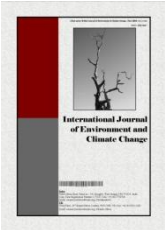


International Journal of Environment and Climate Change

12(11): 283-294, 2022; Article no.IJECC.85581
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Studies on Cultural, Morphological and Pathogenic Variability among the Isolates of *F. verticillioides* Associated with Maize Stalk Rot in Telangana State, India

Mamatha Ch. [a*], B. Mallaiah [a], Nandappa Chorgasti [a] and D. Bhadru [a]

[a] *Department of Plant Pathology, PJTSAU, Rajendranagar, Hyderabad-30, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1130973

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/85581

Original Research Article

Received 07 February 2022
Accepted 11 April 2022
Published 12 July 2022

ABSTRACT

Maize (*Zea mays* L.) is one of the important cereal crops of the world and world's third most leading cereal crop, after wheat and rice. Maize is affected by various biotic and abiotic stresses. Among the biotic stresses, fusarium wilt of maize caused by *Fusarium verticillioides* is most serious disease of maize. Tweleve isolates of *F. vericillioides* were studied for its cultural, morphological and pathogenic variability. Microconidia were hyaline, oval to club shaped with a flattened base and measured 5.12-7.11 µm *X* 2.04-3.18 µm (L×W). Macroconidia were sickle shaped with 3-5 septa and measured 20.01-31.12 µm *X* 2.01-3.21 µm (L×W). The radial mycelial growth of test isolates ranged from 4.32 mm to 8.65 mm at 10 days after inoculationon on PDA medium. However, maximum mycelial growth was recorded by the isolate F-ISO-5 in all the three mediums and mean maximum growth of isolates were observed in CMA. The fungal colony of *Fusarium* isolates on PDA were initially white, floccose which turned purple to dark brown after 7 days of incubation at 28 ± 2ºC. Cultures developed pigmentation like pink, light purple, dark violet which varied with age. All the tested isolates were pathogenic on tested maize cultivar (kaveri- 50). However, the disease severity was varied among the isolates. *Fusarium* isolates F-ISO-7 was highly virulent which caused severe disease upon inoculation with disease score of 8.0 on 1-9 scale followed by F-ISO-1, F-ISO-3, F-ISO-4, F-ISO-5, F-ISO-6 and F-ISO-8.

**Corresponding author: E-mail: mamathamammuluch@gmail.com;*

Keywords: Cultural; morphological; pathogenic variability; fusarium; maize.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It is cultivated in tropics, sub tropics and temperate regions under irrigated and rainfed conditions. Globally, maize is known as queen of cereals, because it has the highest genetic yield potential among the cereals. In most of the developing countries maize is consumed directly as food. Maize occupies an important place as a source of human food (26%), animal feed (11%), poultry feed (48%), industrial products (12%) and seed (3%) in India. Maize is cultivated in an area of 9380.07 thousand hectares with an annual production of 28752.8 thousand tons in India. In Telangana State, India, the crop is grown in almost all districts in an area of 630 thousand hectares with a production of 2555.64 thousand tonns and productivity of 4057 Kg^{-1} hectare (INDIANSTAT, 2017-2018)." The other important maize growing states in India are Karnataka, Bihar, Rajastan, Maharashtra, Madhya Pradesh, Utter Pradesh, Andhra Pradesh, and Himachal Pradesh etc. Maize is affected by various biotic and abiotic stresses. Among the biotic stresses, fungal diseases are one of the major constraints in realizing the potential yields of this crop.

Of the fungal diseases, post flowering stalk rots poses a major threat to the productivity of maize crop. Post flowering stalk rot is complex disease which occurs at post flowering stage of the crop in both *kharif* and *Rabi* season. In India, eight fungi and three bacteria were reported to cause stalk rots" [1]. "Among all, *Fusarium* stalk rot (*Fusarium verticillioides),* Charcoal rot *(Macrophomina phaseolina),* Late wilt *(Cephalosporium maydis)* are more prevalent and destructive in India [2]". "Among the stalk rots, *Fusarium* stalk rot caused by *F. verticillioides* was first reported from USA by Pammel [3] as a serious root and stalk disease. Later, Valleau [4] reported that *F. moniliforme* was a primary cause of root and stalk rot of maize. In India, the disease was first reported from Mount Abu, Rajasthan State, India [5]" and "prevalent in most of the maize growing areas of country where water stress occurs at the flowering stage of the crop. The disease becomes apparent when crop enters senescence phase and severity increases during grain filling stage. The rotting extends from the infected roots to the stalk and causes premature drying, stalk breakage and ear dropping and thus resulting in reduction of maize yields [6]". "The disease causes internal decay and discoloration of stalk tissues, directly reducing yield by blocking translocation of water and nutrients, thus resulting in death and lodging of the plant [7]". The fungus survives on crop residues in the soil or on the soil surface.

Field observations revealed the difference in virulence with in *Fusarium verticillioides* populations from different conventional maize growing areas indicating the emergence of new pathotypes. The pathogen is mainly soil borne therefore needs to know the nature of pathogen for better management practice of *Fusarium* wilt disease of maize. However the present study was investigated to cultural, morphological and pathogenic variability of *Fusarium* isolates present in the different soils of Telangana State, India.

2. MATERIALS AND METHODS

Survey was carried out in the major maize growing regions of Telangana State, India, during kharif – 2019, where cereals are cultivated extensively by the farmers and experimented at Department of Maize Pathology, Maize Research Centre, ARI, Rajendranagar.

2.1 Reagents and Equipments

Sulfuric acid (Synth, Brazil)....
UV-Vis spectrophotometer (BelPhotonics, Mod. M-51, Italy)...

2.2 Isolation of *Fusarium verticillioides* Isolates

"Maize plants showing typical symptoms were collected from different locations and used for isolation of the pathogen. These samples were first washed with tap water followed by sterile distilled water. Diseased portions with some healthy portion were cut into small bits of 3-5 mm size, surface sterilized by dipping them in sodium hypochlorite conc. (1% - *v/v*) solution for one minute and then 3-4 bits were transferred aseptically to petri plates containing potato dextrose agar (PDA) medium and were incubated at 25 ± 1 ºC in an incubator" [8].

2.3 Cultural and Morphological Variability

Observations on colony colour, pigmentation, sporulation, growth pattern of each isolate were recorded 12 days after incubation at 28 ± 2ºC.

2.4 Colony Colour and Pigmentation

Colony colour and pigmentation of all the isolates grown on different media was determined with the help of Munsell's colour chart [9]. Twelve day old culture of *Fusarium verticillioides* were used to note down the colony colour and pigmentation. The pigmentation of the colony was recorded from the under surface of the *Petri* plate.

2.5 Sporulation

To determine sporulation in each isolate, discs of 5 mm size were cut from 10 day old cultures. Three such discs were placed in a test tube containing 15 mL of distilled water and were vortexed to dislodge the conidia from mycelial mat. Spore load was measured by using haemocytometer [8].

2.6 Preparation of Slides

A small amount of pure culture was taken using a sterile needle and transferred onto a clean sterile slide. The culture of each isolate was taken from four positions of the culture plate. Total three culture plates of each isolate were used for the morphological studies of length, width and septa after 10 days of incubation at 28 ± 2 ºC. The culture was stained with conc. 0.1% (*m/v*) lacto phenol cotton blue and observations on different morphological characteristics were recorded by computerized inverted microscope for each of the isolate on different media *viz*., potato dextrose agar (PDA), corn meal agar (CMA) and czepec dox agar (CDA) media.

2.7 Pathogenicity Test

Pathogenicity of the different *F. verticillioides* isolates was tested by toothpick method (AICMIP, 1983). For this purpose, round bamboo tooth picks about 6.5 cm long were boiled three times (about 1 h each time) in tap water to remove toxic substances. After each boiling these were thoroughly washed in fresh water and dried in the sun. When these were thoroughly dried, they were loosely packed in bundles and put into the glass jars/ bottles and enough potato dextrose broth is added to thoroughly moisten the toothpicks.

Sterilized toothpicks were inoculated with the culture of the pathogen aseptically. The growth of the fungus covers the toothpicks and inoculum is ready for use in about 10 days and inoculated on 50 days old plants. The lower internode (second/third) above soil level is opened with a jabber and the toothpick was inserted into the hole. The Symptoms were recorded on 45 days after inoculation. For scoring disease severity of *Fusarium* stalk rot 1-9 disease rating scale (AICMIP, 1983) is followed.

3. RESULTS AND DISCUSSION

3.1 Morphological Variability among the Isolates

Morphological characters such as size, shape, septation and colour of conidia were studied for 12 isolates. Conidiophores were elongated and branched, each branch usually terminated with a spore bearing monophialide. The pathogen was found to produce two types of asexual spores *viz.,* microconidia and macroconidia. The resting spores called chlamydospores were also observed in age old culture.

Microconidia were hyaline, oval to club shaped with a flattened base and measured 5.12-7.11 µm *X* 2.04-3.18 µm (L×W). They were formed from monophialides and were found in long chains. Macroconidia observed were sickle shaped, hyaline with apical cell curved and tapered, and basal cell notched (Plate 1). They were typically 4-6 celled with 3-5 septa and measured 20.01-31.12 µm *X* 2.01-3.21 µm (L×W). Chlamydospores were globose, intercalary, solitary or in chains. Morphological variability of all the 12 isolates was depicted in the Table 1.

The fusarium isolates F-ISO-1, F-ISO-4, F-ISO-5, F-ISO-6, F-ISO-8, F-ISO-9. F-ISO-10, F-ISO-11 and F-ISO-12 showed sickle shaped macroconidia with blunt ends and *Fusarium* isolates F-ISO-2, F-ISO-3 and F-ISO-7 showed elongated sickle shaped macroconidia. Pyriform to oval microconidia were observed in F-ISO-1, F-ISO-2, F-ISO-3, F-ISO-4, F-ISO-5, F-ISO-6, F-ISO-9 and F-ISO-12 where as in F-ISO-7, F-ISO-8, F-ISO-10 and F-ISO-11 round to oval microconidia were seen. More number of septa was found in F-ISO-7 with 4-6 septa and remaining isolates were showed 4-5 septa only. Thaware et al. [10] also reported eight isolates of *Fusarium oxysporum* f.sp. *ciceri* with similar characteristics. Anita et al. [11] found the significant variations in morphology and cultural

characters of different isolates of *Fusarium verticillioides viz.,* Fv SC-01, Fv SC-02, Fv SC-03 and Fv SC-04.

3.2 Cultural Variability among *Fusarium* Isolates

All the twelve isolates were cultured on three different media *viz.,* potato dextrose agar (PDA), czepek dox agar and corn meal agar and grown at 28 ± 2 ºC, were studied separately for their cultural characters and mentioned in Table 2, 3 and 4 respectively. Observations on colony colour, mycelial growth pattern and growth rate were recorded at 12 days after inoculation. The fungal colony of *Fusarium* isolates on PDA were initially white, floccose, compact and dense which turned to dark brown after 7 days of

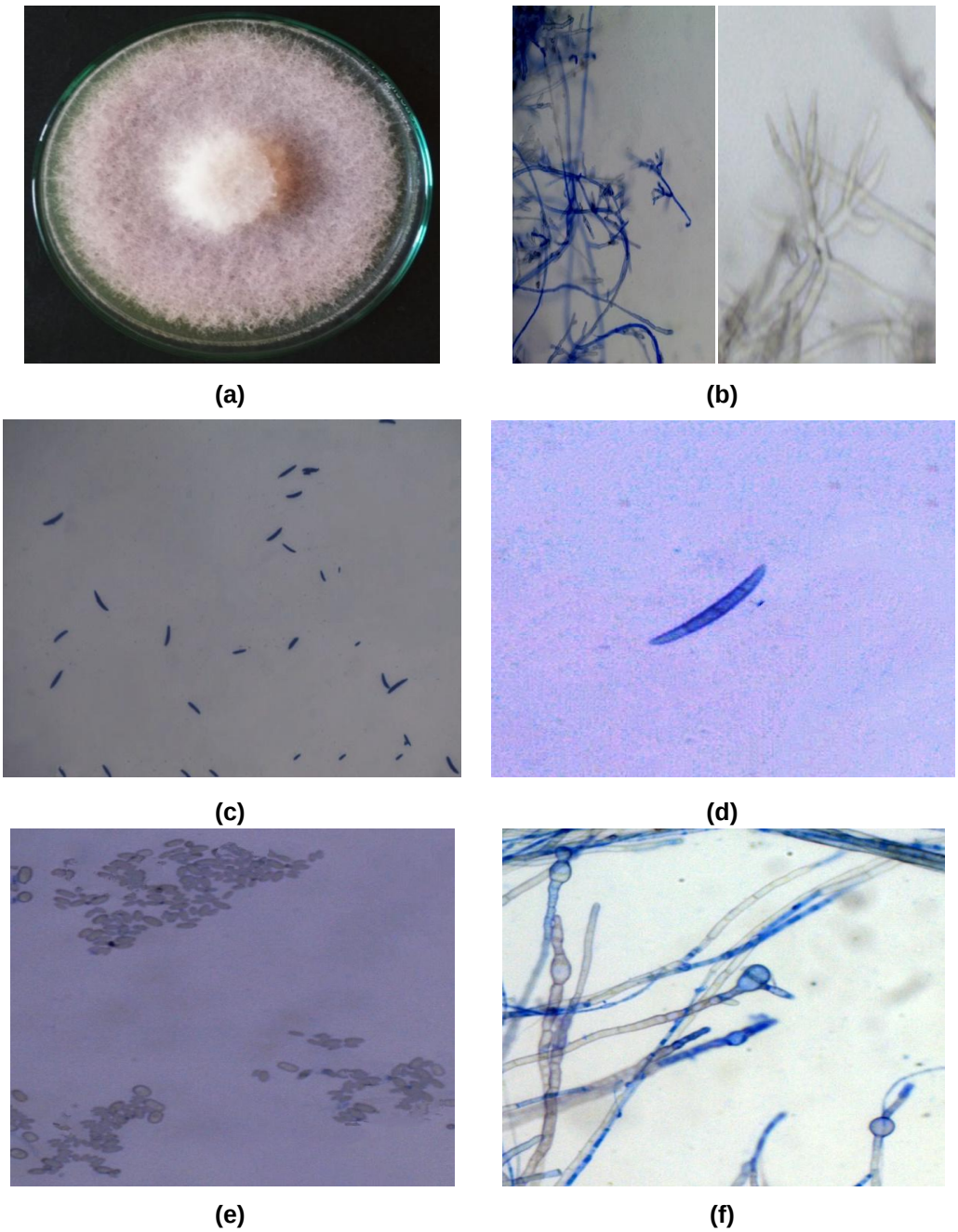


Plate 1. Morphological characters of *Fusarium verticillioides* (F-ISO-7)

Note: (a) Mycelialgrowth o PDA (b) mycroscopic view of mycelia, conidia, conidiophores, monophialides (c) & (d) macroconidia (e) microconidia in groups (f) Chlamydospores of Fusarium verticillioides(F-ISO-7)

Table 1. Morphological characteristics of different isolates of *Fusarium verticillioides*

S. N.	Isolates	Macro conidia			Micro conidia			Colour
		Septation	Size (µm)	Shape	Septation	Size (µm)	shape	
1	F-ISO-1	3-5	25.41x2.92	Sickle shape with blunt end	0-1	5.83x2.51	Pyriform to Oval	Hyaline
2	F-ISO-2	3-5	31.12x3.11	Elongated sickle shape	0-1	6.41x3.12	Pyriform to Oval	Hyaline
3	F-ISO-3	3-5	30.11x2.97	Elongated sickle shape	0-1	5.71x2.76	Pyriform to Oval	Hyaline
4	F-ISO-4	3-5	26.13x2.71	Sickle shape with blunt end	0-1	6.22x2.31	Pyriform to Oval	Hyaline
5	F-ISO-5	3-5	29.01x3.11	Sickle shape with blunt end	0-1	5.92x2.72	Pyriform to Oval	Hyaline
6	F-ISO-6	3-5	23.08x2.17	Sickle shape with blunt end	0-1	7.06x3.18	Pyriform to Oval	Hyaline
7	F-ISO-7	4-6	28.36x2.42	Elongated sickle shape	0-1	7.11x2.04	Round to Oval	Hyaline
8	F-ISO-8	3-5	25.12x3.21	Sickle shape with blunt end	0-1	5.81x2.91	Round to Oval	Hyaline
9	F-ISO-9	3-5	23.96x2.01	Sickle shape with blunt end	0-1	6.27x2.82	Pyriform to Oval	Hyaline
10	F-ISO-10	3-5	20.01x2.12	Sickle shape with blunt end	0-1	5.12x2.24	Round to Oval	Hyaline
11	F-ISO-11	3-5	22.12x2.12	Sickle shape with blunt end	0-1	5.42x2.22	Round to Oval	Hyaline
12	F-ISO-12	3-5	25.71x2.45	Sickle shape with blunt end	0-1	5.91x2.41	Pyriform to Oval	Hyaline

Table 2. Cultural characters of different isolates of *F. verticillioides* on PDA medium

S. no	Isolates	Colony diameter (cm)*	Growth rate (mm day)*	Colony type	Colony colour on the reverse side of the plate
1	F-ISO-1	5.17	5.26	spongy and White	Orange
2	F-ISO-2	7.87	6.82	Sparse and orange	Light yellow
3	F-ISO-3	8.28	9.17	Dense and violet	Brown
4	F-ISO-4	5.60	6.13	Dense and white to violet	Brown to white
5	F-ISO-5	8.65	9.40	Dense and violet	Dark brown
6	F-ISO-6	8.38	10.19	Dense and light violet	Light brown
7	F-ISO-7	8.37	9.31	Dense and light violet	White
8	F-ISO-8	4.95	5.22	Spongy and orange	Light yellow
9	F-ISO-9	5.03	5.27	Dense and light brown	White
10	F-ISO-10	4.32	4.46	Spongy and orange	Orange
11	F-ISO-11	4.71	4.94	Spongy and white	Light yellow
12	F-ISO-12	4.92	5.14	Dense and light brown	Brown
CD (P=0.05)		0.089	0.075	-	-

** Mean of five replications*

Table 3. Cultural characters of different isolates of *F. Verticillioides* on czepek dox agar medium

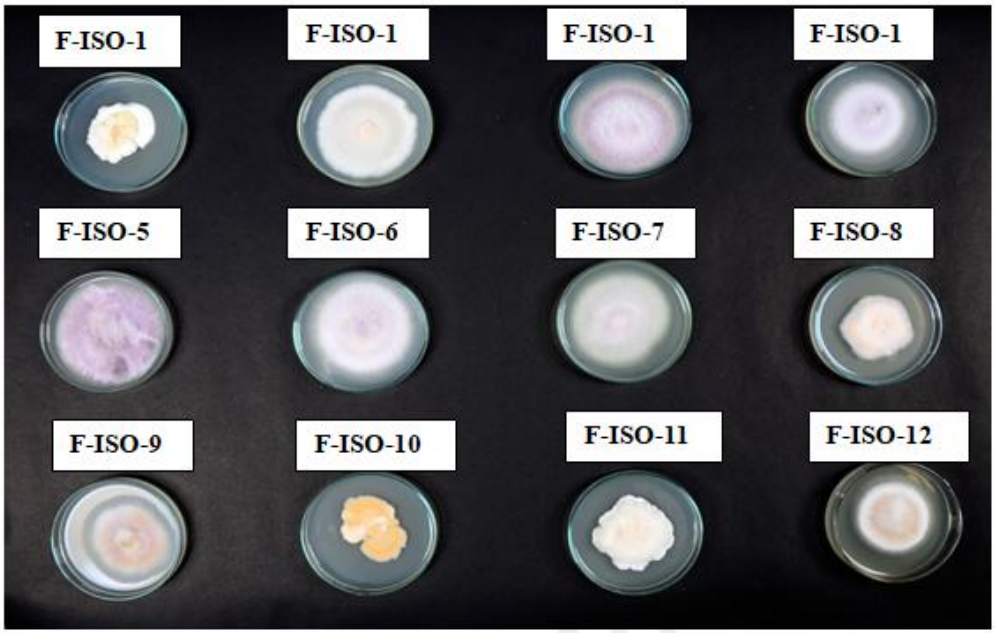
S. No	Isolates	Colony diameter (cm)*	Growth rate (mm day)*	Colony type	Colony colour on the reverse side of the plate
1	F-ISO-1	4.95	5.27	Spongy and white	Dark yellow
2	F-ISO-2	8.56	9.14	Sparse and light orange	White
3	F-ISO-3	6.45	7.44	Dense and light violet	White
4	F-ISO-4	8.20	8.09	Dense and light violet	Light yellow
5	F-ISO-5	8.91	9.15	Dense and violet	Dark brown
6	F-ISO-6	8.42	8.53	Dense and light orange	Light yellow
7	F-ISO-7	8.23	9.33	Dense and light violet	White
8	F-ISO-8	4.83	5.64	Spongy and orange	Light yellow
9	F-ISO-9	5.34	3.21	Sparse and brown	White
10	F-ISO-10	4.35	4.94	Spongy and white	Light yellow
11	F-ISO-11	4.26	4.54	Spongy and white	White
12	F-ISO-12	7.63	7.20	Sparse and violet	Violet
CD(P=0.05)		0.035	0.308	-	-

**Mean of three replications*

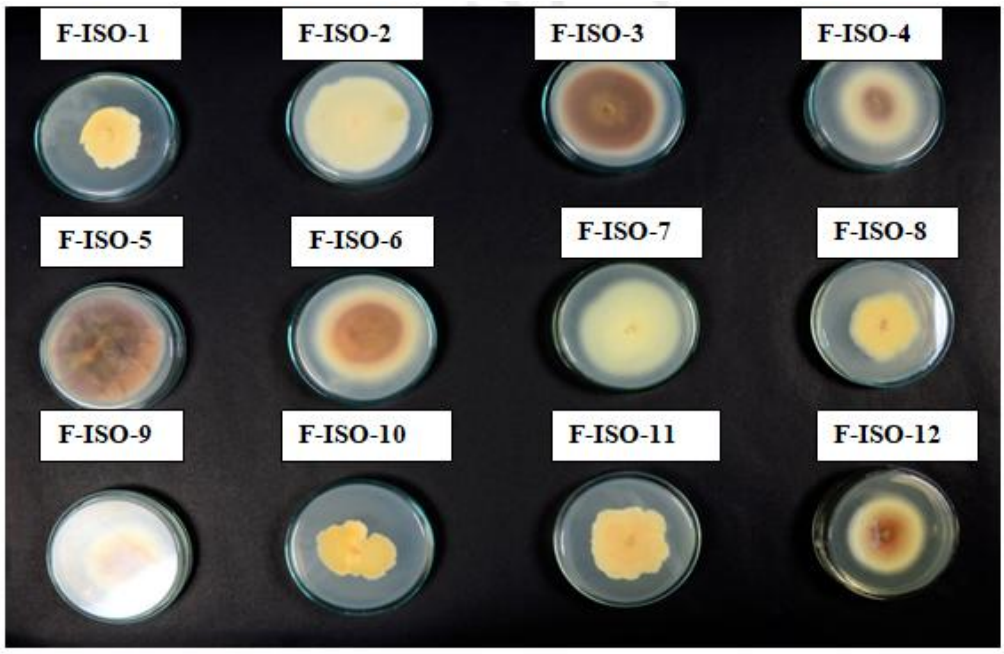
Table 4. Cultural characteristics of different isolates of *Fusarium verticillioides* on corn meal agar

S. No	Isolates	Colony diameter (cm)*	Growth rate (mm day)*	Colony type	Colony colour on the reverse side of the plate
1	F-ISO-1	3.20	4.22	Spongy and white	White
2	F-ISO-2	8.72	9.11	Very sparse and light orange	White
3	F-ISO-3	8.67	9.40	Very sparse and light violet	Violet
4	F-ISO-4	8.82	10.38	Very sparse and light violet	Violet
5	F-ISO-5	8.93	9.62	Very sparse and violet	Violet
6	F-ISO-6	8.85	10.31	Very sparse and light violet	Violet
7	F-ISO-7	8.13	8.75	dense and creamish	Light yellow
8	F-ISO-8	6.29	7.17	Spongy and orange	Light yellow
9	F-ISO-9	5.46	6.32	Dense and brown	Brown
10	F-ISO-10	4.42	4.94	Spongy and light yellow	Yellow
11	F-ISO-11	4.07	4.28	Spongy and white	White
12	F-ISO-12	5.93	6.45	Dense and creamish	White
CD(P=0.05)		0.045	0.054	-	-

incubation at 28 ± 2ºC. Cultures developed pigmentation like pink, light purple, dark violet which varied with age (Plate 2, 3 and 4 respectively). Mahsane [12] studied the cultural characteristics and reported that three isolates were produced light pink, five were creamy, one were light brown, six were light yellow, three were light to dark coloured pigmentation. Spongy, compact and dense growth of colonies was observed on PDA and Czepek dox agar medium, sparse and fast growth was observed on CMA.

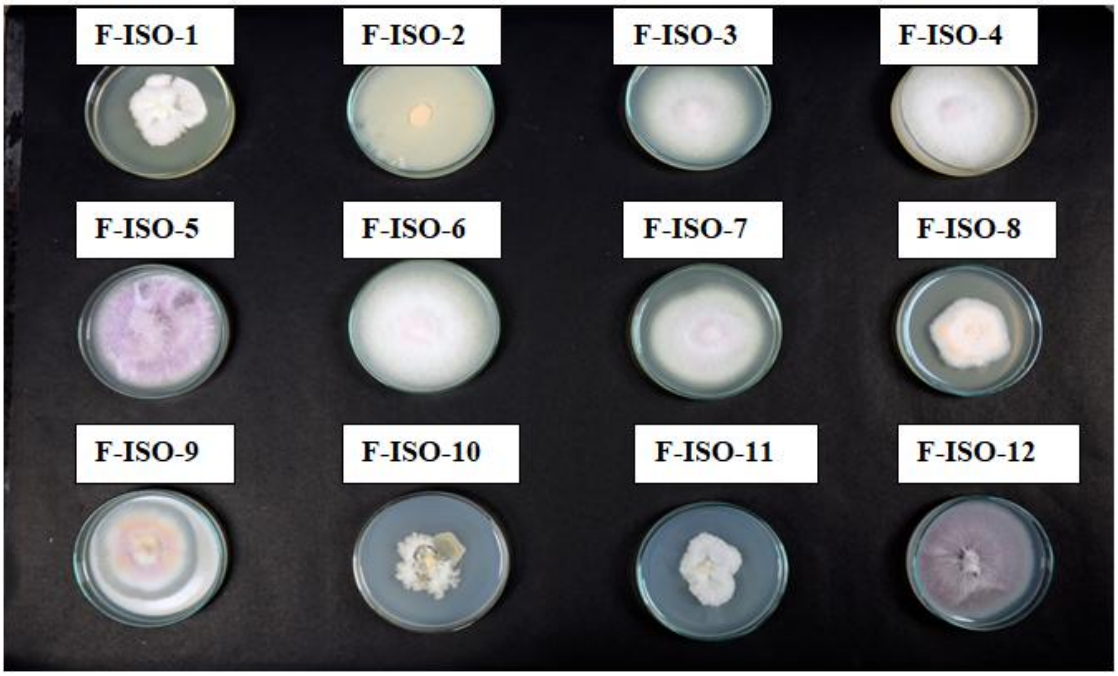


(a) Aerial colony growth

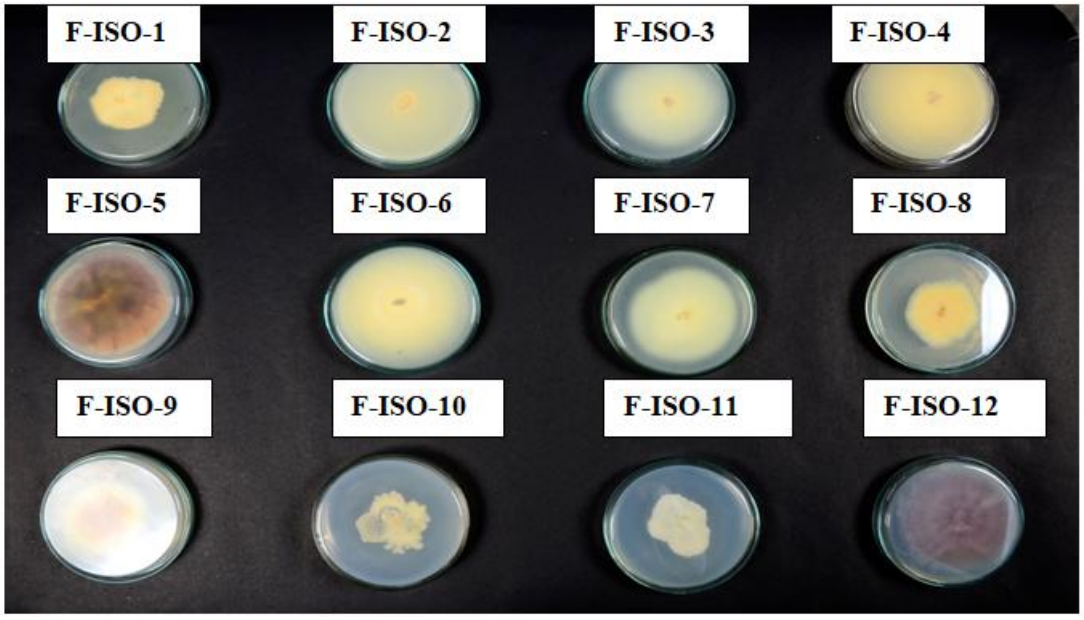


(b) Colony growth on reverse side of Petri plate

Plate 2. Growth of isolates *F. verticillioides* on PDA medium



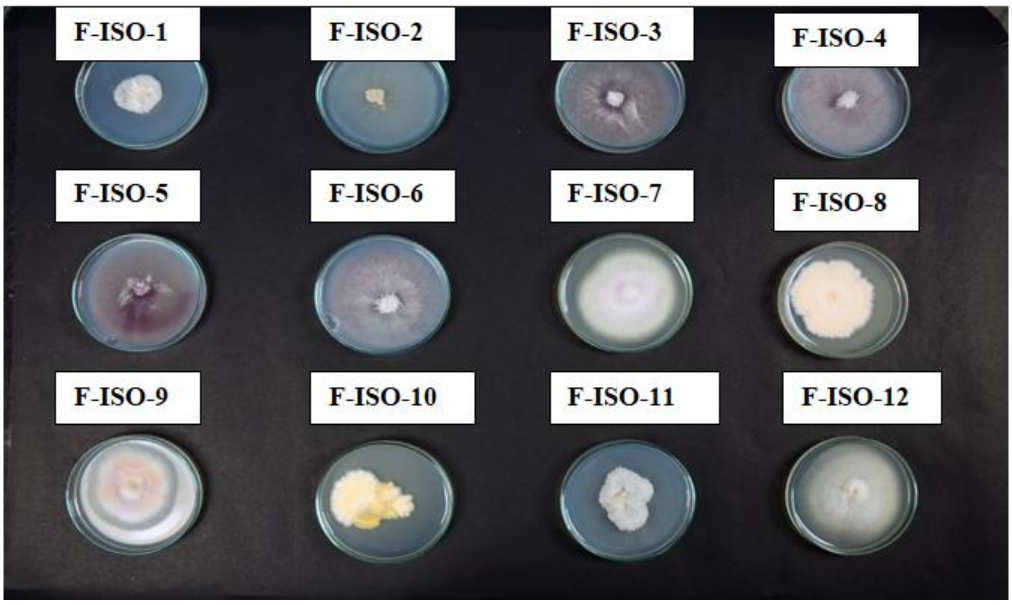
(a) Aerial colony growth



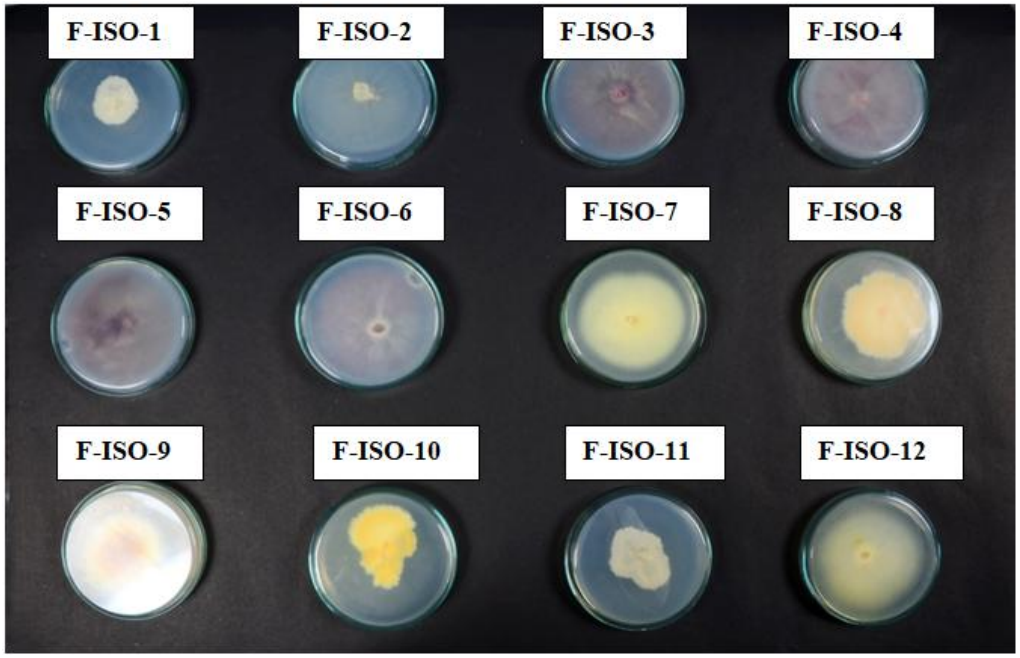
(b) Colony growth on reverse side of *Petri* plate

Plate 3. Growth of isolates *F. verticillioides* on czepek dox agar medium

"The radial mycelial growth of test isolates ranged from 4.32 to 8.65 on PDA. However, maximum mycelial growth was recorded by the isolate F-ISO-5 in all the three mediums and mean maximum growth of isolates were observed in CMA. These findings are in agreement with the Nurbaya et al. [13]" "findings who reported that fungi isolated from soil, or from substrates in the soil, i.e., plant debris, grow well on CMA, a relatively weak medium compared to PDA. These results of the present study are in consonance with the previous findings of many workers [14, 15,16,17].



(a) Aerial colony growth



(b) Colony growth on reverse side of *Petri* plate

Plate 4. Growth of isolates *F. verticillioides* on corn meal agar medium

3.3 Pathogenicity Test

The pathogenicity tests conducted for all 12 isolates by tooth pick method of inoculation in to the second internode of susceptible maize hybrid Kaveri-50 at 50 DAS. The typical PFSR symptoms were observed in inoculated plants. Drying of the lower leaves, lower internodes turned into grey-green color and wilt of entire plant prematurely, and stalks are hollow and weak leading to the lodging of the plant [18,19]. No such symptoms were observed in controls. All the tested isolates were pathogenic on tested maize cultivar (kaveri- 50). However, the disease severity was varied among the isolates. *Fusarium* isolates F-ISO-7 was highly virulent which caused severe disease upon inoculation with disease score of 8.0 on 1-9 scale followed

Table 5. Virulence of different isolates of *F. verticillioides* on maize plants at MRC – Rajendranagar State, India

S. No.	Place of collection	Isolate	Disease score (1-9 scale)
1	Arepally	F-ISO-1	5.6
2	Oglapur	F-ISO-2	5.0
3	Rajendranagar	F-ISO-3	5.3
4	Jammikunta	F-ISO-4	7.0
5	Veenavanka	F-ISO-5	6.3
6	Huzurabad	F-ISO-6	6.0
7	Thimmapur	F-ISO-7	8.6
8	Gundlapalli	F-ISO-8	7.0
9	Allipuram	F-ISO-9	3.2
10	Tanikella	F-ISO-10	4.0
11	Narasimhapuram	F-ISO-11	3.0
12	Chintakani	F-ISO-12	4.0

by F-ISO-1, F-ISO-3, F-ISO-4, F-ISO-5, F-ISO-6 and F-ISO-8. The results of pathogenicity test and disease severity score for each isolate is presented in Table 5. The fungal isolates after inoculation and upon development of characteristic symptoms were consistently re-isolated and their identity was confirmed. Koch's postulates were fulfilled thus confirming the association of stalk rots of Maize. Similar results were reported by Dharanendra Swamy et al. [20] in which PFSR isolates PFSRFv_88 and PFSRFv_118 were highly virulent which caused severe infection upon challenge inoculation with disease score 8. Schoeman et al. [21] reported the virulene of 15 *F. verticillioides* isolates on the maize cultivar CRN 3505 with mean ear rot symptoms not greater than 3 per cent. And no significant differences were found among the isolates at $P<0.05$ and $P<0.1$. Olowe et al. [22] also reported that out of 32 *F. verticillioides* strains screened, 9.4 per cent were classified as highly virulent, 12.5 per cent as virulent, 37.5 per cent as moderately virulent, 21.8 per cent as slightly virulent, and 18.8 per cent as non-virulent.

4. CONCLUSION

In the present study cultural, morphological and pathogenic variability of 12 isolates causing wilt of maize in different maize growing areas of Telangana State, India showed that the radial growth of colony diameter was different for different isolates. Cultural and morphological variations among the twelve isolates of *Fusarium verticillioides*, was studied on different solid media i.e., Corn meal agar, Potato dextrose agar and czpek dox agar. Initially the colour of all isolates was white which changed gradually with different pigments like pink, pale yellow, light yellow etc. Among the isolates tested, maximum mycelial growth was recorded by the isolate F-ISO-5 in all the three Medias and mean maximum growth of isolates were observed in CMA.

Although all the isolates produced micro and macro conidia, these isolates varied in size (length and width) of the conidia, septation in macro conidia, colony colour and growth rate. All the isolates exhibited slight variation with respect to cultural and morphological characteristics. All isolates show pathogenic causing wilt disease of maize. These results provide baseline information on morphological, cultural and pathogenic variability of *F. verticillioides* which constitute an important input for further investigation of *Fusarium verticillioides* biology in order to define its evolutionary potential.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERANCES

1. Raju CA, Lal S. Relationship of *Cephalosporium acremonium* and *Fusarium moniliforme* with stalk rot of maize. Indian Phytopathology. 1976;3:227-231.
2. Khokhar MK, Sharma SS, Gupta R. Integrated management of post flowering stalk rot of maize caused by *Fusarium verticillioides*. Indian Phytopathology. 2014;67(3):228-233.

3. Pammel LH. Serious root and stalk diseases of corn. IOWA Agriculturist. 1914;15:156-158.
4. Valleau WD. Seed corn infection with *Fusarium moniliforme* and its relation to the root and stalk rots. Kentucky Agricultural Experiment Station. 1920;226:5.
5. Arya HC, Jain BL. Fusarium seedling blight of maize in Rajasthan. Indian Phytopathology. 1964;17:51-57.
6. Colbert TR, Kang MS, Myers O, Zuber MS. General and specific combining ability estimates for pith cell death in stalk internodes of maize. Field Crop Research. 1987;17:155-162.
7. Dodd JL. Grain sinks size and predisposition of *Zea mays* to stalk rots. Plant Disease. 1980; 64:553-537.
8. Aneja KR. Experiments in microbiology, plant pathology and biotechnology. 4th ed. New Age International (P) Ltd., Publishers, New Delhi. 2003;35-42.
9. Soil Survey Staff. *Soil Survey Manual*. U S Department of Agriculture Hand Book No.18; 1951.
10. Thaware DS, Kohire OD, Gholve VM. Cultural, morphological and molecular variability of *Fusarium oxysporum* f.sp. *ciceri* isolates by RAPD method. International Journal of Current Microbiology and Applied Sciences. 2017;6(4):2721-2734.
11. Anita J, Sharma SS, Dhakar H. Morphological characterization and biochemical defense studies of *Fusarium verticillioides* (sheldon) causing post flowering stalk rot of specialty corn. International Journal of Chemical Studies. 2017;5(6):902-905.
12. Mahsane AO. Studies on genetic diversity of *Fusarium udum* causing wilt of pigeon pea (*Cajanus cajan* (L.) Mill sp). M. Sc. thesis submitted to V.N.M.K.V., Parbhani (M.S.); India. 2013.
13. Nurbaya., Kuswinanti T, Rosmana A, Baharuddin, Syamsuddin M. Growth rate and identification of *Fusarium* spp. assosiated with *Aquillaria*s pp. from Nunukan regency, North Kalimantan. International Journal of Current Research and Academic Review. 2014;2(11):33-40.
14. Ahmad MA. Variability in *Fusarium oxysporum* f.sp. *ciceri* for chickpea wilt resistance in Pakistan. Ph. D. (Agri.) thesis, (Abs.) submitted to Quaid-i-Azam University, Islamabad, Pakistan; 2010.
15. Islam R, Momotaz R, Islam M, Ahmed AU. Annual Report on variability studies of *Fusarium oxysporum* f.sp. *ciceri* causing chickpea wilt. Bangladesh Research Institute, Bangladesh; 2011.
16. Nagare AJ. Studies on safflower wilt caused by *Fusarium oxysporum* f.sp. *carthami* (Klisiewicz and Houston). M. Sc. (Agri.) thesis submitted to Int.VNMKV, Parbhani (India); 2011.
17. Anser M, Srivastava M. Morphological variability and pathogenic reactions of *Fusarium oxysporum* f.sp. *ciceri* isolates to cultivars of chickpea. Annals of Plant Protection Sciences. 2013;21(2):345-348.
18. AICRP. Annual Report of AICRP Maize Pathology. Udaipur center; 2014.
19. INDIASTAT. 2016-2017. Available:http://www.indiastat.com/agriculture/2/stats.aspx
20. Dharanendra Swamy S, Mahadeva Kumar S, Hemareddy HB, Amruthesh, K.N, Mamatha, S, Sridhara G, Swapnil R, Vasantha Kumar T, Lakshmidevi N. First report of *Fusarium equiseti*-the incitant of post flowering stalk rot of maize (*Zea mays* L.) in India. Crop Protection; 2019. DOI: https://doi.org/10.1016/j.cropro.2019.105035
21. Schoeman A, Flett BC, Rensburg BJ, Ncube E, Vilijoen. Pathogenicity and toxigenicity of *Fusarium verticillioides* isolates collected from maize roots, stems and ears in South Africa. European Journal of Plant Pathology. 2018;152:677-689.
22. Olowe OM, Sobowale AA, Olawuyi OJ, Odebode AC. Variation in pathogenicity of *Fusarium verticillioides* and resistance of maize genotypes to Fusarium ear rot. Archives of Phytopathology and Plant Protection. 2018;51(17):939-950.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/85581