12.81	2516.08	13.24	2655.29	12.91
Karnataka	2021.80	10.69	2030.04	10.68	2163.00	10.51
Odisha	1318.68	6.97	1304.18	6.86	1306.00	6.35
Gujarat	1342.81	7.10	1367.57	7.19	1378.78	6.70
West Bengal	1224.09	6.47	1268.57	6.67	1271.35	6.18
Bihar	992.62	5.25	964..48	5.07	964.20	4.69
Maharashtra	962.19	5.09	860.75	4.53	1040.00	5.06
Telangana	1027.85	5.43	891.69	4.69	820.62	3.99
Haryana	677.98	3.58	650.63	3.42	494.53	2.40
Uttar Pradesh	750.07	3.96	844.43	4.44	880.76	4.28
Tamil Nadu	660.91	3.49	814.43	4.28	1592.31	7.74
Total of Above States	16090.34	85.05	16014.48	84.25	17234.27	83.77
Other States	2828.04	14.95	2992.76	15.75	3338.24	16.23
All India	18918.39	100.00	19007.24	100.00	20572.51	100.00

Source: State Directorate of Horticulture

Table 3: State-wisemarket arrival and weighted average wholesale prices of tomato

States	June, 2020		May, 2020		June, 2019	
	Market Arrivals (in Tonnes)	Average Wholesa le Prices (Rs/Qtl.)	Market Arrivals (in Tonnes)	Average Wholesal e Prices (Rs/Qtl.)	Market Arrivals (in Tonnes)	Average Wholesal e Prices (Rs/Qtl.)
Karnataka	115038.00	1274.2	71774.00	489.21	38772.00	1699.12
Uttar Pradesh	30110.00	971.03	35189.60	954.63	34764.00	1820.77
Andhra Pradesh	23275.00	1277.51	19520.10	498.79	6115.22	1803.59
Gujarat	18368.10	1853.05	12101.00	867.61	24942.60	2238.02
NCT of Delhi	13050.30	755.68	7758.48	552.62	15299.30	1310.22
Chhattisgarh	12065.00	1742.99	11118.00	937.63	8641.00	2411.64
Telangana	8765.62	1668.33	6770.03	567.94	8563.09	2705.74
Haryana	7287.02	694.53	7957.78	695.71	8148.31	1425.72
Rajasthan	7073.52	908.63	6548.17	662.79	9050.29	1269.5
Maharashtra	6944.00	1619.42	6502.00	582.60	39777.00	1730.64
Odhisa	6794.73	2722.43	8117.16	1844.26	4805.54	3845.93
Punjab	5787.70	543.83	4817.64	664.86	8832.43	855.79
Kerala	4807.09	2649.44	3222.91	1437.80	4342.81	3506.56
Jammu and Kashmir	4246.40	1472.48	5709.30	1632.41	1496.05	2014.15
West Bengal	3552.45	2649.63	4370.48	1630.15	4413.59	3761.50
Madhya Pradesh	3380.24	1294.32	1419.46	685.76	4775.79	1197.64
Uttrakhand	2518.30	968.62	4484.20	954.85	2692.80	622.35
Himachal Pradesh	1490.47	1211.94	1289.33	1176.48	1273.41	1711.94
Chandigarh	1175.10	NA	902.94	NA	1367.38	1071.31
Tripura	394.14	5550.25	207.75	2378.34	32.90	4106.47
Nagaland	75.00	3000.00	124.7	2785.25	8.5	6905.88
TOTAL:	276431.00	1764.54	219905.03	1099.98	228464.00	2812.94

Source: 1. Arrivals:http://agmarknet.gov.in/PriceTrends/SA_TotalArrival.aspx
2. Prices:http://agmarknet.gov.in/PriceTrends/SA_Pri_Month.aspx

Table 4: All India monthly arrivals of tomato Arrivals in '000 Tonnes

Month	All India arrivals				
	2016	2017	2018	2019	2020
January	234.60	235.33	315.69	239.64	242.25
February	219.81	198.81	277.57	209.22	212.93
March	241.82	213.84	273.20	211.17	199.04
April	237.94	270.25	239.62	209.77	169.06*
May	338.76	325.09	303.30	207.96	219.91
June	291.48	277.80	338.44	228.46	276.43
July	288.92	219.84	392.71	264.80	
August	391.04	235.16	417.35	303.75	
September	411.59	365.19	450.24	357.98	
October	385.85	327.06	443.29	351.01	
November	362.09	231.20	300.57	319.28	
December	281.27	274.73	275.37	299.16	

*less arrivals due to disruption because lockdown
Source:http://agmarknet.gov.in/PriceTrends/SA_TotalArrival.aspx

Table 5: Monthly arrivals of tomato in Delhi Arrivals in '000 tonnes

Month	Arrivals of Delhi				
	2016	2017	2018	2019	2020
January	21.16	22.97	21.79	21.37	22.27
February	24.24	23.63	21.80	21.28	14.65
March	23.79	23.51	26.28	21.58	14.96
April	24.11	21.58	19.82	20.98	12.17
May	21.92	17.45	21.73	16.38	7.76
June	14.29	14.67	21.57	15.30	13.05
July	14.90	13.18	19.76	17.03	
August	22.04	13.11	23.61	22.06	
September	18.64	19.03	22.66	20.16	
October	25.03	18.52	23.17	17.83	
November	21.02	16.94	22.03	23.06	
December	24.24	19.19	23.68	20.90	

Source:http://agmarknet.gov.in/PriceTrends/SA_TotalArrival.aspx

Table 6: All India monthly average wholesale prices of tomato (Prices in Rs/Quintal)

Month	2016	2017	2018	2019	2020
January	1742.0	1294.4	1705.9	1811.5	1522.2
February	1331.5	1177.5	1293.1	1552.2	1306.3
March	979.1	1279.0	1160.0	1986.2	1207.6
April	1246.9	1440.5	1140.5	2112.1	1291.9
May	2297.3	1427.5	1266.1	2747.6	1099.9
June	2995.3	2026.1	1764.2	2812.9	1764.5
July	2658.4	3983.7	2044.5	3074.8	
August	1876.0	3927.0	1750.6	2718.8	
September	1797.8	2543.5	1588.6	2236.7	
October	1839.8	2712.1	1568.5	2861.6	
November	1682.2	3537.1	1639.5	2647.1	
December	1181.1	2147.8	1399.2	1557.7	

Source:http://agmarknet.gov.in/PriceTrends/SA_Pri_Month.aspx

Table 7: List of villages surveyed.

S.No.	District	Mandals	Villages	GPS
1.	East Godavari (NTZ)	Amalapuram	Amalapuram	16.5775° N, 82.0031° E
			Nadipudi	16.6488° N, 81.8340° E
			Palagummi	16.4744° N, 81.8798° E
		Kothapalle	Kothapalle	15.0176° N, 78.6136° E
			Subbampeta	17.0591° N, 82.3153° E
			Ponnada	17.1196° N, 82.3642° E
		Ramachandra puram	Ramachandra puram	16.8372° N, 82.0325° E
			Kandulapalem	16.8180° N, 82.0850° E
			Venkatayapalem	17.5641° N, 81.2574° E
2.	West Godavari (CTZ)	Yelamanchili	Yelamanchili	17.5472° N, 82.8573° E
			Abbirajupalem	16.5021° N, 81.8416° E
			Medapadu	17.0054° N, 82.0993° E
		Kovvur	Kovvur	17.0126° N, 81.7274° E
			Chidipi	17.0912° N, 81.6816° E
			Seethampeta	17.1202° N, 81.3434° E
		Achanta	Achanta	16.6020° N, 81.8077° E
			PenuLingagudemi	16.5847° N, 81.8211° E
			Bimalapuram	16.5558° N, 81.8491° E
3.	Krishna (STZ)	Agiripalli	Agiripalli	16.6800° N, 80.7852° E
			Adavinekkalam	16.6312° N, 80.7235° E
			Edara	16.7274° N, 80.7526° E
		Ibrahimpatnam	Ibrahimpatnam	16.5928° N, 80.5228° E
			Elaprolu	16.6019° N, 80.5584° E
			Jupudi	16.6042° N, 80.4980° E
		Penuganchiprolu	Penuganchiprolu	16.9017° N, 80.2475° E
			Anigandlapadu	16.8938° N, 80.2875° E
			Lingagudem	16.9010° N, 80.2175° E

Fusarium wilt disease incidence in east Godavari dist.

The survey results revealed that (Table 8), tomato crop grown in East Godavari district (NTZ) was affected with fusarium wilt disease in both *kharif* and *rabi* 2018-19with wide variation in per cent disease incidence. Over all fusarium wilt per cent disease incidence at mandal level during *kharif* 2018-19 ranged from 7.48 per cent (Kothapalle mandal) to 14.55 per cent (Amalapuram mandal) and in *rabi*, 2018-19 ranged from 24.44 per cent (Amalapuram mandal) to 27.86 per cent (Indervelli mandal). Per cent wilt disease incidence of tomato is recorded more in *rabi* season than in *kharif*, 2018-19.At village level during *kharif* 2017-18, wilt disease incidence ranged from 2.50 per cent (Muthunur village) to 21.33 per cent (Amalapuram village) and in *rabi*,2018-19, disease incidence ranged from 22.00 per cent (Nadipudi village) to 32.30 per cent (Tejpur village).Within mandals *viz*, in Amalapuram mandal, wilt disease incidence during *kharif*, 2018-19ranged from 9.00 per cent (Palagummi village) to 21.33 per cent (Amalapuram village) with overall per cent disease incidence of 14.55. In *rabi*, 2017-18, disease incidence ranged from 22.0 per cent (Nadipudi village) to 25.33 per cent (Amalapuram village) with overall per cent disease incidence of 24.45 in Amalapuram mandal. Fusarium wilt disease incidence was observed more pronouncedly observed and recorded during at flowering and fruit set stage and more incidence in *rabi*, 2018-19 only. In Indervelli mandal, wilt disease incidence in *kharif*, 2018-19ranged from 2.50 per cent (Muthunur village) to 14.65 per cent (Tejpur village) with overall per cent disease incidence of 7.48 per cent. During *rabi*, 2017-18, disease incidence ranged from 25.00 per cent (Indervelli village) to 32.30 per cent (Tejpur village) with overall disease incidence of 27.86 per cent. Fusarium wilt disease incidence was observed in this mandal more pronouncedly during flowering and fruit set stage.

In Ramachandra mandal, wilt disease incidence in *kharif*, 2018-19 ranged from 10.00 per cent (Ramachandra village) to 15.33 per cent (Venkatayapalem village) with over all

disease incidence of 12.11 per cent and in *Rabi*, 2018-19, ranged from 24.0 per cent (Kandulapalem village) to 29.60 per cent (Venkatayapalem village) with overall disease incidence of 27.30 per cent. Disease incidence was observed more pronouncedly during growth, flowering and fruit set stage.

Table 8: PDI (%) of wilt disease in east Godavari district

S.No	Mandal	Name of the village	Fusarium wilt disease (2018-19)				Average wilt incidence (PDI)		Previous crops grown	Irrigation facility	Cultivars grown	Type of soils
			Kharif		*Rabi*		*kharif*	*Rabi*				
			PDI (%)	Crop stage	PDI (%)	Crop stage	PDI	PDI				
1	Amalapuram	Amalapuram	21.33	Fi & Fs	25.33	Fi & Fs	14.55	24.44	Cotton & soyabean	Open	Karishma, bharat (local), 440	Black cotton
2		Nadipudi	13.33	,,	22.00	,,			Cotton & soyabean	Open borewells & drip	PHS 448	
3		Palagummi	9.00	Gs	26.00	,,			Soyabean	Drip & bore well	440,UAS 448,810	
4	Indervelli	Kothapalle	5.30	Gs	25.00	,,	7.48	27.86	Brinjal, Beans, cabbage	Open & drip	440, 810 dutch	Black cotton
5		Muthunur	2.50	Gs	26.30	,,			Soyabean & cotton	open	440, local	
6		Tejpur	14.65	Fi &Fs	32.30	,,			Brinjal, bhendi,cabbage & beans	drip	440	
7	Ramachandra	Ramachandra	10.00	Fi	28.30	,,	12.11	27.30		drip	UAS 448	Black cotton
8		Kandulapalem	11.00	,,	24.00	,,			Soybean,Bengal gram,cotton	Open wells & drip	448,440 & local variety	
9		Venkatayapalem	15.33	,,	29.60	,,			Bengal gram	drip	448	
Mean PDI of fusarium wilt			11.38		26.53							
(Fi- Flower initiation, Fs- Fuit set, Gs- Growth stage)												

Fusarium wilt disease incidence of tomato in west Godavari district.

Tomato crop grown in West Godavari district was affected with fusarium wilt disease and the survey results revealed that (Table 9) overall mean per cent disease incidence in *kharif*, 2018-19 ranged from 5.13 per cent (Zaheereabad mandal to 6.73 per cent (Yelamanchili mandal) and in *rabi*, 2018-19 ranged from 10.98 per cent (Jharasanagam mandal) to 22.30 per cent (Yelamanchili mandal).

Per cent wilt disease incidence during *kharif*, 2018-19ranged from 2.30 per cent at Kovvur village (Jharasanagam mandal) to 11.60 per cent in Jharasanagam village (Jharasanagam mandal) and during *rabi*, 2018-19 recorded with 8.60 per cent at PenuLingagudemi village (Seethampeta mandal) to 24.60 per cent in Abbirajupalem village (Yelamanchili mandal).

In Yelamanchili mandal per cent wilt disease incidence during *kharif* 2018-19 recorded with range from 4.60 per cent (Kanukunta village) to 9.60 per cent (Abbirajupalem village) and in *rabi*, 2017-18, wilt disease incidence ranged from 18.00 per cent (Gummadiddal village) to 24.60 per cent (Nallevelli village). Disease incidence was observed and recorded during flower initation and fruit set stage in both the seasons with more severity in *rabi* season. Most popular grown hybrids are US 440, PHS 448 and other local varieties.

In Medapadu mandal, during *kharif*, 2018-19, wilt disease incidence ranged from 2.30 per cent (Kovvur village) to 11.60 per cent (Jharasanagam village) and in *Rabi*, 2018-19, disease incidence ranged from 10.00 per cent (Jharasanagam village) to 12.66 per cent (Kovvur village). Disease incidence was observed and recorded during crop growth stage at 35 to 45 day old coinciding with flower initation and during fruit set stage in both the seasons, with more severe in *rabi*, 2018-19. Most popular grown hybrids are US 440, PHS 448 and other local varieties.

In Seethampeta mandal, during *kharif*, 2018-19, disease incidence ranged from 3.40 per cent (Seethampeta village) to 8.40 per cent (Raipalli village) and in *Rabi*, 2018-19, disease incidence ranged from 8.60 per cent (Raipalli village) to 14.60 per cent (Seethampeta village). Fusarium wilt disease incidence was more severe in *rabi* season and was observed during flowering initiation and fruit set stage of the crop.

Table 9: PDI (%) of fusraium wilt disease in West Godavari District (2017-18)

S.No	Name of the mandal	Name of the Place	Disease incidence (%) (2017-18)				Mean disease incidence		Previous crops grown	Irrigation facility	Cultivars grown	Type of soil
			Kharif		Rabi		kharif	Rabi				
			PDI	Crop stage	PDI	Crop stage						
1	Gummaidala	Yelamanchili	6.00	Vg	18.00	Fi & Fs	6.73	22.3	Cauliflower,chilli ,brinjal, melons	Drip, borewell	440	Red & black
2		Yelamanchili	4.60	,,	24.30	Fi & Fs			Bengalgram,maize,cabbage	Borewell,drip	440, 448	black

3		Abbirajupalem	9.60	,,	24.60	Fi & Fs			Potato, brinjal,cabbage, ginger		Kapila, 440	black
4	Medapadu	Medapadu	11.60	Fi & Fs	10.00	Fi & Fs	6.50	10.98	Brinjal,chilli,cabbage, beans	Borewell & drip	440, 448	Red & black
5		Edulaplly	2.30	Vg	12.66	Fi & Fs			Potato, cabbage	drip	440, 448	
6		Chidipi	5.60	Vg	10.30	Fi & Fs			Gourds, sugarcane		440, 448	red
7	Seethampeta	Seethampeta	3.40	Vg	14.60	Fi & Fs	5.13	12.26	Melons, brinjal	drip	440	red
8		Achanta	3.60	Vg	13.6	Fi & Fs			Sugarcane, brinjal, beans	Open & drip	Kapila, Lakshmi,440,448	Red & black
9		PenuLingagudemi	8.40	Vg	8.6	Gs			Leafy vegetable,Melons, gourds & beans	drip	440, 448	red
	Average per cent disease incidence		6.12	Vg	Vg	Fi & Fs						
	(Fi- Flower initiation, Fs- Fuit set, Vg-Vegetative Growth)											

Fusarium wilt disease incidence in krishna district.

Krishna district is the largest tomato growing district in Andhra Pradesh State, having good transportation facility and connectivity to nearby markets it is cultivated throughout the year in all seasons *i.e*., *Kharif*, *Rabi* and Summer. Survey results revealed that (Table 10) mean per cent wilt disease incidence in *Kharif*, 2018-19 ranged from 12.36 per cent (Agiripalli mandal) to 13.48 per cent (Ibrahimpatnam mandal) and in *rabi* 2017-18, disease incidence ranged from 28.29 per cent (Agiripalli mandal) to 29.00 per cent (Ibrahimpatnam mandal).

In Agiripalli mandal, per cent wilt disease incidence of tomato in *kharif* 2018-19, ranged from 9.80 per cent (Jupudi village) to 16.20 per cent (Ibrahimpatnam village) and in *rabi* 2018-19, per cent wilt disease incidence ranged from 26.00 per cent (Jupudi village) to 32.55 per cent (Mangapally village). In this mandal fusarium wilt was more pronounced in *rabi*, 2018-19and the disease incidence was observed during the crop growth stage with attaining 40 day old, coinciding with flower initiation, fruit set and in first harvesting stage.

In Ibrahimpatnam mandal, per cent wilt disease incidence in *kharif* 2018-19 ranged from 12.50 per cent (Anigandlapadu village) to 15.30 per cent (Ibrahimpatnam village) and in *rabi*, 2018-19 per cent wilt disease ranged from 26.90 (Anigandlapadu village) to 32.60 per cent (Lingagudem village). Characterstic symptoms of fusarium wilt disease incidence were noticed during flower initiation and fruit set stage. Per cent disease incidence was observed and recorded more in *rabi* season due to warm climatic conditions.

Hybrids (PHS 448, UAS 440) and local varieties laxmi were grown more poprlalry due to having different crop duration.

In Penuganchiprolu mandal, PDI of wilt disease in *kharif* 2018-19 ranged from 10.40 per cent (Damaragidda village) to 18.33 per cent (Thadapally village) and during in *rabi*, 2017-18, PDI ranged from 27.80 per cent (Ragadidoswada village) to 29.30 per cent (Damaragidda village). Wilt disease incidence was more during *rabi* season compared to *kharif* due to favourable climatic conditions and facilitating the causal organism to express disease incidence. Hybrids and local varieties were grown depending on the marketing conditions and price. (Table 11, 12)

Anitha and Rebeeth (2009) reported similar results with fusarium wilt disease incidence of 75 per cent at Nachipalayam village, Coimbatore district, 30 per cent at Coimbatore,Tamil Nadu (Vethavalli and Sudha, 2012) [6], and from 12 per cent to 59 per cent in all tomato growing areas of Tamil Nadu State (Amutha and Darwin, 2017) [5-7].

Bharat and Sharma (2013) observed similarly that fusarium wilt disease incidence of tomato was 27.65 per cent at Kadriyana, Himachal Pradesh, with more incidence in warmer regions with recording 20 per cent and above as disease incidence depends on environmental conditions as causal organism requires soil temperature around 28ºC for its growth and development (Gupta and Thind, 2012) [8,9].

Cai *et al*. (2003) observed that three different host specific races of *Fusarium oxysporum* f. sp. *Lycopersici*, (race 1, 2 and 3) have been identified from different countries and it may be one of the reason behind the variation of disease intensity with varying at pathogenic, morphological and genetic level [10]. Charoenporn *et al.* (2010) reported similarly that multiplication and spread of soil borne diseases especially fusarium wilt is more when a specific crop is grown continuously [11].

In Sirmour district of Himachal Pradesh, fusarium wilt disease incidence ranged from 20 to 90 per cent and Madhavi *et al.* (2006) revealed that fusarium wilt disease incidence was upto 30 per cent and noticed in all most all tomato growing areas of Andhra Pradesh [12].

Jayanta *et al*. (2018) observed that wilt disease incidence ranged from 8.33 to 38.66 per cent with maximum incidence of 26.21 per cent at Kalaburgi district, followed by 21.25 per cent at Raichur district, Karnataka State [13].

khan *et al*. (2017) recorded from their studies and reported similarly that fusarium wilt disease incidence of tomato at Masauli block (Barabanki district) was 80.34 per cent followed by 74.50 per cent in Arniya block (Bulandshahr district) with over all disease incidence ranging from 10.67 to 80.34 per cent in all surveyed districts of Uttar Pradesh [14]. Mamatha *et al*. (2013) from their studies reported similarly that fusarium wilt of tomato disease incidence ranged from 0 to 78.70 per cent in Uttar Pradesh [15].

Manikandan and Raguchander (2014) reported similarly that wilt disease incidence ranged from 19 to 45 percent in almost all tomato growing areas of Tamil Nadu State [16].

Bharat *et al*. (2014) also revealed similarly that the wilt disease incidence varied from region to region and within a region, the intensity of the disease varied depending upon the variation of pathogen [17].

Sahu *et al*. (2013) also reported that fusarium wilt disease incidence in tomato recorded with 26.00 per cent in Raipur district, Chattisgard, with initial incidence in the month of October, progressing onwards in next successive months [18].

Table 10: Per cent wilt disease incidence in Krishna district

S.No	Mandal	Name of the village	Per cent Disease incidence (PDI) (%) (2017-18)				Average PDI		Previous crops grown	Irrigation facility	Cultivars grown	Type of soil
			Kharif		Rabi		Kharif	rabi				
			DI	Crop stage	DI	Crop stage						
1	Agiripalli	Ibrahimpatnam	16.20	Fi & Fs	26.33	Fi & Fs	12.36	28.29	Brinjal, bhendi, beans	Flooing, drip	Himsoan, 3140,810,440, 448	Red, sandy loam
2		Elaprolu	11.10	Gs	32.55	,,			Gourds, cucurbits		Himsoan, 3140,810,440, 448	
3		Jupudi	9.80	,,	26.00	,,			Beans (bhushy), bhendi, brinjal			Red
4	Ibrahimpatnam	Ibrahimpatnam	15.30	Fi & Fsi	27.50	,,	13.48	29.00	Brinjal, leafy vegetable,cucmber	drip		Light red
5		Anigandlapadu	12.50	,,	26.90	,,			Cucumber,bhendi, gourds	borewell		
6		Lingagudem	12.65	,,	32.60	,,			Beans,gourds,cucmber			
7	Penuganchiprolu	Damergidda	10.40	Gs	29.30	,,	13.24	28.56	Carrot,cabbage	drip		Black,chalka,light sandy
8		Ragadidoswada	11.00	,,	27.80	,,						
9		Bimalapuram	18.33	Fi & Fs	28.60	,,						
	Average disease incidence		13.02	NA	28.62	NA						
	(Fi- Flower initiation, Fs- Fuit set, Vg-Vegetative growth)											

Table 11: PDI of fusarium wilt of tomato at different crop stages in Andhra Pradesh state (2018-19).

Vegetative growth stage PDI (%)	flower initiation and fruit set PDI stage (%)
10.05	18.84

Table 12: District-wise average incidence of fusarium wilt of tomato in Telanagana state (2018-19)

S.No	District	Mandal	Kharif PDI (%)	Rabi PDI (%)	Mean incidence PDI (%)
1	East Godavari	Amalapuram	14.55	24.44	19.47
		Kothapalle	7.48	27.86	17.67
		Ramachandra	12.11	27.30	19.70
2.	West Godavari	Yelamanchili	6.73	22.30	14.51
		Kovvur	6.50	10.98	8.74
		Seethampeta	5.13	12.26	8.69
3.	Krishna	Agiripalli	12.36	28.29	20.32
		Ibrahimpatnam	13.48	29.00	21.24
		Penuganchiprolu	13.24	28.56	20.90
	Average overall incidence		10.17	23.44	16.80

Symptomatology

Fusarium wilt diseased symptoms on tomato observed during survey are drooping of leaves, stunted in growth, loss of leaf turgidity, yellowing of lower leaves (Figure 1), inter veinal clearing, initial yellowing of leaves and stem on one side of the plant (Figure 1), chlorosis, necrotic browning and dead of whole plant on advanced stage of infection. Fusarium wilt of tomato incidence often occurs on mature plants on initiation of flowering and during fruit set stage. Vascular discoloration with brown in colour was observed when epidermis and cortical tissue of the main stem is cut and opened (Figure 1). Initially fusarium wilt diseased symptoms on tomato plants were observed during flowering stage coinciding with initiation of lateral roots having minimum of 8 to 12 branches. Partial or total absent of fruits were noticed on diseased plants. Fusarium wilt disease incidence was mostly visible at flowering and fruit set stage initially in patches extending to the entire field with increase on age of the plant and accompanying with favourable environmental conditions.

Decal *et al*. (2000) observed and reported similar characterstic symptoms of fusarium wilt of tomato such as browning of vascular system due to blocking of xylem vascular bundles, impending water movement with half of the leaf or branch getting affected with the other half seemingly unaffected [19].

Ramamoorthy and Samiyappan (2001) and Smith *et al.* (1997) reported similarly that browning of the vascular tissue is the chief characteristic symptom of fusarium wilt of tomato and symptoms become more apparent during between flowering and fruit set stage [20,21].

Snyder and Hans (2003) [23], Sally *et al*. (2006) and Ignjatov *et al*. (2012), observed similar characteristic symptoms of fusarium wilt such as drooping of leaves, yellowing, yellowing initially on one side of the plant, stunted in growth "netted" appearance due to clearing of the veinlets, vein clearing on the outer portion of the young leaves followed by epinasty of the older leaves, vascular discolouration, more pronouncedly during flowering and fruit set stage during warm climatic conditions.

Fig 1

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