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Morpho-cultural variability of *Fusarium solani* isolates causing root rot of okra in low and mid hills of Himachal Pradesh

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Abstract

Morphological and cultural variability was studied among the okra root rot pathogen isolates (35) of *Fusarium solani* collected from infested okra fields constituting three agroclimatic zones of Himachal Pradesh. The isolates cultured on potato dextrose agar medium showed considerable cultural variabilities in conidia dimensions, colony colour, colony diameter, and number of septa. Colony diameter among *F. solani* isolates ranged from 74-86 mm and produced white/ greyish white growth with light pink/purplish/brownish pigmentation. Aggressiveness of all the 35 isolates was tested by soil infestation method where isolates were categorized as highly, moderately, or weakly pathogenic. The isolates produced macroconidia of size ranged from 18.23-30.85×4.70-5.99 µm with 1-5 septation, microconidia of size 5.91-11.71×2.78-3.97 µm with 0-1 septation and chlamydospore of size 8-12×8-10 µm. Based on these morpho-cultural characteristics and cluster analysis using SPSS 16.0 software, all 35 isolates grown on PDA medium at 25±1 ºC were categorized into seven morpho-cultural groups and were designated as FS-MV-1 to FS-MV-7.

Key words: Root rot, morpho-cultural, variability, *Fusarium solani*

Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable grown in almost all parts of India. The okra fruits along with its seeds are a source of variety of nutrients and therefore acquire a high position in nutritional charts. Its fruits are edible and are rich source of calcium, iron, saturated fats, carbohydrates, proteins, riboflavins and vitamin A, B, C, E and K, etc. hence provide nutritional and health benefits. Okra production has been suffering to a great extend because of many fungal diseases but root rot is one of the destructive diseases caused by many fungal pathogens like *Fusarium* spp. and *Rhizoctonia solani* where the most frequently associated pathogen with root rot was *Fusarium solani.* (Purba 2004). A deep comprehension of the populations of pathogens is important as they show variations in pathogenicity, response to management systems, environment, and host differences. Thus, population biology of the pathogen needs to be studied thoroughly. In Himachal Pradesh, root rot caused by *F. solani* has also emerged as a major disease constraint in okra production so a detailed investigation of pathogen causing okra root rot is required. In this regard, major okra growing areas were investigated for pathogens association and prevalence of major pathogen in different areas of HP besides morphological studies were carried out which revealed *Fusarium solani* to be major causal organism for okra root rot in Himachal Pradesh along with *Fusarium oxysporum* and *Rhizoctonia solani.*

Materials and methods

Isolation of pathogen and pathogenicity test:

The fungal cultures were isolated from diseased tissues using standard methodology on PDA. The diseased samples were washed with sterilized water and cut into small bits of 2-3 mm having half healthy and half diseased portion. These bits were surface sterilized by dipping in 1% sodium hypochlorite solution for 10-15 seconds followed by washing three times in sterilized distilled water under laminar air flow hood. The bits were dried in 2-folds of sterilized filter papers to remove excess moisture and transferred into PDA Petri plates under aseptic conditions and incubated in BOD at 25±1°C. After 48 hrs. of

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incubation, growing mycelium was transferred to PDA slants and purified by single spore culture. Fungal colony arising from single spore of each isolate was maintained on PDA medium and used for further studies. Pathogenicity test was performed on susceptible okra cultivar 'P-8' in pots under controlled condition by three methods *viz.,* a) seed inoculation b) soil inoculation and c) seed-cum-soil inoculation to confirm the pathogenic nature of isolate. The spore suspension of the fungus having 4.0×10^5 spores/ml was used as inoculum. All the isolates of the fungus were multiplied on sterilized corn flour and sand mixture (1:9 w/w basis) for 10-15 days in flasks. The inoculum of each isolate was separately mixed @ 100 g/kg sterilized soil and this mixture was put in the plastic pots. Ten apparent healthy and surface sterilized seeds of susceptible okra variety P-8 were sown in each sick pot (6" diameter). Seeds sown in pots having sterilized soil without inoculum served as check. The pots were transferred to the green house and watered daily and observed for the development of disease symptoms. The pathogen was re-isolated from the diseased plant and cultured by standard methods discussed previously. The characteristics of pathogen culture thus obtained was compared with that of corresponding inoculated culture of the pathogen to prove the pathogenicity.

Identification of pathogen

The identification of test pathogens was done by studying morpho-cultural parameters. The test pathogens were grown on PDA in Petri plates and incubated for 5 days at 25±1°C in BOD incubator. The mycelium was scraped by using sterilized needle and placed over the glass slide and examined under compound microscope at 10X and 40X. *Fusarium solani* was identified based on colony colour and colony growth on PDA, size of microconidia and macroconidia and compared with the morphological characters documented in taxonomic keys (Booth, 1971). *F. solani* was identified based on colony colour, diameter, and the size of macroconidia and microconidia.

Identification based on morphological characters

Collection of isolates was done and then studied by following methods for different parameters of morphological identification of the pathogen.

a) Colony diameter

Colony diameter was measured by the measuring scale after 9th day (from 3 replications).

b) Colony colour

Colour of colonied were observed visually from the front and back of the Petri plate at 9th day (from 3 replications).

b) Colony growth

Growth pattern and shape of colony was examined by observing mycelium (from 3 replications).

d) Dimensions of macro and microconidia

The length, breadth, and number of septa of macro and microconidia were observed under compound microscope at 40 x magnifications by using stage and ocular meter. Data of fifteen conidia were recorded from all 35 isolates.

Results and Discussion

Isolation of *Fusarium solani* isolates

During *Kharif* season of 2019-20, 2020-21 and 2021-22 different okra growing localities were surveyed and thirty-five isolates of pathogen associated with root rot of okra were collected from six districts of the state, belonging to three agro-climatic zones (Table 1) which included 18 isolates from district Kangra, 5 from Hamirpur, and three each from Bilaspur, Chamba, Una and Mandi districts. Majority of the isolates were collected from Kangra district.

Pathogenicity test

Pathogenicity with root rot of okra associated pathogen (*F. solani*) isolates was proved under pot culture conditions on variety 'P-8' making sick soil by adding 100 g inoculum per kg of soil. Initial symptoms appeared early at the seedling stage, mostly during two-three leaf stage of the plant. Initially the tender leaves start wilting and drooping, in advanced stages, blackening of collar regions of stem takes place, which progresses up to 1-2 cm above the soil level. On uprooting, it was found that the root system of infected plants was poorly developed, damaged, and decayed. On examining the collar region, it was noticed that the blackening and decaying progressed up to stellar region thereby disrupting the nutrient supply to the growing parts. The pathogen was recovered after isolation from plants exhibited characteristics symptoms in pathogenicity test. Pure culture obtained by single spore matched exactly with the inoculated test pathogen hence pathogenicity proved.

The pathogenicity of all the 35 isolates of *Fusarium solani* was tested by soil infestation method (Wagh 2009). Observations on root rot/wilt incidence

Table 1. *Fusarium solani* isolates collected from different locations

Isolate No./Name	Location	Agro-Climatic Zone	Latitude	Longitude	District
Fs01	Palampur	Zone-II	32.1109°N	76.5363°E	Kangra
Fs02	Nagri	Zone-II	32.1314°N	76.4708°E	Kangra
Fs03	Banuri	Zone-II	32.1018°N	76.5575°E	Kangra
Fs04	Bharmat	Zone-II	32.1071°N	76.5676°E	Kangra
Fs05	Sungal	Zone-II	32.0835°N	76.5821°E	Kangra
Fs06	Maranda	Zone-II	32.0801°N	76.5112°E	Kangra
Fs07	Bhawarna	Zone-II	32.0398°N	76.4997°E	Kangra
Fs08	Panchrukhi	Zone-II	32.0566°N	76.5647°E	Kangra
Fs09	Panapar	Zone-II	32.0441°N	76.4501°E	Kangra
Fs10	Ghalour	Zone-I	31.8365°N	76.2790°E	Kangra
Fs11	Jawalamukhi	Zone-I	31.8752°N	76.3203°E	Kangra
Fs12	Paprola	Zone-II	32.0528°N	76.6341°E	Kangra
Fs13	Alhilal	Zone-II	32.0646°N	76.6138°E	Kangra
Fs14	Kangra	Zone-I	32.1015°N	76.2731°E	Kangra
Fs15	Nagrota	Zone-II	32.1054°N	76.3789°E	Kangra
Fs16	Hatwas	Zone-II	32.1125°N	76.4016°E	Kangra
Fs17	Abdullapur	Zone-I	32.1245°N	76.2667°E	Kangra
Fs18	Zamanabad	Zone-I	32.1195°N	76.2660°E	Kangra
Fs19	Putrial	Zone-I	31.7467°N	76.4546°E	Hamirpur
Fs20	Bara	Zone-I	31.8731°N	76.2117°E	Hamirpur
Fs21	Fatehpur	Zone-I	31.3742°N	76.3156°E	Hamirpur
Fs22	Bharmoti	Zone-I	31.7629°N	76.3475°E	Hamirpur
Fs23	Sujanpur	Zone-I	31.8339°N	76.5055°E	Hamirpur
Fs24	Ghumarwin	Zone-I	31.9156°N	76.3710°E	Bilaspur
Fs25	Chhajoli	Zone-I	31.5170°N	76.6507°E	Bilaspur
Fs26	Naswal	Zone-I	31.4716°N	76.6788°E	Bilaspur
Fs27	Saru	Zone-III	32.1030°N	76.5821°E	Chamba
Fs28	Parel	Zone-III	32.5630°N	76.1187°E	Chamba
Fs29	Banota	Zone-III	31.5527°N	76.6369°E	Chamba
Fs30	Amb	Zone-I	31.6798°N	76.1175°E	Una
Fs31	Andora	Zone-I	31.6858°N	76.1143°E	Una
Fs32	Mubarikpur	Zone-I	31.7095°N	76.0827°E	Una
Fs33	Jogindernagar	Zone-II	31.9912°N	76.7899°E	Mandi
Fs34	Naun	Zone-III	31.5597°N	77.0262°E	Mandi
Fs35	Siyanji	Zone-III	31.4837°N	76.9801°E	Mandi

Zone I = Sub-Mountain and Low Hills Sub-Tropical Zone (365-914 meters amsl), Zone II = Mid Hills Sub-Humid Zone (915-1523 meters amsl), Zone III = High Hills Temperate Wet Zone (1524-2472 meters amsl)

made after 10-15 days of sowing categorized the isolates into four groups as highly pathogenic (>40% root rot/wilt incidence), moderately pathogenic (20-40% root rot/wilt incidence), weakly pathogenic (0-20% root rot/wilt incidence) and non-pathogenic (no root rot/wilt incidence) Data presented in Table 2 showed that 25 isolates *viz.,* Fs01, Fs02, Fs05, Fs10, Fs11, Fs12, Fs14, Fs15, Fs16, Fs17, Fs18, Fs19, Fs21, Fs24, Fs25, Fs26, Fs27, Fs28, Fs29, Fs30, Fs31, Fs32, Fs33, Fs34 & Fs35 showed root rot/wilt incidence above 40 per cent and categorized as highly pathogenic. Nine isolates namely Fs04, Fs06, Fs07, Fs08, Fs09, Fs13, Fs20, Fs22 & Fs23 showed root rot/wilt incidence between 20-40 per cent and those were categorized as moderately pathogenic whereas one isolate of *Fusarium solani viz.,* Fs03 showed root

Table 2. Pathogenicity test of different isolates of *Fusarium solani* causing root rot in okra in pots under net house conditions

Isolate	Disease incidence (%)		Categorization*
	10DAS	15DAS	
Fs01	13.33	66.67	Highly pathogenic
Fs02	13.33	46.67	Highly pathogenic
Fs03	00.00	13.33	Weakly pathogenic
Fs04	06.67	20.00	Moderately pathogenic
Fs05	13.33	46.67	Highly pathogenic
Fs06	20.00	33.33	Moderately pathogenic
Fs07	06.67	26.67	Moderately pathogenic
Fs08	13.33	33.33	Moderately pathogenic
Fs09	06.67	33.33	Moderately pathogenic
Fs10	13.33	40.00	Highly pathogenic
Fs11	13.33	40.00	Highly pathogenic
Fs12	20.00	40.00	Highly pathogenic
Fs13	13.33	33.33	Moderately pathogenic
Fs14	26.67	53.33	Highly pathogenic
Fs15	20.00	46.67	Highly pathogenic
Fs16	20.00	53.33	Highly pathogenic
Fs17	13.33	46.67	Highly pathogenic
Fs18	13.33	46.67	Highly pathogenic
Fs19	13.33	40.00	Highly pathogenic
Fs20	00.00	33.33	Moderately pathogenic
Fs21	06.67	46.67	Highly pathogenic
Fs22	00.00	33.33	Moderately pathogenic
Fs23	00.00	33.33	Moderately pathogenic
Fs24	33.33	80.00	Highly pathogenic
Fs25	26.67	60.00	Highly pathogenic
Fs26	26.67	66.67	Highly pathogenic
Fs27	26.67	53.33	Highly pathogenic
Fs28	13.33	60.00	Highly pathogenic
Fs29	13.33	40.00	Highly pathogenic
Fs30	20.00	46.67	Highly pathogenic
Fs31	00.00	40.00	Highly pathogenic
Fs32	13.33	46.67	Highly pathogenic
Fs33	06.67	46.67	Highly pathogenic
Fs34	13.33	53.33	Highly pathogenic
Fs35	13.33	46.67	Highly pathogenic

*0-20%- Weakly pathogenic, 20-40%- Moderately pathogenic, >40%- Highly pathogenic

rot/wilt incidence up to 13.33 per cent after 15 days of sowing and categorized as weakly pathogenic. The results of pathogenicity observed in the present investigation are in accordance with the findings of earlier workers. Association of *Fusarium solani* with root rot of okra has been established by various workers. Patel and Vala (2003) isolated *F. solani* from wilt affected okra plant and experimentally established its pathogenic association and causal nature by confirming Koch's postulates. El-Mohamedy (2004) proved pathogenicity test with *F. solani*, *R. solani* and *M. phaseolina* causal agents of okra damping off and root rot diseases by applying inoculum and found that the most aggressive fungi were *F. solani* and *R. solani*.

Purba (2004) reported that *F. solani* was most frequently associated pathogen with root rot in okra in Himachal Pradesh ranging from 8.35 to 78.94 per cent. Purba (2004) also reported pathogenicity of *F. solani* to cause root rot of okra by adding 21 days old inoculum prepared on sand: maize meal (9:1) in pot and observed symptoms of the disease as blackening of collar region of stems and decaying of roots in young seedlings. Sharma (2011) also reported that *R. solani* and *F. solani* were associated with damping off of okra in Himachal Pradesh and observed that maximum pre-emergence mortality was recorded in Hamirpur district (60.0%) and post-emergence mortality in Kangra district (20.5%).

Identification based on morphological characters

Pathogen was identified based on the characteristic symptoms produced after inoculation and morphological identification of conidia. *Fusarium solani* was identified with morphological characters like size, color, shape of conidia as well as number of septation in conidia. These parameters were studied by using compound microscope at 40 X with stage and ocular micrometres (Table 3). Macro and micro conidia were observed measuring 18.23-30.85×4.70-5.99 µm mostly with 1-5 septa and fusiform, cylindrical somewhat curved with a short blunt apical point whereas cylindrical to oval measuring 5.91-11.71×2.78-3.97 µm mostly with no septation, respectively.

Pathogen was identified on the basis of the morphological characters which were favoured with the earlier documented literature. Chattopadhyay and Basu (1957), observed that *F. solani*, the causal agent of okra wilt produced oval shaped thick-walled microconidia with rounded ends or straight with pointed ends measuring 2.8-5.5 x 5.5-6.5 µm; macroconidia with 1-3 septa and measuring 10.9-36.3 x 3.3-6.5 µm. Ravichandran and Kumar (2012) found that 13 different isolates of *F. solani* (Mart.) Sacc., collected from different parts of Andhra Pradesh showed variation in morphological character of microconidia from 3-4 X 1-2 µm to 9-10 X 1-3µm & macroconidia 13-15 X 3-4 µm to 27-29 X 4-5 µm in size they also reported the number of septa in macroconidia & microconidia 3-5 and 0-1 respectively and conidia were hyaline.

Gupta *et al*. (2011) found that 20 different isolates of *F. oxysporum* f. sp. *pisi* collected from different parts of Himachal Pradesh showed variation in morphological characteristics, microconidia varied from 3.16 x 3.16 to 9.13 x 5.44 µm and macroconidia varied from 11.77 x 3.16 to 24.60 x 5.91 µm in size.

Table 3. Morphological characteristics of *Fusarium solani* associated with root rot of okra

Character	Test pathogen (Isolated pathogen)	*Fusarium solani* (Booth, 1971 and Mycology Online)
Colour of colony on PDA	White to greyish white colonies were growing rapidly with aerial mycelium and agar typically develops a light pink/ purplish/ brownish discoloration.	White to cream (greyish white) colonies growing rapidly with aerial mycelium and agar typically develops a bluish brown discoloration.
Growth on PDA	3.8 – 4.00 cm in four days	4.5 cm in four days
Macroconidia	18.23-30.85×4.70-5.99 µm mostly with 1-5 septa and fusiform, cylindrical somewhat curved with a short blunt apical point.	28-42×4.5-6 µm mostly with 3-5 septa and fusiform, cylindrical, often moderately curved, with an indistinct pedicellate at foot cell and a short blunt apical point.
Microconidia	Cylindrical to oval measuring 5.91-11.71×2.78-3.97 µm mostly with no septation.	Cylindrical and rather broader to oval measuring 8-16×2-4 µm may become 1 septate
Chlamydospores	Smooth to rough walled chlamydospores of 8-12×8-10 µm were formed terminally or in chains on short lateral branches.	Globose to oval, smooth to rough-walled chlamydospores of 9-12×8-10 µm borne singly or in pairs on short lateral hyphal branches.

Morphological characteristics of test pathogen were found in line with the description of *F. solani*. Thus, based on morphological characteristics the pathogen causing root rot of okra was identified as *Fusarium solani.*

Morpho-cultural variability

The results of different parameters like conidia dimensions, colony color, colony diameter, and number of septa studied for morpho-cultural variability with pure-culture of all the isolates are presented in Table 4.

In general, the growth of fungus varied from 74 mm to 86 mm after 9 days of incubation on PDA medium at 25 ± 1 ºC. The isolate Fs20, Fs24, Fs25 and Fs28 were most fast growing followed by Fs26 and Fs32. Various colors *viz.,* white and greyish white colonies were observed in different isolates. Light pink, purplish to brownish pigmentation was found in

Table 4. Morphological and cultural characteristics of different isolates of *Fusarium solani*

Isolate	Average size of conidia						Colony colour	Pigmentation	Colony diameter in mm (9DAI)
	Macroconidia			Macroconidia					
	(L)$^{\times}$ (µm)	(B)× (µm)	No. of Septa	(L)$^{\times}$ (µm)	(B)× (µm)	No.of Septa			
Fs01	20.83	5.19	2-3	8.35	2.99	0	White	-	78
Fs02	19.91	5.01	1-3	5.65	2.78	0	White	-	78
Fs03	18.80	4.90	2-3	8.82	3.01	0	Greyish White	-	78
Fs04	20.24	5.11	2-3	8.93	3.22	0	White	-	80
Fs05	21.76	4.88	2-3	6.26	2.79	0	White	-	76
Fs06	20.48	4.77	2-3	8.74	3.07	0	White	Light pink	78
Fs07	19.60	4.74	2-3	6.60	3.05	0	White	Light pink	78
Fs08	19.09	4.72	2-3	6.13	2.94	0	White	-	80
Fs09	20.09	4.57	2-3	6.04	3.04	0	White	-	78
Fs10	21.89	5.23	2-4	8.90	2.94	0	White	Light pink	76
Fs11	21.67	5.31	2-3	8.77	2.89	0	White	Light pink	78
Fs12	20.45	4.98	2-3	8.97	2.87	0	White	-	76
Fs13	22.49	5.21	2-3	8.89	3.02	0	White	-	74
Fs14	23.67	5.18	2-3	8.74	2.89	0	White	-	78
Fs15	22.77	5.13	2-3	8.46	2.97	0	White	-	74
Fs16	22.79	5.15	2-3	8.69	2.99	0	White	-	76
Fs17	20.92	4.83	2-3	8.77	3.07	0	White	-	74
Fs18	21.92	4.87	2-3	8.72	2.87	0	White	-	80
Fs19	18.59	4.74	1-3	6.68	2.97	0	Greyish White	-	78
Fs20	18.23	4.70	1-3	6.52	2.78	0	White	-	86
Fs21	23.73	5.06	3-4	10.68	3.79	0	White	Light pink	78
Fs22	22.39	5.03	2-3	5.91	2.86	0	White	-	80
Fs23	21.22	4.82	1-3	6.83	2.92	0	White	-	82
Fs24	30.35	5.95	3-4	11.14	3.05	0	White	Purplish	86
Fs25	28.47	5.81	3-4	10.70	3.30	0	White	Purplish	86
Fs26	25.20	5.39	2-4	10.24	3.23	0	White	Light pink	84
Fs27	25.63	5.41	3-4	10.47	3.81	0-1	Greyish White	-	80
Fs28	28.26	5.62	4-5	10.76	3.45	0-1	White	-	86
Fs29	28.21	5.31	3-4	10.71	3.46	0	White	-	82
Fs30	30.95	5.99	2-3	11.71	3.56	0	White	Light pink	82
Fs31	28.68	5.83	2-3	11.04	3.97	0	White	Light pink	80
Fs32	23.77	5.18	2-3	10.70	3.09	0	White	Light pink	84
Fs33	25.86	5.57	3-4	9.26	2.91	0	White	Brownish	74
Fs34	28.39	5.72	3-4	10.44	3.95	0	White	Brownish	78
Fs35	23.54	5.15	2-3	8.62	3.27	0	White	Brownish	76
Range	18.23-30.95	4.57-5.99	1-5	5.65-11.71	2.78-3.97	0-1			74-86

the isolates of *F. solani.* Length of macroconidia varied from 18.23-30.85 µm with an average of 23.17 µm and width varied from 4.70-5.99 µm with an average value of 5.17 µm with a range of 1-5 septa. Length of microconidia varied from 5.91-11.71 µm with an average of 8.77 µm and width varied from 2.78-3.97 µm with an average value of 3.14 µm with a range of 0-1 septa. Thus, on the basis of these morpho-cultural characteristics, isolates grown on PDA medium at 25±1 ºC were categorized into 7 morpho-cultural groups (FS-MV-1 to FS-MV-35) as presented in Table 5.

FS-MV: *Fusarium solani* morpho variability

These morpho-cultural groups were designated as FS-MV-1- FS-MV-7 (Table 5, Fig. 1). FS-MV-1 comprised of 5 isolates (Fs-02, Fs-07, Fs-08, Fs-09 and Fs-19) with white to greyish white colony having slightly light pink pigmentation, macroconidia

Table 5. Grouping of 35 isolates of *Fusarium solani* based on morpho-cultural characteristics

Group No.	Isolate	Morpho-cultural characteristics
FS-MV-1	Fs-02, Fs-07, Fs-08, Fs-09, Fs-19	Colony is white to greyish white in colour having slightly light pink pigmentation, macroconidia measuring 19.91-21.89 x 4.57-5.01µm with 1-3 septa whereas microconidia measuring 5.65-6.68 x 2.78-3.04 µm with no septation and around 78-80 mm growth on PDA at 9DAI.
FS-MV-2	Fs-01, Fs-03, Fs-04, Fs-06, Fs-11, Fs-18, Fs-22, Fs-23	Colony is white to greyish white in colour having light pink pigmentation, macroconidia measuring 18.80-22.39 x 4.77-5.31 µm with 1-3 septa whereas microconidia measuring 5.91-8.93 x 2.86-3.22 µm with no septation and around 78-82 mm growth on PDA at 9DAI.
FS-MV-3	Fs-14, Fs-21, Fs-27	Colony is white to greyish white in colour having light pink pigmentation, macroconidia measuring 23.67-25.63 x 5.06-5.41 µm with 2-4 septa whereas microconidia measuring 8.74-10.68 x 2.89-3.81 µm with 0-1 septa and around 78-80 mm growth on PDA at 9DAI.
FS-MV-4	Fs-05, Fs-10, Fs-12, Fs-13, Fs-15, Fs-16, Fs-17, Fs-33, Fs-35	Colony is white in colour having light pink to purplish/ brownish pigmentation, macroconidia measuring 20.45-25.86 x 4.83-5.57 µm with 2-4 septation whereas microconidia measuring 6.26-9.26 x 2.79-3.27 µm with no septation and around 74-76 mm growth on PDA at 9DAI.
FS-MV-5	Fs-20	Colony is white in colour having no pigmentation, macroconidia measuring 18.23 x 4.70 µm with 1-3 septa whereas microconidia measuring 6.52 x 2.78 µm with no septation and around 86 mm growth on PDA at 9DAI.
FS-MV-6	Fs-29, Fs-30, Fs-31, Fs-34	Colony is white in colour having light pink to brownish pigmentation, macroconidia measuring 28.21-30.95 x 5.31-5.99 µm with 2-4 septation whereas microconidia measuring 10.44-11.71 x 3.46-3.99 µm with no septation and around 78-82 mm growth on PDA at 9DAI.
FS-MV-7	Fs-24, Fs-25, Fs-26, Fs-28, Fs-32	Colony is white in colour having light pink to purplish pigmentation, macroconidia measuring 23.77-30.35 x 5.18-5.95 µm with 2-5 septa whereas microconidia measuring 10.24-11.14 x 3.05-3.45 µm with 0-1 septation and around 84-86 mm growth on PDA at 9DAI.

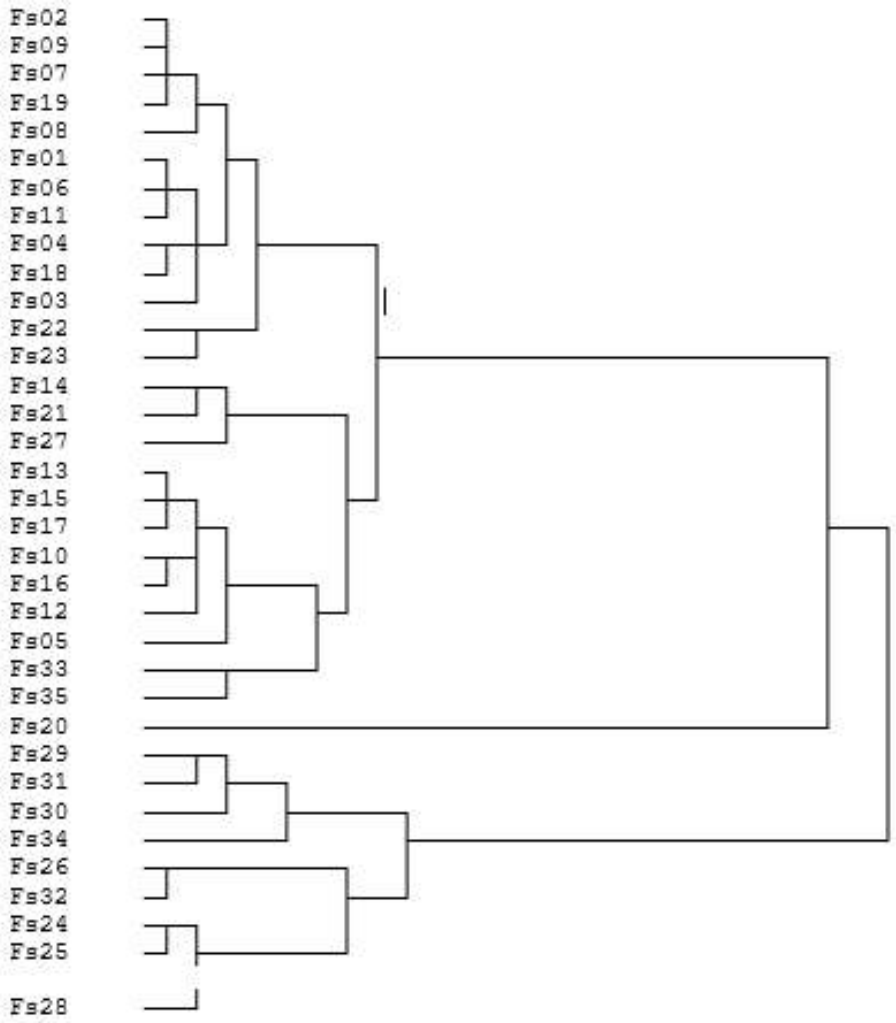

Figure 1: Cluster analysis indicating diversity within 35 isolates of *Fusarium solani* using SPSS 16.0 software

measuring 19.91-21.89 x 4.57-5.01µm with 1-3 septa whereas microconidia measuring 5.65-6.68 x 2.78-3.04 µm with no septation and around 78-80 mm growth on PDA at 9DAI. Isolates Fs-01, Fs-03, Fs-04, Fs-06, Fs-11, Fs-18, Fs-22, and Fs-23 with white to greyish white colony having light pink pigmentation, macroconidia measuring 18.80-22.39 x 4.77-5.31 µm with 1-3 septa whereas microconidia measuring 5.91-8.93 x 2.86-3.22 µm with no septation and around 78-82 mm growth on PDA at 9DAI were grouped under FS-MV-2 group. Group FS-MV-3 constitute three isolates (Fs-14, Fs-21 and Fs-27) with white to greyish white colony colour having light pink pigmentation, macroconidia measuring 23.67-25.63 x 5.06-5.41 µm with 2-4 septa whereas microconidia measuring 8.74-10.68 x 2.89-3.81 µm with 0-1 septa and around 78-80 mm growth on PDA at 9DAI. Group 4 had nine isolates (Fs-05, Fs-10, Fs-12, Fs-13, Fs-15, Fs-16, Fs-17, Fs-33 and Fs-35) had white colony colour having light pink to purplish/brownish pigmentation, macroconidia measuring 20.45-25.86 x 4.83-5.57 µm with 2-4 septation whereas microconidia measuring 6.26-9.26 x 2.79-3.27 µm with no septation and around 74-76 mm growth on PDA at 9DAI. Group 5 includes only one isolate (Fs20) which had white colony colour having no pigmentation, macroconidia measuring 18.23 x 4.70 µm with 1-3 septa whereas microconidia measuring 6.52 x 2.78 µm with no septation and around 86 mm growth on PDA at 9DAI. Group FS-MV-6 (Fs-29, Fs-30, Fs-31 and Fs-34) had white colony colour having light pink to brownish pigmentation, macroconidia measuring 28.21-30.95 x 5.31-5.99 µm with 2-4 septation whereas microconidia measuring 10.44-11.71 x 3.46-3.99 µm with no septation and around 78-82 mm growth on PDA at 9DAI. Isolate Fs-24, Fs-25, Fs-26, Fs-28 and Fs-32 were clubbed in group FS-MV-7 which had white colony colour having light pink to purplish

pigmentation, macroconidia measuring 23.77-30.35 x 5.18-5.95 µm with 2-5 septa whereas microconidia measuring 10.24-11.14 x 3.05-3.45 µm with 0-1 septation and around 84-86 mm growth on PDA at 9DAI.

Present findings are in conformity with the results of Ali *et al*. (2013) who studied the biology of five different isolates of *Fusarium solani*, causing root rot of okra in Peshawar and reported variation in the fungal colony colour. Colony colour was reported to be white to off white, creamy, and chocolate colour or bright or silver coloured. Chavan *et al*. (2011) also reported variation in cultural characteristics of eight isolates of *F. solani* infecting patchouli. They observed maximum colony diameter in isolate Fs1 (90.00 mm) whereas minimum colony diameter in isolate Fs7 (84.00 mm) on PDA medium. Wagh *et al*. (2010) reported that six isolates of *F. oxysporum* f. sp. *lini* varied significantly in their cultural characteristics on PDA. Isolate Fol-6 was recorded as fast growing (82.00 mm) while remaining isolates showed moderate mycelium growth ranging from 71.6mm to78.7mm. They also reported variations with respect to colony pigmentation where isolates Fol-2, Fol-3 and Fol6 produced a bright white mycelium, while isolates Fol-1 and Fol-4 produced slight white mycelium and isolate Fol-5 produced violet coloured mycelial pigmentation. Dubey *et al*. (2010) also studied 112 isolates of *F. oxysporum* f. sp. *ciceri* causing chickpea wilt and reported them to be highly variable in their colony growth pattern, size of colony and pigmentation. White coloured mycelium was observed in most of isolates but other pigmentations such as violet, yellow, and prominent grey were also reported.

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