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Physiological and Cultural Variabilities among *Fusarium oxysporum* f.sp. *cepae* Isolates in Onion

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The effect of culture media, carbon sources, nitrogen sources, temperature and pH on the mycelial growth of *Fusarium oxysporum* f.sp.*cepae* was investigated. The fungus grew the best on Czapek's dox medium and glucose was the best source of carbon whereas peptone was the best source of nitrogen. Growth was maximum at 30°C which was reduced drastically below 20°C and above 35°C. The most suitable pH for optimum growth of fungus was 6.5.

Key words: Culture media - Carbon and Nitrogen sources - pH- Temperature - *Fusarium oxysporum* f.sp. *cepae*

Onion (*Allium cepa* var *aggregatum* G.Don) is one of the important vegetable crop grown in India. China ranks first in world onion production followed by India, U.S.A, Turkey, Pakistan, Russia, Indonesia, Vietnam, and Myanmar. China occupies 28 per cent of world area and 32 per cent of the production, India ranks second in world area and production, which occupies 17 per cent area and 10 per cent production. Basal rot of onion is a devastating disease of onion caused by *Fusarium oxysporum* Schlechtend: Fr. f. sp. *cepae* (Hans.) (Coskuntuna and Ozer, 2008).

Control of this disease was possible to a limited extent, with the help of fungicides, biocontrol agents and cultural practices. Biocontrol agents like *Trichoderma harzianum* (TH3) and *Pseudomonas* sp. (Pf 12) effectively reduced the growth of the *Fusarium oxysporum* sp. *cepae* (Malathi and Mohan, 2011). For the development of cultural management practices, there is necessity to identify the nutritional requirements and environmental conditions for the infection and survival of the pathogen (Imran Khan *et al*., 2011). Hence, the present investigation was conducted to study the effect of physiological factors on the mycelial growth of the fungus.

Materials and Methods

Isolation of pathogen

Onion bulbs infected with basal rot disease were collected from fifteen different places of Tamil Nadu (Table 1). The pathogen was isolated from the diseased tissues of onion by tissue segment method (Rangaswami, 1958). The infected portions of onion bulbs were cut into small pieces using sterilized scalpel and these were surface sterilized with 0.1 per cent mercuric chloride for one minute and washed thrice with sterile distilled water and then placed on previously poured and solidified Petri dish containing Potato Dextrose Agar (PDA) medium. These plates were incubated at room temperature (28 ± 2ºC) for five days and observed for the growth of the fungus. The hyphal tips of fungi grown from the pieces were transferred aseptically to PDA slants for maintenance of the culture.

Growth characters of Fusarium oxysporum f.sp.cepae isolates on different solid media

In order to compare the growth of *Fusarium oxysporum* f.sp. *cepae* on nine solid media *viz*., Potato dextrose, oatmeal, carrot dextrose, radish dextrose, beet root dextrose, czapek's dox, modified czapek's dox, richard's medium and rose bengal. The sterilized warm medium @ 15 ml was poured in sterilized Petri dishes (10 cm) and allowed to solidify. The pathogen was inoculated at the centre of the plate by placing a five days old nine mm culture disc. Plates were incubated at room temperature (28±2°C) and three replications were maintained in each medium and the radial growth of the mycelia was measured seven days after inoculation.

Growth characters of Fusarium oxysporum f.sp.cepae isolates on different liquid media

Potato dextrose, oatmeal, carrot dextrose, radish dextrose, Czapek's dox, modified Czapek's dox, richard's, rose bengal and beetroot dextrose broth were prepared (without adding agar). From the prepared medium 100 ml was distributed in 250 ml Erlenmeyer flasks and autoclaved at 120$_0$C at 15 psi for 20 minutes. The flasks were separately inoculated with a five days old nine mm culture disc of the pathogen and three replications were maintained in each medium. The mycelial mat was filtered through a preweighed Whatman No.1 filter paper, dried in hot air oven at 100$_0$C until constant weight was obtained and the mycelia dry weight was measured.

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Table 1. *Fusarium* isolates collected in Tamil Nadu, India

Place	District	Isolate	Onion Variety
Kodumudi	Erode	ERKFOC1	CO4
Vengumpur		ERVFOC2	CO5
Perumalkovil pudhur		ERPFOC3	CO4
Sekkanurani	Madurai	MDSFOC1	MDU1
Palamedu		MDPFOC2	CO5
Usilampatti		MDUFOC3	CO3
Sempatti	Dindugal	DNSFOC1	CO3
Ottanchathram		DNOFOC2	CO5
Tharmathupatti		DNTFOC3	CO4
Udumalpet	Coimbatore	COUFOC1	CO3
Pedhappampatti		COPFOC2	CO5
Annur		COAFOC3	CO5
Mettupatti	Theni	THMFOC1	MDU1
Bodinayakanur		THBFOC2	CO5
Periyakulam		THPFOC3	CO5

Effect of carbon and nitrogen sources

The czapek's dox medium was substituted with carbon sources *viz.*, carboxy methyl cellulose, glucose, fructose, mannitol, sucrose, starch and nitrogen sources such as ammonium nitrate, ammonium oxalate, ammonium sulphate, urea, sodium nitrate, peptone and potassium nitrate and sterilized. The medium without nitrogen and carbon source served as control. The sterilized warm medium was poured in the sterilized Petri plates and allowed to solidify. Petri plates were inoculated with five days old nine mm culture disc of the pathogen and incubated at the room temperature (28±2°C) for seven days. Three replications were maintained for each carbon and nitrogen source and the diameter of mycelial growth was recorded (Lily and Barnet, 1951).

Effect of pH

Czapek's dox medium was prepared and distributed in 250 ml conical flask @ 100 ml/flask and the pH of the medium was adjusted to different pH levels *viz*., 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0 and 8.5 with 0.1 N HCl or 0.1 N NaOH using digital pH meter and sterilized in autoclave at 120$_0$C at 15 psi for 20 minutes. Fifteen ml of the medium from each pH level were poured onto sterilized Petri dishes and allowed to solidify. A nine mm PDA culture disc of actively growing *Fusarium oxysporum* f.sp.*cepae* was placed at the center of each Petri dish containing medium under aseptic conditions. The plates were incubated at room temperature (28±2°C) for seven days. Three replications were maintained for each pH level and the mycelial growth of the pathogen was measured at seven days after incubation (Gangadhara *et al.,* 2010).

Effect of temperature

Isolates were inoculated in Czapek's dox medium and different temperature was maintained *viz.,* 5, 10, 15, 20, 25, 30, 35, and 40°C (Gangadhara *et al*., 2010). Three replications were maintained for each temperature and the mycelial growth of the pathogen was measured at seven days after incubation.

Results and Discussion

Effect of culture media

Fungi secure food and energy from the substrate upon which they live in nature. In order to culture the fungus in laboratory, it is necessary to furnish essential elements and compounds in the medium for growth and other life processes. All media are not equally good for all isolates of *Fusarium oxysporum* f.sp.*cepae*.

Table 2. Growth of *Fusarium oxysporum* f. sp. *cepae* isolates on solid media

Isolate	Mycelial growth (cm)*									
	7 DAI**									
	Potato dextrose	Modified Czapek (dox)	Czapek (dox)	Richards	Oat meal	Rose bengal	Carrot dextrose	Radish dextrose	Beet root dextrose	Mean
ERKFOC1	8.34	7.98	8.74	8.10	7.45	5.98	7.67	6.08	4.65	7.22
ERVFOC2	8.25	7.99	8.65	8.09	7.58	5.78	7.70	5.97	4.23	7.14
ERPFOC3	8.47	7.32	8.87	7.45	7.08	5.21	7.45	6.21	4.18	6.92
MDSFOC1	8.63	7.56	8.83	7.89	6.63	5.08	7.58	5.32	3.90	6.82
MDPFOC2	7.71	7.91	8.71	7.65	6.32	5.31	7.08	5.89	3.75	6.70
MDUFOC3	8.33	7.01	8.43	6.90	7.67	4.79	6.78	5.63	4.15	6.63
DNSFOC1	8.56	8.14	8.90	8.23	7.70	6.40	8.27	7.83	4.70	7.64
DNOFOC2	7.59	7.45	8.57	7.43	6.21	4.98	6.63	6.07	4.11	6.56
DNTFOC3	7.92	6.95	8.32	7.21	6.56	4.12	6.32	6.08	3.46	6.33
COUFOC1	8.40	7.45	8.55	7.90	5.90	4.33	7.70	5.65	3.98	6.65
COPFOC2	7.47	6.84	8.57	7.47	6.94	5.10	6.21	5.98	3.67	6.47
COAFOC3	7.64	6.74	8.64	7.67	7.65	5.08	7.34	6.45	3.91	6.79
THMFOC1	8.47	7.87	8.85	7.70	6.90	5.35	7.21	5.98	3.22	6.84
THBFOC2	8.26	7.34	8.66	6.21	6.52	4.70	7.18	5.41	3.48	6.42
THPFOC3	8.28	6.55	8.67	6.56	6.39	5.45	7.09	5.66	3.77	6.49
Mean	8.15	7.41	8.66	7.50	6.90	5.18	7.21	6.01	3.94	

* Mean of three replications **DAI-Days after inoculation CD(P=0.05) ; Isolates = 0.18 Medium = 0.14 ; Isolates×Medium = 0. 55

In the present investigation the isolates exhibited variations of growth in different solid media tested. All fifteen isolates grew well in Czapek's dox medium (8.66 cm) followed by Potato Dextrose Agar (8.15 cm) while the lowest growth was recorded in beet root agar medium (6.01 cm). Among the isolates,

DNSFOC1 collected from Sempatti recorded maximum mycelial growth 8.90 cm in czapek's dox medium (Table 2) followed by EROFOC3 (8.87 cm) collected from perumalkovil pudhur.

Among nine liquid media tested, czapek's dox liquid medium recorded the highest mean mycelial dry weight (507.89 mg) followed by potato dextrose liquid medium (467.44 mg) while beet root broth showed the least dry weight (280.43 mg) (Table 3). Among the isolates, DNSFOC1 collected from Sempatti recorded maximum dry mycelial weight 546.24 mg in czapek's dox broth (Table 2) followed by MDPFOC2 (538.23 mg) collected from Palamedu.

Table 3. Growth of *Fusarium oxysporum* f. sp. *cepae* isolates on liquid media

Isolate	Mycelial dry weight (mg)*									
	7 DAI**									
	Potato dextrose broth	Modified Czapek (dox) broth	Czapek (dox) broth	Richards broth	Oat meal broth	Rose bengal broth	Carrot dextrose broth	Radish dextrose broth	Beet root dextrose broth	Mean
ERKFOC1	478.34	486.34	532.45	456.88	375.25	325.98	395.32	345.25	264.56	406.70
ERVFOC2	481.98	492.65	512.21	472.65	391.68	341.31	374.98	371.68	253.52	410.29
ERPFOC3	500.34	485.36	498.38	465.39	369.12	329.23	417.26	359.13	292.78	412.99
MDSFOC1	435.87	478.31	509.91	458.31	351.81	341.43	361.26	341.81	250.78	392.16
MDPFOC2	465.12	487.98	538.23	457.58	396.54	316.14	398.45	326.54	238.56	403.39
MDUFOC3	495.24	451.32	511.02	431.22	342.92	373.32	341.69	390.32	275.50	401.39
DNSFOC1	508.33	498.54	546.24	482.54	413.05	389.45	440.66	398.45	312.62	443.32
DNOFOC2	481.34	398.32	511.75	367.32	318.56	312.71	431.24	333.56	208.56	377.16
DNTFOC3	496.65	376.98	467.87	346.98	298.42	342.01	422.68	321.43	292.12	373.90
COUFOC1	486.36	437.26	471.45	417.26	318.24	321.24	341.35	311.24	301.24	378.40
COPFOC2	401.24	391.26	491.38	374.86	374.56	345.56	375.68	324.56	326.52	378.40
COAFOC3	425.68	467.93	482.41	434.93	362.67	334.67	379.13	354.67	314.67	395.19
THMFOC1	443.33	421.24	487.14	411.24	286.44	301.25	347.81	327.45	257.45	364.81
THBFOC2	472.85	422.68	520.98	402.68	386.42	325.82	327.54	355.82	305.82	391.17
THPFOC3	438.95	413.33	500.45	413.89	365.48	310.75	399.34	315.75	311.75	385.52
Mean	467.44	447.30	507.89	426.24	356.74	334.05	383.62	345.17	280.43	

*Mean of three replications **DAI-Days after inoculation ; CD(P=0.05) Isolates = 10.15 ; Medium = 7.86 Isolates×Medium = 30.46

Haware *et al*., (1986) modified the czapek's dox agar medium by adding PCNB, streptomycin and malachite green which was highly effective for the growth of *Fusarium oxysporum.* Similarly, czapeks dox agar was the best for the radial growth of *Fusarium oxysporum* as this fungus gave maximum growth of 85 mm (Farooq *et al*., 2005). Imran Khan *et al.* (2011) reported that five isolates of *Fusarium oxysporum* f.sp.*ciceri* produced maximum growth on potato dextrose agar medium (85.76 mm) followed by Richard's medium (84.62 mm) and Czapek's dox medium (72.56 mm).

Table 4. Effect of carbon sources on growth of *Fusarium oxysporum* f. sp. *cepae*

Isolate	Mycelial dry weight (mg)*							
	7 DAI**							
	Sucrose	Fructose	Glucose	Mannitol	Carboxy methyl cellulose	Starch	Control	Mean
ERKFOC1	7.97	7.45	8.85	5.88	6.61	7.45	4.65	6.98
ERVFOC2	8.21	6.95	8.57	5.47	6.34	7.58	4.23	6.76
ERPFOC3	8.16	7.45	8.14	5.35	6.57	7.08	4.18	6.70
MDSFOC1	8.09	6.84	8.23	5.21	6.19	6.63	3.90	6.44
MDPFOC2	8.22	6.74	8.57	5.67	5.98	6.32	3.75	6.46
MDUFOC3	8.18	7.87	8.45	5.21	6.42	7.67	4.15	6.85
DNSFOC1	8.32	8.04	8.82	5.27	6.62	7.03	4.20	6.90
DNOFOC2	8.07	6.55	8.75	5.45	6.16	6.21	4.43	6.53
DNTFOC3	8.19	7.98	8.34	5.38	6.25	6.56	3.42	6.59
COUFOC1	8.26	7.99	8.19	5.11	6.19	5.90	3.94	6.51
COPFOC2	8.23	7.32	7.98	5.39	6.34	6.94	3.61	6.54
COAFOC3	7.93	7.56	8.73	5.76	5.78	7.65	3.90	6.76
THMFOC1	8.12	7.91	8.21	5.48	6.57	6.90	3.21	6.63
THBFOC2	8.18	7.01	8.42	5.78	6.11	6.52	3.40	6.49
THPFOC3	8.25	7.45	8.35	5.41	6.31	6.39	3.77	6.56
Mean	8.16	7.41	8.43	5.45	6.27	6.88	3.91	

* Mean of three replications **DAI-Days after inoculation CD(P=0.05) Isolates = 0.20 Medium = 0.14 Isolates×Medium = 0. 54

Effect of carbon and nitrogen sources

Carbon source is important for the growth and development of fungi. The results of this experiment indicated that all the carbon sources were suitable for the growth of *Fusarium oxysporum* f.sp.*cepae.* Glucose recorded maximum mean mycelial growth (8.43 cm) followed by sucrose (8.16 cm). Mannitol recorded the minimum mean mycelial growth (5.45 cm) (Table 4). Among the isolates of *Fusarium oxysporum* f.sp.*cepae,* ERKFOC1 isolate from Kodumudi showed the highest mycelial growth (8.85 cm) in glucose as a carbon sources.

Nitrogen is required for protein synthesis and other essential functions in fungal cell. Peptone

amended medium allowed maximum mean mycelial growth (8.53 cm) followed by potassium nitrate (8.05 cm) (Table 5). Among the isolates of *Fusarium oxysporum* f.sp.*cepae,* MDPFOC2 collected from Palamedu showed the highest mycelial growth (8.79 cm) in peptone as a nitrogen source. Such variability occurs among growth pattern of the isolates in respect to carbon and nitrogen sources, perhaps due to difference in their environment conditions where they were collected.

Similar results were obtained by Farooq *et al*. (2005) who showed that glucose and peptone were the best carbon and nitrogen sources for *Fusarium oxysporum* f.sp.*ciceri*. Glucose, maltose and sucrose were excellent for maximum mycelial growth of *Fusarium avenaceum.* Glucose (483.26 mg) was found to be good carbon source for the growth of *Fusarium oxysporum f.sp. ciceri* followed by maltose (476.19 mg) (Imran Khan *et al*., 2011).

Table 5. Effect of nitrogen sources on growth of *Fusarium oxysporum* f. sp. *cepae*

Isolate	Mycelial dry weight (mg)*								
	7 DAI**								
	Ammonium nitrate	Ammonium oxalate	Ammonium sulphate	Potassium nitrate	Sodium nitrate	Peptone	Urea	Control	Mean
ERKFOC1	7.45	7.34	6.21	8.24	7.78	8.32	6.08	5.08	7.06
ERVFOC2	6.95	7.67	6.34	8.25	7.49	8.45	5.97	5.47	7.07
ERPFOC3	7.45	7.24	6.57	8.47	7.32	8.27	6.21	5.35	7.11
MDSFOC1	6.84	7.48	6.19	7.63	7.56	8.67	5.32	5.21	6.86
MDPFOC2	6.74	7.19	5.98	7.71	7.91	8.79	5.89	5.67	6.99
MDUFOC3	7.87	7.32	6.42	8.33	7.21	8.72	5.63	5.21	7.09
DNSFOC1	7.05	7.66	6.89	8.21	8.14	8.69	6.23	5.47	7.29
DNOFOC2	6.55	7.68	6.47	7.59	7.45	8.57	6.07	5.45	6.98
DNTFOC3	7.98	7.39	5.98	7.92	6.95	8.69	6.08	5.38	7.05
COUFOC1	7.79	7.79	6.62	8.40	7.25	8.30	5.65	5.11	7.11
COPFOC2	7.32	7.32	6.27	7.47	6.84	8.54	5.98	5.39	6.89
COAFOC3	7.56	7.56	6.45	7.64	6.54	8.53	6.45	5.76	7.06
THMFOC1	7.91	7.45	6.19	8.47	8.27	8.69	5.98	5.48	7.30
THBFOC2	7.01	6.84	6.48	8.26	7.34	8.37	5.41	5.78	6.94
THPFOC3	7.45	6.74	6.21	8.28	6.25	8.49	5.66	5.41	6.81
Mean	7.33	7.39	6.35	8.05	7.33	8.53	5.91	5.41	

*Mean of three replications **DAI-Days after inoculation CD(P=0.05); Isolates = 0.20 Medium = 0.14; Isolates×Medium = 0. 57

Results of the study indicated that the role of C:N ratio was very important to colonize organic substances in the soil. Increased inoculum potential and disease severity were positively correlated with the food base of organic substances. Crop debris that served as a food base can also serve as an infection bridge. Increasing the C/N ratio of the medium resulted in reduced macroconidial formation and increased chlamydospore production.

Effect of pH

Change in pH plays an important role in hydrogen ion concentration which is essential for the growth of fungi. In the present study, maximum

Table 6. Effect of pH levels on the growth of *Fusarium oxysporum* f. sp. *cepae* isolates

Isolate	Mycelial dry weight (mg)*										
	7 DAI**										
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	Mean
ERKFOC1	2.91	3.15	4.25	6.08	7.78	8.48	8.74	6.24	4.11	0.75	5.249
ERVFOC2	1.55	3.12	4.13	5.97	7.49	8.57	8.65	6.64	3.96	0.46	5.054
ERPFOC3	0.98	3.95	4.98	6.21	7.32	8.64	8.87	6.37	3.98	0.0	5.13
MDSFOC1	1.73	2.62	3.60	5.32	7.56	8.53	7.83	6.10	3.67	0.36	4.732
MDPFOC2	0.58	2.71	3.75	5.89	7.91	8.57	8.11	5.97	3.71	0.58	4.778
MDUFOC3	1.17	3.12	4.15	5.63	7.21	8.45	8.43	6.44	3.12	0.17	4.789
DNSFOC1	2.97	4.65	5.60	6.53	8.44	8.98	8.92	6.87	3.38	0.97	5.733
DNOFOC2	0.35	3.73	4.71	6.07	7.45	8.85	7.97	6.43	3.57	0.0	4.913
DNTFOC3	0.39	2.01	3.06	6.08	6.95	8.34	8.32	5.97	4.13	0.0	4.525
COUFOC1	1.56	2.16	3.18	5.65	7.25	8.79	8.55	6.60	3.42	0.0	4.716
COPFOC2	1.49	2.69	3.67	5.98	6.84	7.98	7.87	6.28	3.44	0.0	4.624
COAFOC3	2.01	2.80	3.81	6.45	6.54	8.73	7.84	6.42	3.62	0.21	4.843
THMFOC1	2.23	2.14	3.12	5.98	7.87	8.61	8.85	6.10	3.94	0.0	4.884
THBFOC2	1.02	2.34	3.38	5.41	7.34	8.52	8.66	6.41	3.27	1.02	4.737
THPFOC3	1.35	2.72	3.70	5.66	6.25	8.35	8.67	6.20	3.40	0.0	4.63
Mean	1.49	2.92	3.94	5.93	7.35	8.56	8.42	6.34	3.61	0.30	

* Mean of three replications **DAI-Days after inoculation CD(P=0.05) Isolates = 0.15 pH = 0.12 Isolates×pH = 0. 46

mean mycelial growth was observed at pH 6.5 (8.56 cm) followed by pH 7.0 (8.42 cm) and less growth was observed below pH 5.0 and above pH 7.5 (Table 6). Farooq *et al*. (2005) reported that the growth of *F.oxysporum* was maximum (80 mm) at pH 7. *Fusarium* species grew well at a pH range of 6.5 to 7.0 (El-Sayed *et al*., 2008). Imran Khan *et al*. (2011) reported that between pH 6.5 and pH 7.0 was found to be optimum for the growth of *Fusarium oxysporum f.sp. ciceri. Fusarium oxysporum* had maximum radial growth at pH 6.5 followed by pH 7.5 (Bhale, 2012).

Among the isolates, DNSFOC1 from Sempatti recorded maximum mycelial growth 8.98 cm followed by DNOFOC2 (8.85 cm) collected from

Table 7. Effect of temperature on the growth of *Fusarium oxysporum* f. sp. *cepae* isolates

Isolates	Mycelial growth (cm)* 7 DAI**								Mean
	5°C	10°C	15°C	20°C	25°C	30°C	35°C	40°C	
ERKFOC1	0.0	0.0	1.25	4.25	5.18	8.34	7.41	0.0	3.30
ERVFOC2	0.0	0.0	1.13	4.13	5.97	8.47	7.53	0.0	3.40
ERPFOC3	0.0	0.0	1.08	4.08	5.25	8.23	7.56	0.0	3.27
MDSFOC1	0.0	0.0	1.94	3.94	5.41	8.60	6.48	0.0	3.29
MDPFOC2	0.0	0.0	1.65	3.65	5.57	8.71	6.35	0.0	3.24
MDUFOC3	0.0	0.0	2.89	4.65	5.79	8.85	7.66	0.0	3.73
DNSFOC1	0.0	0.0	2.74	4.72	5.84	8.81	7.42	0.0	3.69
DNOFOC2	0.0	0.0	1.48	4.48	5.49	8.55	6.20	0.0	3.27
DNTFOC3	0.0	0.0	1.49	3.49	5.32	8.79	6.55	0.0	3.20
COUFOC1	0.0	0.0	1.93	3.93	5.17	8.35	5.97	0.0	3.16
COPFOC2	0.0	0.0	1.51	3.51	5.34	8.59	6.93	0.0	3.23
COAFOC3	0.0	0.0	1.93	3.93	5.79	8.52	7.65	0.0	3.47
THMFOC1	0.0	0.0	1.19	3.19	5.42	8.44	6.96	0.0	3.15
THBFOC2	0.0	0.0	1.44	3.44	5.74	8.35	6.54	0.0	3.18
THPFOC3	0.0	0.0	1.73	3.73	5.47	8.43	6.33	0.0	3.21
Mean	0.0	0.0	1.69	3.91	5.50	8.51	6.90	0.0	

* Mean of three replications ******DAI-Days after inoculation CD(P=0.05) Isolates = 0.12 Temperature = 0.09 Isolates × Temperature = 0.36

Ottanchathram at pH 6.5. Variation in growth and sporulation of isolates at a particular pH may be due to fact that a particular isolate grew better at a specific pH. The other possible reason may be that isolates collected from a particular location may have become adopted to particular pH for growth and sporulation (Mehta *et al.,* 2005).

Effect of temperature

Each fungus has its own temperature range for growth and sporulation. Growth of all organisms is affected by temperature because it mediates metabolic reactions. The temperature range between 0°C and 40°C was the most suitable for growth of microorganisms, the minimum temperature being associated with the transition phase at freezing and the maximum temperature influenced the catabolism of microorganisms (Gilloly *et al*., 2001). In the present study, growth of the fungus was drastically reduced below 20°C and above 35°C. The fungus attained the mean maximum growth of 8.51 cm at 30°C (Table 7).

Among the isolates, MDUFOC3 from Usilampatti recorded maximum mycelial growth 8.85 cm followed by DNSFOC1 (8.81 cm) from Sempatti at 30°C. Farooq *et al*. (2005) observed that at 25°C and 30°C the *Fusarium oxysporum* attained the maximum growth 76.8 and 85.4 mm. Temperature above 37°C affected the hyphal tip elongation and appressorial formation (Agrios, 2006). A temperature of 25–30°C was found to be favourable for germination, germ-tube elongation, sporulation and growth, although the fungus could tolerate higher temperatures. Activity of the fungus was enhanced at high relative humidities.

El-Sayed *et al*.(2008) reported that growth of *Fusarium* spp. was best between 25°C and 30°C. 30°C was optimum for the growth of *Fusarium oxysporum* f.sp.*ciceri* which was an important factor for growth, reproduction and survival of the fungus (Imran Khan *et al*., 2011).

The results of this study determined the culture conditions required to optimize the growth better understanding of *Fusarium oxysporum* f.sp.*cepae* isolates. These results will be helpful for the cultural management of the disease.

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