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Cultural, Morphological and Pathogenic Variability in *Colletotrichum capsici* causing Die-back and Fruit Rot of Chilli

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ABSTRACT

Chilli is an important cash crop and India is the largest grower, consumer and exporter of dry chillies and other products to over 90 countries around the world. This crop suffers heavy losses in yield due to many diseases especially dieback and fruit rot diseases the frequent epiphytotics of the diseases in the Kashmir valley. During the past few years and extend of damage infelicated necessitated us to generate basic information on the important aspects like status, variability, hostrang and integrated management of the disease. Thus, the present study was undertaken to know the behavior of the disease and biology of the pathogen so as to device better managemental practices of the diseases to avoid losses. The objectives of the study were carried out as per the latest methodologies adopted by various workers in the world. Pathogenic behavior of twenty isolates of *C. capsici*, developed from fruits of chilli, was established following Koch's Postulates. Colonies varied in their cultural behavior ranging from cottony to fluffy, mostly suppressed with regular to irregular margins. Colour of colonies ranged between white to grey. Growth rate of isolates was between 32.0-67.5 mm. Morphological studies of isolates revealed variations in their colour, size, shape, acervuli production, setae size and shape, conidia. Average conidial size varied from 2.23-33.6 μm and average setae size varied from 4.48-177.21 μm. On the basis of disease reaction expressed by differential hosts, ten groups (races) of *C. capsici* were identified. The group 1 comprised of isolates Cc-1, Cc-15 whereas group 2 included the isolate Cc-2, Cc-6, Cc-16. The Cc-3, Cc-10 were included in group-3 whereas group-4 included the isolate Cc-18, Cc-20, Cc-12, Cc-9. The group 5 comprised of isolates Cc-13, Cc-14. The group 6 comprised of Cc-17, Cc-19. The group 7 comprised of isolates Cc-5, Cc-11. Similarly, the isolate Cc-7 was clubbed under group 8.

Key words: Chilli, *Colletotrichum capsici*, dieback, fruit rot, variability

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important cash crop grown under both tropical and subtropical conditions (Pickersgill, 1997). India is the largest grower, consumer and exporter of chilli, currently exporting dry chilli and chilli products to over 90 countries around the world (Singhal, 1999). It is a native plant of America originating somewhere either in Central America or Northern America. *Capsicum* contains approximately 20-27 species, of which five viz., *C. annuum, C. baccatum, C. chinese, C. frutescens* and *C. pubescens* are domesticated in different parts of the world. Among the cultivated *Capsicum*, *C. annuum* is one of the most commonly cultivated crops worldwide (Tong and Bosland, 1999) followed by *C. frutescens* (Bosland and Votava, 2000). Chilli is prone to number of fungal (Walker, 1952) bacterial and viral diseases which

significantly affect its production and quality. However, huge losses to the crop are incurred mostly by fungal diseases. Of these diseases dieback and fruit rot has assumed the status of major disease in some important chilli growing countries. Anthracnose causes extensive pre and post harvest damage to chilli fruits causing anthracnose lesions. Even small anthracnose lesions on chilli fruits reduced their marketable value (Manandhar *et al*., 1995). *Colletotrichium capcisi* is most adhesive that adhere to the plant surface and remain latent until such physiological changes occur in the fruit and cause economic losses to the farmers due to low fruit quality and is our marketability many post harvest diseases of fruit exhibit the phenomenon of quiescence in which symptoms do not develop until the fruit ripens. *Colletotrichum* species are the most adhesive discs that adhere to plant surfaces and remain latent until physiological changes occur in fruits (Bailey *et al*., 1992). Chilli anthracnose usually develops under high humid conditions when rain occurs after the fruits have started to ripen with reported losses of up to 84% (Thind and Jhooty, 1985). Economic losses caused by the disease are mainly attributed to lower quality and marketability. When any of the progeny exhibits a characteristic that is different from those present in the ancestral individuals or descent individuals, this individual is called a variant (Agrios, 2005). Sharma *et al*. (2005) studied the pathogenic variability in *C. capsici* studied in Himachal Pradesh by Sharma *et al*. (2005) found 15 pathotypes of *Colletotrichium capcisi* existed from 30 isolates studied in India and proposed 15 pathotypes of *C. capsici* existed among 37 isolates from different chilli growing regions of Himachal Pradesh. In recent years, the disease has frequently been observed in the Kashmir valley and is assuming serious proportions causing heavy losses to the crop. Perusal of the literature reveals that except the evaluation of fungicides against the causal pathogen (Dhar, 1995), no systemic work on the variability of *Colletotrichum capsici* has been conducted in Jammu and Kashmir State where agro-climatic conditions are entirely different from rest of the country. The frequent epiphytotics of the disease in valley witnessed during past few years and extent of the damage inflicted by it, has necessitated us to generate basic information on variability of the pathogen. The present studies were therefore initiated to find out the variability of *Colletotrichum capsici* isolates.

MATERIALS AND METHODS

During survey extensive survey in the valley during Kharif (growing season) April-May 2010 and 2011 for disease assessment chilli fruits from susceptible cultivar (KL-1) exhibiting typical and variable symptoms of *C. capsici* were collected from nine chilli growing locations across three districts of Kashmir valley viz., Srinagar, Budgam and Pulwama.

Cultural variability: Cultural variability among the isolates was studied on the basis.

Type and colour of colony: Five millimeter mycelial discs of 7 days old culture of each isolate was transferred to the centre of sterilized Petri plates containing potato dextrose agar medium and incubated at 25±1°C. Colony character viz., colour and margins were recorded after 10 days of inoculation.

Growth rate of fungus: To provide a uniform assessment of pathogen growth rates, isolates were cultured on PDA medium in 90 mm petri plates. A two step inoculation method was performed. *C. capsici* isolates from the stored collection were initially inoculated on to PDA and following suitable growth of each isolates. Five millimeter fungal disc from the periphery of 7 days old fungal

isolates were transferred to the centre of PDA Petri plates. The isolates were incubated at 25±1°C. The colony diameter was recorded after 10 days of incubation by taking two perpendicular measurements and their average calculated.

Morphological variability: The morphological variation among the various isolates of *C. capsici* was studied on artificial culture in the laboratory.

Mono-conidial culture of each isolate was first grown on potato dextrose agar medium and then semi-permanent shades prepared from 10 days old culture, stained with cotton blue in lactophenol. The important characters studied were as under:

Hyphae = Septation, colour and width
Setae = Size (length and breadth)
Acervuli = Colour and size
Conidia = Colour and size

Pathogenic variability: In order to identify physiological races of *C. capsici,* attempts were made to develop a differential set of capsicum varieties. Twenty cultivars of *C. annuum* were evaluated for resistance to 20 chosen isolates of *C. capsici.*

Preparation of inoculum: Conidial suspension was prepared in sterilized distilled water by harvesting acervuli from freshly sporulating cultures by scraping the surface of PDA slants with sterilized spatula. Serial dilutions of the spore suspension were prepared; inoculum density was adjusted to 5×10^5 spore mL^{-1} using a haemocytometer and used as standard inoculums for carrying out different studies.

Detached fruit method: In this method, fruits were first washed with distilled water and pin pricked gently with sterilized needle prior to inoculation (Thind and Jhooty, 1990) and then inoculated by placing uniform drop of spore suspension. The inoculated fruits were placed in a humidity chamber and kept at 25±1°C. Observations were recorded up to 7 days after inoculation. The disease was estimated by visual observation based on the lesion development on the fruit. The disease was scored on the basis of 0-5 point scale (Dasgupta, 1981). Where, (0) no infection, (1) 1-2% fruit area infected, (2) 2.1-5% fruit area infected, (3) 5.1-10% fruit area infected, (4) 10.1-25% fruit area infected and (5) >25% fruit area infected. Fruits showing reaction type of 0, 1 and 2 or either of these were graded as resistant (R) while those falling in 3, 4 and 5 or either of these were rated as susceptible (S).

Analysis of data: The data of various experiments were subjected to statistical analysis with the help of computer. The data was subjected to appropriate transformations, wherever needed as suggested by Gomez and Gomez (1984) before analysis.

Experimental findings: The experimental findings of the research work are presented under following heads.

Identification: On the basis of morphological characters, pathogenicity and comparison with the authentic description (Smith and Black, 1990), the fungus was identified as *C. capsici.*

Table 1: Variability in cultural characteristics of different isolates of *Colletotrichum capsici* on potato dextrose agar medium

Isolate	Source/ location	Cultural characters/colony characteristics	Radial growth after 7 days (mm)
Cc_1	Muran	Mycelium white, fluffy, margin regular.	42.0
Cc_2	Tahab	Mycelium white, fluffy, greyish at the centre, margin regular	63.2
Cc_3	Pampore	Mycelium white, cottony, suppressed with irregular margin	42.0
Cc_4	Narkara	Mycelium grey, whitish at the periphery, raised in centre, v-shaped pattern, irregular margin	67.5
Cc_5	Gogoo	Mycelium white, suppressed in the centre, regular margin, v-shaped pattern	35.5
Cc_6	Kawosa	Mycelium white, fluffy, greyish at the centre, margin regular	65.0
Cc_7	Chitargam	Mycelium white, fluffy, raised at the centre, suppressed at the margin	32.0
Cc_8	Bandipora	Mycelium white, cottony, margin regular	38.0
Cc_9	Ompora	Mycelium grey, with white periphery, suppressed, irregular margin	60.2
Cc_{10}	Khudwani	Mycelium white, cottony, suppressed at the centre, margin regular	43.5
Cc_{11}	Palpora	Mycelium dull white, fluffy, brownish tinge at the centre, v-shaped pattern, margin irregular	39.0
Cc_{12}	Shalimar	Mycelium dull grey, suppressed, regular margin	62.5
Cc_{13}	Tailbal	Mycelium dull white, greyish at the centre, suppressed, irregular margin	65.5
Cc_{14}	Noorbagh	Mycelium dull white, light grey at the centre, fluffy, regular margin	64.0
Cc_{15}	Kanipora	Mycelium white, fluffy, regular margin	42.5
Cc_{16}	Zakura	Mycelium white, fluffy , greyish at the center, regular margin	65.0
Cc_{17}	Narbal	Mycelium light brown, grey at the centre, suppressed, irregular margin	40.0
Cc_{18}	Harwan	Mycelium light smokey grey with white tinge , raised at the centre, regular margin	63.5
Cc_{19}	Shaltang	Mycelium brown, grey at centre, fluffy, suppressed, margin irregular	45.5
Cc_{20}	Chadura	Mycelium smoky grey, periphery white suppressed, margin regular	63.5

Cc: *Colletotrichum capsici*

Variability study: Variability amongst the isolates was recorded with respect to cultural, morphological and pathogenic characters.

Isolation and purification of *Colletotrichum capsici* isolates: A total number of 20 isolates of *C. capsici* were obtained from 20 different sites of the three districts surveyed (Table 1).

Cultural variability: Isolates of *Colletotrichum capsici* differed with respect to their cultural characteristics. The characters viz., type and colour of colony, growth rate of fungus and pigmentation were recorded.

Type and colour of colony: The *Colletotrichum capsici* isolates grown on PDA showed variation in their colony characteristics. Colony colour varied from light to dark grey with whitish or brownish tinge. Mostly the colonies had cottony or fluffy mycelial growth with regular to irregular margin (Table 1). The cottony growth was observed in three isolates viz., Cc-3, Cc-8, Cc-10 and fluffy growth in nine isolates viz., Cc-1, Cc-2, Cc-6, Cc-7, Cc-11, Cc-14, Cc-15, Cc-16 and Cc-19. Among the cottony type of colonies, suppressed growth was observed in Cc-3, Cc-5, Cc-7, Cc-9, Cc-10, Cc-12, Cc-13, Cc-17, Cc-19, Cc-20 and Cc-5 also with suppressed growth developed v-shape pattern. Among the fluffy type of colonies Cc-7, centre was raised.

Isolates studied also varied in colony colours (Table 1) white colonies were observed in thirteen isolates viz., Cc-1, Cc-2, Cc-3, Cc-5, Cc-6, Cc-7, Cc-8, Cc-10, Cc-11, Cc-13, Cc-14, Cc-15, Cc-16 whereas, six isolates viz., Cc-4, Cc-9, Cc-18, Cc-19, Cc-20 were greyish in colour and one isolate Cc-17 light brown with greyish centre.

The colony margins varied from regular to irregular (Table 1). Regular margins were observed in twelve isolates viz., Cc-1, Cc-2, Cc-5, Cc-6, Cc-8, Cc-10, Cc-12, Cc-14, Cc-15, Cc-16, Cc-18, Cc-20 whereas, seven isolates Cc-3, Cc-4, Cc-9, Cc-11, Cc-13, Cc-17, Cc-19 had irregular margins. Margins were whitish in Cc-4, Cc-9, Cc-20 isolates. Besides, V-shaped margins were observed in isolate Cc-4 and Cc-5. In some isolates margins were followed by dull white to grey rim.

Growth rate of fungus: Perusal of the Table 1 further revealed that variation in the radial growth after 7 days (mm). Cc-4 with mean radial growth 67.50 mm was fastest followed by Cc-2, Cc-14, Cc-28, Cc-20 and Cc-9, respectively. Least growth rate of 32 mm was recorded in Cc-7.

Morphological variability: Variations were observed amongst the isolates with respect to morphological characters like conidia size, shape, acervuli production, setae size and its characters.

Conidial size: Average conidial size of isolates ranged from 19.70-33.60×2.23-4.86 µm (Table 2). The average maximum conidial length (33.60 µm) observed in Cc-14 was significantly higher than other isolates, whereas minimum length (19.70 µm) in Cc-4 was recorded. Average maximum conidial breadth of 4.86 µm was observed in Cc-4 while minimum conidial breadth of 2.23 µm observed in Cc-10. Least conidial length (19.70 µm) and breadth (2.23 µm) was in Cc-4 and Cc-10, respectively.

Conidial shape: Perusal of Table 2 further reveals that all the isolates had fusiform to falcate type of conidia. Ten isolates viz., Cc-1, Cc-2, Cc-3, Cc-5, Cc-6, Cc-7, Cc-8, Cc-10, Cc-11, Cc-13, Cc-14, Cc-15 were having fusiform conidia and Cc-4, Cc-9, Cc-12, Cc-16, Cc-18, Cc-19, Cc-20 having falcate conidia.

Table 2: Variability in conidial shape and size of *Colletotrichum capsici* isolates

	Length (µm)*		Breadth (µm)*		
Isolate	Range	Mean	Range	Mean	Shape
Cc_1	13.2-29.7	27.30	1.98-5.280	3.03	Fusiform
Cc_2	19.8-42.9	30.70	1.65-4.950	4.56	Fusiform
Cc_3	13.2-52.8	28.20	1.65-4.950	3.50	Fusiform
Cc_4	6.3-33.00	19.70	1.65-16.50	4.86	Falcate
Cc_5	9.9-33.00	22.20	0.33-3.300	2.88	Fusiform
Cc_6	16.5-26.4	18.09	1.65-3.300	3.07	Fusiform
Cc_7	16.5-44.4	28.40	1.65-12.40	4.56	Fusiform
Cc_8	13.2-51.8	32.70	2.65-4.880	3.50	Fusiform
Cc_9	13.2-41.8	29.10	1.42-2.280	1.43	Falcate
Cc_{10}	12.1-66.8	28.60	1.42-3.380	2.23	Fusiform
Cc_{11}	16.5-25.5	21.40	1.65-4.330	3.30	Fusiform
Cc_{12}	13.3-46.8	26.10	6.12-2.660	6.31	Falcate
Cc_{13}	9.9-24.00	18.20	1.65-15.12	4.11	Fusiform
Cc_{14}	10.2-42.3	33.60	1.52-18.22	3.33	Fusiform
Cc_{15}	11.2-58.1	27.10	1.52-20.12	4.11	Fusiform
Cc_{16}	21.2-62.3	29.10	4.41-16.12	4.44	Falcate
Cc_{17}	11.2-59.1	28.09	4.22-12.12	4.21	Falcate
Cc_{18}	12.1-47.2	30.10	1.42-1.620	1.48	Falcate
Cc_{19}	9.9-33.00	32.20	0.88-4.600	3.36	Falcate
Cc_{20}	8.8-55.00	29.40	1.22-5.500	4.22	Falcate

*Mean of 50 observations, Cc: *Colletotrichum capsici*

Table 3: Variability in acervuli production and setae size of different isolates of *Colletotrichum capsici* on potato dextrose agar medium

	Setae size (µm)*		No. of acervuli 5 mm dia.	
Isolate	Length (range)	Breadth (range)	mycelial disc	Characteristics
Cc_1	63.20 (66.0-129.8)	5.35 (4.4-6.6)	51	Submerged, scattered
Cc_2	119.80 (114.4-193.6)	4.84 (4.4-5.5)	32	Submerged, scattered
Cc_3	116.50 (107.8-149.6)	5.65 (4.4-6.6)	35	Raised, scattered
Cc_4	106.00 (105.6-129.8)	5.06 (4.4-6.6)	47	Raised, scattered
Cc_5	164.50 (112.4-183.6)	5.50 (4.4-6.6)	53	Raised, scattered
Cc_6	89.88 (65.0-129.8)	5.20 (4.4-5.5)	38	Submerged, scattered
Cc_7	112.45 (110.0-140.6)	5.35 (4.4-6.6)	53	Raised, scattered
Cc_8	99.59 (65.0-122.7)	5.35 (4.4-6.6)	42	Submerged, scattered
Cc_9	177.21 (115.6-190.6)	4.48 (4.4-5.5)	39	Submerged, scattered
Cc_{10}	110.59 (105.6-121.7)	5.30 (4.4-6.6)	35	Raised, scattered
Cc_{11}	121.95 (107.8-149.6)	4.48 (4.4-5.5)	54	Raised, scattered
Cc_{12}	107.11 (68.0-120.8)	5.35 (4.4-6.6)	32	Submerged, scattered
Cc_{13}	98.49 (68.0-129.7)	5.35 (4.4-6.6)	39	Raised, concentric rings
Cc_{14}	116.12 (115.5-190.6)	5.35 (4.4-6.6)	38	Raised, concentric rings
Cc_{15}	120.11 (66.0-122.7)	4.48 (4.4-5.5)	55	Submerged, scattered
Cc_{16}	118.22 (113.0-188.6)	5.10 (4.4-6.6)	34	Submerged, scattered
Cc_{17}	132.33 (107.8-149.6)	5.35 (4.4-6.6)	48	Submerged, scattered
Cc_{18}	107.11 (105.6-129.8)	5.30 (4.4-5.5)	32	Submerged, scattered
Cc_{19}	121.22 (108.2-130.2)	5.30 (4.4-5.5)	50	Submerged, scattered
Cc_{20}	83.30 (66.0-129.0)	4.52 (4.4-5.5)	36	Submerged, scattered

*Mean of 50 observations, Cc: *Colletotrichum capsici*

Variability in acervuli production and setae size: Perusal of the Table 3 revealed variation in setae size and acervuli production. Irrespective of the isolates setae measure 65.0-194.6×4.4-6.6 µm. The maximum size of the setae have been observed in isolate Cc-14 measuring 115.6-190.6×4.4-6.6 µm with an average of 177.21×5.40 µm in Cc-9.

An insight into data further reveals that as irrespective of the isolates, Acervuli production ranged from 32-55/5 mm mycelial disc. The least production of 32/5 mm mycelia disc was recorded in isolate Cc-2, Cc-12 and Cc-18.

Isolates varied significantly in their characteristics (Table 3) Cc-1, Cc-2, Cc-6, Cc-8, Cc-9, Cc-12, Cc-15, Cc-16, Cc-17, Cc-18, Cc-19, Cc-20 were submerged and scattered Cc-3, Cc-4, Cc-5, Cc-7, Cc-10, Cc-11 were raised and scattered whereas, only two isolates named Cc-13, Cc-14 were appeared raised with concentric ring.

Pathogenic variation: Twenty isolates of *Colletotrichum capsici* from chilli fruits collected from three districts of Kashmir valley were inoculated on to a set of twenty different chilli genotypes taken as differential lines and observations on disease reaction types were recorded after 7 days (Table 4). The diseases intensity was recorded lowest in Cc1, Cc2 and Cc6 against SH-SC-1 (1.0%), SH-SC-13 (1.0%) and SH-SC-3 (1.0%).Cc15 was lowest against 3 chilli genotypes i.e., SH-SC-19, SH-P-82, SH-SC-1003 and highest diseases intensity was recorded in Cc3, Cc4, Cc14 and Cc12 against KL-1 (32.2%), SH-P-444 (34.3%), SH-SC-7 (72.1%) and SH-P-444 (35.0%). The data of Table 5 revealed that the isolates exhibited at different virulent pattern when inoculated on the 20 chilli differential genotypes. In all, 20 isolates were identified based on similarity or dissimilarity in reaction types exhibited by these differential lines. The isolates

Table 4: Variation in *Colletotrichum capsici* isolates in their disease inteusity on various chilli genotypes

	Disease inteusity* (%)																			
Isolate	SH-SC-1	SH-SC-17	SH-SC-108	SH-P-444	KL-1	SH-SC-19	SH-P-104	SH-SC-9	SH-SC-1111	SH-SC-1154	SH-P-201	SH-P-82	SH-KC-23	SH-C-16	SH-SC-7	SH-SC-4	SH-P-13	SH-SC-13	SH-SC-3	SH-SC-1003
Cc_1	1.0	7.7	17.1	18.2	16.8	2.2	12.1	1.1	13.2	1.3	6.8	3.4	8.8	3.0	5.8	10.0	1.1	10.0	2.1	4.1
Cc_2	6.0	19.1	2.0	3.4	18.2	13.6	38.2	5.6	41.4	2.0	2.2	3.3	6.6	4.4	9.1	5.0	9.3	1.0	4.6	6.0
Cc_3	11.0	18.0	16.6	5.5	32.2	37.1	13.3	4.2	21.2	30.1	12.1	14.3	7.1	8.8	15.6	4.4	25.1	25.0	5.6	3.2
Cc_4	17.0	21.2	7.0	34.3	18.0	3.1	13.1	17.2	31.4	16.5	30.3	27.7	5.5	22.0	12.2	3.2	28.1	19.9	13.3	10.3
Cc_5	21.1	12.2	30.1	11.6	36.6	4.5	16.6	17.2	3.4	1.2	1.1	2.6	4.4	3.1	5.7	2.2	1.6	8.1	3.8	7.1
Cc_6	12.3	14.1	2.0	3.1	25.1	13.0	13.4	9.9	5.4	4.1	2.7	4.8	14.1	2.0	9.9	5.0	20.3	2.6	1.0	12.2
Cc_7	27.2	1.2	6.6	29.2	14.6	14.1	2.2	5.8	9.1	3.1	10.0	18.8	3.3	7.7	5.1	19.1	10.0	16.7	10.1	2.1
Cc_8	23.6	28.1	7.3	27.2	34.3	1.1	3.3	2.2	14.0	28.3	11.3	27.9	28.7	11.1	19.2	32.1	4.6	26.1	7.8	2.2
Cc_9	27.7	30.1	15.5	18.9	18.5	1.7	3.4	15.5	18.1	13.1	14.4	15.0	13.6	25.5	5.6	14.6	7.8	17.1	8.8	20.0
Cc_{10}	14.0	6.6	6.2	12.1	21.2	11.2	12.2	4.2	15.0	22.2	12.7	12.2	7.6	13.8	16.7	2.1	13.1	19.1	12.2	1.1
Cc_{11}	24.2	30.1	5.5	10.2	16.9	3.3	12.1	11.1	2.6	1.6	1.1	5.0	2.5	2.4	11.1	1.3	1.2	13.1	1.2	7.2
Cc_{12}	11.8	17.5	18.2	35.0	22.0	1.6	5.0	36.1	15.6	37.2	8.2	2.8	12.02	32.5	19.1	31.2	33.0	20.2	14.6	15.6
Cc_{13}	26.6	20.1	22.1	25.1	23.4	25.5	2.1	1.6	10.3	17.7	18.6	30.3	31.1	17.1	23.3	13.1	17.2	6.6	9.3	6.0
Cc_{14}	16.4	17.7	14.2	26.7	19.7	1.1	1.1	2.7	12.1	25.5	14.1	17.0	24.2	18.6	72.1	14.1	10.1	7.8	19.3	12.1
Cc_{15}	1.1	6.2	12.2	12.8	15.9	1.0	18.1	5.0	12.7	12.4	12.7	1.0	8.1	2.1	12.3	19.1	5.0	22.1	2.2	1.0
Cc_{16}	14.4	17.3	3.8	1.1	32.1	32.2	7.8	16.6	18.1	3.3	3.1	1.1	10.2	5.0	13.6	1.1	22.1	1.2	2.2	19.1
Cc_{17}	15.1	25.6	33.3	29.1	35.6	14.2	18.0	5.7	24.6	4.6	29.0	22.3	7.9	1.1	8.4	4.4	3.1	21.1	20.1	11.2
Cc_{18}	18.1	13.1	12.1	11.3	17.5	3.1	1.1	15.9	13.4	13.6	13.0	1.2	30.1	21.3	14.5	7.6	13.1	11.1	9.9	12.3
Cc_{19}	12.3	19.1	6.1	11.6	16.6	13.1	11.1	12.3	11.8	2.1	30.1	31.0	12.3	5.0	7.8	4.1	1.6	9.8	19.9	7.8
Cc_{20}	18.3	18.3	14.2	11.2	28.2	3.0	1.2	24.4	14.2	14.1	20.1	2.1	6.6	18.8	21.2	11.6	23.3	11.6	24.5	21.2

*Mean of three replicatious, SH: Shalimar, SC: Selection chillies, P: Paprika and Cc: *Colletotrichum capsici*

comprised Cc-1, Cc-15 showing resistant reaction on 9 differential lines viz., SH-SC-1, SH-SC-19, SH-SC-9, SH-SC-1154, SH-SC-16, SH-SC-16, SH-SC-1003, SH-P-82, SH-P-13 and susceptible reaction on the other differential lines viz., SH-SC-17, SH-SC-108, KL-1, SH-SC-111, SH-SC-23, SH-SC-7, SH-SC-4, SH-SC-13, SH-SC-444, SH-P-104, SH-P-201. The isolates comprised of the Cc-2, Cc-6, Cc-16 showing resistant reaction on SH-SC-108, SH-SC-1154, SH-C-16, SH-SC-13, SH-SC-3, SH-P-444, SH-P-201, SH-P-82 and susceptible reaction on rest of genotypes. The isolates comprised Cc-3, Cc-10 showing resistant response on differential host genotypes SH-SC-9, SH-SC-4, SH-SC-1003 whereas, susceptible reaction was exhibited on rest of cultivars. Similarly, the Cc-18, Cc-20, Cc-12 and Cc-9 isolate were clubbed under showing resistant reaction on differential lines viz., SH-SC-19, SH-P-104, SH-P-82 and susceptible response on rest of the differential host genotypes. The isolates comprised Cc-13, Cc-14 showing resistant response on differential host genotypes viz., SH-SC-9, SH-P-104 whereas susceptible reaction exhibited on rest of the cultivars. The isolates comprised of the *Colletotrichum capsici* isolates Cc-17, Cc-19 showing resistant reaction on SH-SC-1154, SH-C-16, SH-SC-4, SH-P-13 chilli genotypes and susceptible reaction on rest of genotypes. The isolates comprised Cc-5, Cc-11 showing resistant response on differential host genotypes viz., SH-SC-19, SH-SC-111, SH-SC-1154, SH-KC-23, SH-C-16, SH-SC-4, SH-SC-6, SH-P-201, SH-P-82, SH-P-13, SH-SC-3 chillies whereas the susceptible reaction was exhibited on rest of cultivars. Similarly, the isolate Cc-7 was clubbed under showing resistant reaction on differential host like SH-SC-17, SH-SC-1154, SH-KC-23, SH-SC-7, SH-SC-1003, SH-P-104 and susceptible response on rest of the differential host genotypes. The isolate comprised Cc-8 showing the resistant reaction on five differential lines viz., SH-SC-19, SH-SC-9, SH-SC-1003, SH-P-104, SH-P-13 and susceptible reaction on rest of the genotypes. Similarly isolate comprised Cc-4 showing resistant response on SH-SC-19, SH-SC-4 and susceptible reaction on rest of the genotypes (Table 6) In all, ten pathogenic groups were identified based on similarity or dissimilarity in reaction types exhibited by these differential lines. The group-1 comprised of isolates Cc-1, Cc-15 showing resistant reaction on 9 differential lines viz., SH-SC-1, SH-SC-19, SH-SC-9, SH-SC-1154, SH-SC-16, SH-SC-16, SH-SC-1003, SH-P-82, SH-P-13 and susceptible reaction on the other differential lines viz., SH-SC-17, SH-SC-108, KL-1, SH-SC-111, SH-SC-23, SH-SC-7, SH-SC-4, SH-SC-13, SH-SC-444, SH-P-104, SH-P-201. The group-2 comprised of the Cc-2, Cc-6, Cc-16 showing resistant reaction on SH-SC-108, SH-SC-1154, SH-C-16, SH-SC-13, SH-SC-3, SH-P-444, SH-P-201, SH-P-82 and susceptible reaction on rest of genotypes. The group 3 comprised of isolates Cc-3, Cc-10 showing resistant response on differential host genotypes SH-SC-9, SH-SC-4, SH-SC-1003 whereas, susceptible reaction was exhibited on rest of cultivars. Similarly, the Cc-18, Cc-20, Cc-12 and Cc-9 isolate were clubbed under group-4 showing resistant reaction on differential lines viz., SH-SC-19, SH-P-104, SH-P-82 and susceptible response on rest of the differential host genotypes. The group-5 comprised of isolates Cc-13, Cc-14 showing resistant response on differential host genotypes viz., SH-SC-9, SH-P-104 whereas susceptible reaction exhibited on rest of the cultivars. The group-6 comprised of the *Colletotrichum capsici* isolates Cc-17, Cc-19 showing resistant reaction on SH-SC-1154, SH-C-16, SH-SC-4, SH-P-13 chilli genotypes and susceptible reaction on rest of genotypes. The group-7 comprised of isolates Cc-5, Cc-11 showing resistant response on differential host genotypes viz., SH-SC-19, SH-SC-111, SH-SC-1154, SH-KC-23, SH-C-16, SH-SC-4, SH-SC-6, SH-P-201, SH-P-82, SH-P-13, SH-SC-3 chillies whereas the susceptible reaction was exhibited on rest of cultivars. Similarly, the isolate Cc-7 was clubbed under group-8 showing resistant reaction on differential host like SH-SC-17, SH-SC-1154, SH-KC-23, SH-SC-7, SH-SC-1003, SH-P-104 and

Table 5: Virulence pattern of *Colletotrichum capsici* isolates on various chilli genotypes

	Reaction type on																				
Isolate	SH-SC-1	SH-SC-17	SH-SC-108	SH-P-444	KL-1	SH-SC-19	SH-P-104	SH-SC-9	SH-SC-1111	SH-SC-1154	SH-P-201	SH-P-82	SH-KC-23	SH-SC-16	SH-SC-7	SH-SC-4	SH-P-13	SH-SC-13	SH-SC-3	HS-SC-1003
Cc_1	R	S	S	S	S	R	S	R	S	R	S	R	S	R	S	S	R	S	R	R
Cc_2	S	S	R	R	S	S	S	S	S	R	R	R	S	R	S	S	S	R	R	S
Cc_3	S	S	S	S	S	S	S	R	S	S	S	S	S	S	S	R	S	S	S	R
Cc_4	S	S	S	S	S	R	S	S	S	S	S	S	S	S	S	R	S	S	S	S
Cc_5	S	S	S	S	S	S	S	S	R	R	R	R	R	R	S	R	R	S	R	S
Cc_6	S	S	R	R	S	S	S	S	S	R	R	R	S	R	S	S	S	R	R	S
Cc_7	S	R	S	S	S	S	R	S	S	R	S	S	R	S	S	S	S	S	S	R
Cc_8	S	S	S	S	S	R	R	R	S	S	S	S	S	S	S	S	R	S	S	R
Cc_9	S	S	S	S	S	R	R	S	S	S	S	R	S	S	S	S	S	S	S	S
Cc_{10}	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	R	S	S	S	R
Cc_{11}	S	S	S	S	S	R	S	S	R	R	R	R	R	R	S	R	R	S	R	S
Cc_{12}	S	S	S	S	S	R	R	S	S	S	S	R	S	S	S	S	S	S	S	S
Cc_{13}	S	S	S	S	S	S	R	R	S	S	S	S	S	S	S	S	S	S	S	S
Cc_{14}	S	S	S	S	S	S	R	R	S	S	S	S	S	S	S	S	S	S	S	S
Cc_{15}	R	S	R	R	S	R	S	R	S	R	R	R	S	R	S	S	R	S	R	R
Cc_{16}	S	S	R	R	S	S	S	S	S	R	R	R	S	R	S	R	S	R	R	S
Cc_{17}	S	S	S	S	S	S	S	S	S	R	S	S	S	R	S	R	R	S	S	S
Cc_{18}	S	S	S	S	S	R	R	S	S	S	S	R	S	S	S	S	S	S	S	S
Cc_{19}	S	S	S	S	S	S	S	S	S	R	S	S	S	R	S	R	R	S	S	S
Cc_{20}	S	S	S	S	S	R	R	S	S	S	S	R	S	S	S	S	S	S	S	S

R: Resistant (reaction types: 0-2); S: Susceptible (reaction types: 3-5), SH: Shalimar, SC: Selection chillies, P: Paprika and Cc: *Colletotrichum capsici*

Table 6: Variation in *Colletotrichum capsici* isolates in their disease reaction on chilli genotypes

Isolate	SH-SC-1	SH-SC-17	SH-SC-108	SH-P-444	KL-1	SH-SC-19	SH-P-104	SH-SC-9	SH-SC-111	SH-SC-1154	SH-P-201	SH-P-82	SH-KC-23	SH-C-16	SH-SC-7	SH-SC-4	SH-P-13	SH-SC-13	SH-SC-3	HS-SC-1003	Group patho type
Cc_1 Cc_{15}	-	+	+	+	+	-	+	-	+	-	+	-	+	-	+	+	-	+	-	-	1
Cc_{2+} Cc_{6+} Cc_{16}	+	+	-	-	+	+	+	+	+	-	-	-	+	-	+	+	+	-	-	+	2
Cc_3 Cc_{10}	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	+	-	3
Cc_{18+} Cc_{20+} Cc_{12+} Cc_9	+	+	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	4
Cc_{13+} Cc_{14}	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	5
Cc_{17+} Cc_{19}	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	-	-	+	+	+	6
Cc_{5+} Cc_{11}	+	+	+	+	+	-	+	+	-	-	-	-	-	-	+	-	-	+	-	+	7
Cc_7	+	-	+	+	+	+	-	+	+	-	+	+	-	+	+	-	+	+	+	-	8
Cc_8	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	-	+	+	-	9
Cc_4	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	10

-: Resistant, +: Susceptible, SH: Shalimar, SC: Selection chillies, P: Paprika and Cc: *Colletotrichum capsici*

susceptible response on rest of the differential host genotypes. The group 9 comprised of isolate Cc-8 showing the resistant reaction on five differential lines viz., SH-SC-19, SH-SC-9, SH-SC-1003, SH-P-104, SH-P-13 and susceptible reaction on rest of the genotypes. Similarly group 10 comprised of isolate Cc-4 showing resistant response on SH-SC-19, SH-SC-4 and susceptible reaction on rest of the genotypes.

DISCUSSION

Chilli (*Capsicum annuum* L.) one of the important commercial vegetable crops is grown extensively almost throughout the world. The Dieback and fruit rot caused by *Colletotrichum capsici* (Butler, 1918) is known to cause extensive damage to this crop rendering its cultivation difficult. *C. capsici* is prevalent in every part of the world and is considered to be a serious and most destructive fruit rot pathogen of chilli (Dastur, 1921; Doolittle, 1954; Grover and Bansal, 1968; Chowdhery, 1957).

Successful execution of a disease management programme, in addition to other factors, depend on the understanding of pathogen population structure and mechanism by which variation arises within populations. Variations in pathogen population can be detected with cultural, morphological and pathogenic characters. During present work efforts were made to ascertain the prevalence of variation in isolates of *C. capsici* from different locations of the valley. Twenty isolates collected from 20 locations of the valley varied in their cultural, morphological, pathogenic characteristics. Isolates of *C. capsici* varied in their cultural characteristics viz., colony type, colour, margin, segmentation and growth rate. Colonies were cottony or fluffy and mostly suppressed with colour ranging from white to grey. Several workers have also reported cultural, morphological, pathogenic variability among isolates *Colletotrichum* spp. (Simmonds 1965; Bailey *et al*., 1992; TeBeast *et al*., 1997; Thaung, 2008).

Conidia and appressions presence or absence of setae, sclerotia, acervuli and teleomorph state and such as colony, growth rate and texture (Simmonds 1965; Smith and Black, 1990; Sutton, 1992; Photita *et al*., 2005; Than *et al*., 2008a, b; Thaung, 2008). Isolates were studied for morphological variation in their setae, conidia and acervuli production.

In the present study, great variation in conidial size was observed with maximum length of 33.60 μm in Cc-14 while minimum length of 19.70 μm in Cc-4. Similarly conidia breadth from 4.86 μm in Cc-16 among the isolates with least breadth in Cc-10. Studies on setae revealed the variations in the size and production amongst all isolates. Setae length varied from 115.6-190.6 μm in Cc-2 and breadth ranged from 4.4-6.6 μm in Cc-3. Maximum setae length (77.21 μm) in Cc-4 was recorded while the minimum length 55.21 μm was recorded in Cc-15. Similarly, mean setae breadth varied from 32.-6.4 μm. The least was recorded in Cc-4 and the maximum was in Cc-17 (Sharma *et al*., 2005).

Acervuli production among the isolates ranged from 32-55 μm but acervuli number and dimensions could not be taken with definiteness for determining the relatives virulence of the isolates. More such studies required to establish such relationship. The results achieved are in conformity to those of Higgins (1926), Singh (1978), Verma (1982) and Thind and Jhooty (1990).

Isolates of *C. capsici* varied little in their colour of colony were nearly whitish, grey, light brown. Twelve isolates whitish, five isolates grey and two isolates were found to be brown. Shape of conidia was another criterion studied for variation among the isolates. All the isolates had Fusiform to Falcate conidia with slight differences in their shape. Ten isolates had fusiform whereas other ten isolates falcate conidia. Similar observations were also observed by Akhtar and Singh (2007).

The present study on pathological variability among the isolates were made by recording the disease response on a set of 20 chilli genotypes selected arbitrarily from the chilli genotype lines, on the basis of their consistent reaction to a few *C. capsici* isolates and taken as differential lines for *C. capsici*. Such a selection of differential lines had been adhered to an account of the fact that the differential for pathogenic and variability in isolates of *C. capsici*. Though a few workers have used some sets of differentials (Sharma *et al*., 2005). On the basis of disease reactions expressed by the differential lines, ten groups (races) of *C. capsici* were identified. The group-1 comprised isolates Cc-1 and Cc-15, whereas group 2 comprising the isolates Cc-2, Cc-6 and Cc-16. The isolates Cc-3 and Cc-10 were included in group 3, whereas isolates Cc-18, Cc-20, Cc-12 and Cc-9 grouped as group 4. The isolates Cc-13 and Cc-4 were included in group 5. The group 6 comprised isolates Cc-17 and Cc-19 whereas group 7 included in Cc-5 and Cc-11. The isolate Cc-7 was under group 8. Isolate Cc-8 and Cc-4 identified as 9 and group 10, respectively. The presence of these ten different groups or so called races can account for varied pathogenic response to the different genotypes. The resistant behaviour of a chilli genotype to *C. capsici* in different parts of the valley could also be understood by existence of such a variability occurring among these isolates. The existence of four different virulence type of the isolates of *C. capsici* in the valley so that the evolved variety shows resistance to all the virulence groups/types of the pathogen.

Ten isolates of *C. acutatum* against seven cultivars reportedly susceptible species of capsicum (Lin *et al*., 2004) and resistant species such as capsicum Chinese 'PBC 932'[17] (AVRDC, 1999; Cerkauskas, 2004) In contrast to *C. baccatum*, susceptibility of the *C. annuum* cultivars have been reported in several studies (Lin *et al*., 2004; Park, 2007; Singh *et al*., 1990) while evolving 79 varieties of capsicum for resistance to *C. capsici* in field trials. Jayalakashmi and Seetharaman (1998) have also evaluated 40 chilli varieties against anthracnose and found resistance only in eight cultivars, whereas, remaining cultivars were either moderately susceptible or highly susceptible.

CONCLUSION

During the survey of the diseases in the Kashmir valley the highest incidence and intensity of Dieback and fruitrot of chilhes (61.36%, 28.75; 76.29, 41.23%), respectively was observed in district Srinagar The pathogen *C. capsici* was isolated in the pure form and pathogenicity established by fallowing Koch's postulates. The pathogen was identified as per the morphological, cultural and pathogenic behavior as *C. capsici*. These studies indicated prevalence of pathogenic variability among the isolates. In all 20 isolates were observed on their pathogenic behavior on 20 chilli host species depending upon their pathogenic behavior. Seed and plant debris survived as source of primary inoculums in the form of mycelium.

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