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Rohit Dangi
Department of Plant Pathology, School of Agricultural Sciences, Janardan Rai Nagar Rajasthan Vidyapeeth Deemed to be University, Udaipur, Rajasthan, India

Kalpana Yadav
Department of Plant Pathology, School of Agricultural Sciences, Janardan Rai Nagar Rajasthan Vidyapeeth Deemed to be University, Udaipur, Rajasthan, India

Corresponding Author:
Rohit Dangi
Department of Plant Pathology, School of Agricultural Sciences, Janardan Rai Nagar Rajasthan Vidyapeeth Deemed to be University, Udaipur, Rajasthan, India

Survey and morpho-cultural variability of Chilli root rot pathogens

Rohit Dangi and Kalpana Yadav

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Abstract
An extensive field survey was conducted during *kharif* 2025 in ten chilli-growing villages across major production districts of southern Rajasthan to assess percent disease incidence and collect representative pathogen isolates. Typical symptoms of Root Rot of Chilli include yellowing and wilting of plants, followed by brown to dark-brown lesions on roots and the collar region. The roots become decayed and rotten, resulting in poor plant growth, easy uprooting, and, under severe infection, complete drying and death of the plant. Root rot percent disease incidence ranged from 23.46 to 39.50%, with the highest incidence recorded in Udaipur and the lowest in Banswara. Initial disease symptoms were observed 15-20 days after transplanting, indicating early establishment and widespread occurrence of the pathogen in the region. Ten isolates of *Rhizoctonia solani* exhibited marked cultural and morphological variability on +potato dextrose agar. Radial growth mycelium was ranged from 57.20 to 90.00 mm, categorizing isolates into slow, moderate and fast-growing groups. Hyphal width varied from 2.73 to 7.69 µm, the number of septa between branches ranged from 1 to 7 and sclerotia production ranged from 5 to 60 sclerotia mm. The substantial variability observed among isolates indicates considerable diversity within the pathogen population, which may influence disease epidemiology and the development of effective management strategies.

Keywords: Root rot, survey, character, PDI

Introduction
Chilli (*Capsicum annuum*) is an important commercial spice-cum-vegetable crop of the family Solanaceae, widely cultivated in tropical and subtropical regions. It is valued for its pungency, colour, flavour, and nutritional properties, and is a rich source of vitamins A, C and E, minerals, carotenoids, and capsaicin. Chilli is consumed in fresh, dried, and processed forms and plays a significant role in vegetable- and spice-based cropping systems due to its high economic returns. The global chilli cultivation area was 18.03 lakh hectares, with a production of 58.22 lakh tonnes and an average productivity of 3,229 kg per hectare (Kumar, 2025) [5]. India is the world's leading producer, consumer, and exporter of chilli, reflecting its substantial economic importance. According to the Directorate of Horticulture (2022-23) [2], Rajasthan ranks 15th in chilli production in the country, occupied about 8048 ha with a total production of 14,388 tonnes during 2024-25, registering an average productivity of around 1.78 t ha^{-1} under prevailing conditions. This reflects a moderate level of yield performance in the state, where production is largely influenced by arid climatic conditions and limited irrigation facilities (Spices Board India, 2024) [10]. In Rajasthan, chilli is cultivated in many districts such as Jaipur, Sikar, Hanumangarh, Bundi, Alwar, and Bhilwara and its cultivation is increasing steadily because of favourable market demand and improved production technologies. Chilli productivity is severely constrained by several diseases caused by fungi, bacteria, and viruses. Among them, Root Rot of Chilli caused by *Rhizoctonia solani* is one of the most destructive soil-borne diseases. The pathogen survives in soil and crop residues for extended periods and infects plants at both nursery and field stages, causing damping-off, root decay, collar lesions, wilting, stunting, and plant death. Understanding the occurrence and variability of *Rhizoctonia solani* is essential for elucidating disease epidemiology and developing effective management strategies. Therefore, the present study was undertaken to survey chilli-growing areas, isolate and identify the pathogen, and evaluate the cultural and morphological variability of isolates associated with chilli root rot in Rajasthan.

Materials and Methods: Survey and collection of disease sample: During the kharif season of 2025, an extensive field survey was conducted in major chilli-growing districts of Rajasthan to collect samples exhibiting symptoms of root rot disease. At each selected location, five chilli fields were surveyed to assess disease occurrence and severity. Diseased samples showing typical symptoms of disease were collected from infected plants and transported to the laboratory for detailed studies on the cultural and morphological variability of the associated pathogen. For microscopic examination, small sections from the diseased leaf tissues were aseptically excised using a sterile blade and prepared for further observation. Per cent disease index (PDI) was calculated using the formula of Wheeler (1969) [11].

$$PDI = \frac{\text{Sum of all individual disease numerical ratings}}{\text{Total number of plants assessed} \times \text{Maximum disease rating}} \times 100$$

Cultural Variability: Cultural variability among the ten isolates of Rhizoctonia solani associated with Root Rot of Chilli was assessed by recording radial mycelial growth, colony colour, colony texture, margin characteristics, and pigmentation on Potato Dextrose Agar (PDA). A 5 mm mycelial disc from the actively growing margin of a 7-day-old culture was aseptically transferred to the centre of sterile Petri plates containing PDA and incubated at 28±2°C. Each treatment was replicated three times.

Radial growth was measured after 96 h of incubation along two perpendicular diameters, and the mean colony diameter was expressed in millimetres. Colony characteristics such as growth habit (aerial fluffy, cottony, compact, or submerged), colony colour (white to light brown), margin type (regular or irregular), and pigmentation on the reverse side were recorded after complete growth of the colony. Based on radial growth, isolates were categorized as slow-, moderate-, or fast-growing.

Morphological Variability: Morphological variability among the isolates of Rhizoctonia solani was studied by examining microscopic characters including hyphal width, branching pattern, constriction at the point of branch origin, septation near the branch, number of septa between two branches, and sclerotial production.

Microscopic Studies: Microscopic observations were made using a calibrated compound microscope. Calibration was performed using an ocular micrometer and a stage micrometer. The stage micrometer was placed on the microscope stage and the ocular micrometer was fitted into the eyepiece. After focusing under the 40X objective lens, the value of one ocular division was calculated using the following formula:

$$\text{Value of one ocular division} = \frac{\text{Stage micrometer reading}}{\text{Ocular micrometer reading}} \times 10\ \mu m$$

Hyphal width was measured at several locations and expressed in micrometres (µm). The number of septa between two adjacent branches and the number of sclerotia per microscopic field (mm²) were also recorded to determine morphological variation among the isolates.

Result and Discussion

A systematic roving survey was undertaken during the kharif season to determine the distribution and incidence of Root Rot of Chilli caused by Rhizoctonia solani in the principal chilli-growing tracts of southern Rajasthan. The survey encompassed fifteen villages distributed across five major chilli-producing districts, namely Udaipur, Pratapgarh, Chittorgarh, Rajsamand and Banswara. Chilli crops comprising both local landraces and commercially cultivated hybrids, including Sitara, HBS-22, Krishna, Excell-401 and Kaveri, were surveyed under prevailing farmer-managed agronomic conditions. Disease incidence was quantified as the percentage of plants exhibiting characteristic symptoms of root rot, including chlorosis, permanent wilting, collar necrosis and extensive root cortical decay.

The survey established that the disease was ubiquitous in all locations examined, indicating the widespread occurrence of the pathogen in the chilli-growing ecosystem of Rajasthan. At the village level, disease incidence ranged from 20.00 to 42.25%. In Udaipur district, incidence varied from 39.55 to 42.25%, with the highest incidence recorded at Menar (42.25%), followed by Bhatewar (40.20%) and Bhanwarsiya (39.55%). In Banswara district, incidence ranged from 20.00 to 26.00%, with maximum incidence at Chayna (26.00%) and minimum at Vadlipada (20.00%). Rajsamand district exhibited disease incidence ranging from 23.00 to 25.00%, whereas Pratapgarh recorded values between 30.00 and 32.00%. In Chittorgarh district, incidence ranged from 27.64 to 30.00%.

District-wise mean incidence revealed a distinct geographical gradient in disease intensity, with Udaipur recording the highest average incidence (40.67%), followed by Pratapgarh (30.83%), Chittorgarh (28.88%), Rajsamand (24.00%) and Banswara (23.48%). Initial symptom expression was consistently observed 15-20 days after transplanting, suggesting early infection and rapid establishment of the pathogen following crop establishment. The observed spatial variation in disease incidence is likely attributable to differences in edaphic and climatic conditions, inoculum density, host genotype, and agronomic management practices. These findings demonstrate the extensive distribution and epidemiological significance of Rhizoctonia solani in the major chilli-growing regions of Rajasthan.

In India, the occurrence of Root Rot of Chilli incited by Rhizoctonia solani and Sclerotium rolfsii was documented in the Jaipur region of Rajasthan, where severe plant mortality was observed during the months of March and April (Kamlesh and Gurjar, 2001) [4].

Table 1: Survey of root rot of chilli in different districts.

S. No.	Village	Districts	Varieties	% Mortality
1.	Bhanwarsiya	Udaipur	Sitara	39.55 (38.97)
2.	Menar			42.25 (40.54)
3.	Bhatewar			40.20 (39.35)
4.	Ghatol	Banswara	HBS 22	23.45 (28.96)
5.	Chayna			26.00 (30.65)
6.	Vadlipada			20.00 (26.56)
7.	Madara	Rajsamand	Krishna	24.00 (29.33)

8.	Moi			25.00 (30.00)
9.	Chokdi			23.00 (28.66)
10.	Dhamottar	Pratapgarh	Excell 401	30.00 (33.21)
11.	Devgarh			30.50 (33.52)
12	Mandakala			32.00 (34.45)
13.	Sarlai	Chittorgarh	Kaveri	29.00 (32.58)
14.	Panchdevala			27.64 (31.69)
15	Reethola			30.00 (33.21)
		SEm+		0.548
		CD at 5%		1.565
		C.V. (%)		2.90

Plate 1: Root rot of chilli (Rhizoctonia solani) in different districts of Rajasthan

Cultural and Morphological Characteristics of Rhizoctonia solani Isolates

Marked variability in cultural and morphological characteristics was observed among the ten isolates of Rhizoctonia solani collected from different chilli-growing districts of southern Rajasthan. The isolates were coded according to their geographical origin as RSU-1 and RSU-2 (Udaipur), RSB-3 and RSB-4 (Banswara), RSP-5 and RSP-6 (Pratapgarh), RSR-7 and RSR-8 (Rajsamand), and RSC-9 and RSC-10 (Chittorgarh).

A. Radial Growth and Colony Characteristics

The ten isolates exhibited significant differences in radial mycelial growth and colony morphology on Potato Dextrose Agar after 96 h of incubation. Radial growth ranged from 57.20 to 90.00 mm. Based on colony diameter, isolates were classified into three growth categories: slow growing (<60 mm), moderately growing (60-80 mm), and fast growing (>80 mm). Two isolates, RSP-5 (59.65 mm) and RSR-7 (57.20 mm), were categorized as slow growing; three isolates, RSB-3 (75.92 mm), RSB-4 (78.30 mm), and RSC-10 (68.70 mm), were moderately growing; whereas RSU-1 (80.69 mm), RSU-2 (89.00 mm), RSP-6 (90.00 mm), RSR-8 (82.70 mm), and RSC-9 (87.98 mm) were classified as fast growing.

Considerable variation was also observed in colony texture, pigmentation, and margin characteristics. Colony texture ranged from sparse fluffy and partially fluffy to cottony and appressed growth. Colony colour varied from whitish and creamy white to greyish white, light brown, and blackish, while pigmentation on the reverse side ranged from white and light brown to dark brown and black. Colony margins were either regular or irregular, and zonation was observed in isolate RSC-10. These results indicate substantial cultural heterogeneity among the isolates.

Lal and Kandhari (2009) [6] and Debbarma and Dutta (2015) [1] reported significant differences in colony colour, growth pattern and sclerotial formation among isolates of R. solani obtained from different hosts and geographical regions, indicating the heterogeneous nature of the pathogen population.

Table 2: Cultural variability of different isolates of Rhizoctonia solanion potato dextrose agar (PDA) media

Isolates	Mycelial growth (mm)	Colony texture	Colony colour	
			Upper side	Pigmentation (invert side)
RSU-1 (Udaipur)	80.69 (63.91)	Sparse fluffy and regular growth	Whitish light brown	Centre brown and marginal white
RSU-2 (Udaipur)	89.00 (70.61)	Partially fluffy with regular	Whitish black	Blackish
RSB-3 (Banswara)	75.92 (60.60)	Cottony fluffy at centre	Whitish	Whitish yellow
RSB-4 (Banswara)	78.30 (62.21)	Cottony fluffy with irregular pattern in peripheral	Centre is black and marginal white	Centre is dark black and peripheral is dull white

RSP-5 (Pratapgarh)	59.65 (50.54)	Appressed with irregular pattern	Grey in peripheral and off white to blackish in centre	Light brown
RSP-6 (Pratapgarh)	90.00 (71.53)	Cottony fluffy with regular pattern in peripheral	Centre light brown and marginal is white	Whitish
RSR-7 (Rajsamand)	57.20 (49.12)	Sparse cottony with regular pattern growth	Creamy whitish	Light brown
RSR-8 (Rajsamand)	82.70 (65.41)	Partially cottony fluffy with irregular pattern in peripheral	Centre light grey and marginal is white	Creamy white
RSC-9 (Chittorgarh)	87.98 (69.70)	Partially fluffy with regular pattern	Centre light brown and marginal white	Light brown
RSC-10 (Chittorgarh)	68.70 (55.98)	Partially sparse with zonation and regular pattern in peripheral	Whitish brown	Light blackish in centre with peripheral whitish
SEm±	1.52			
CD at 5%	4.55			
C.V. (%)	4.27			

*Average of three replications. Figure in parentheses is √arcsine per cent angular transformed values

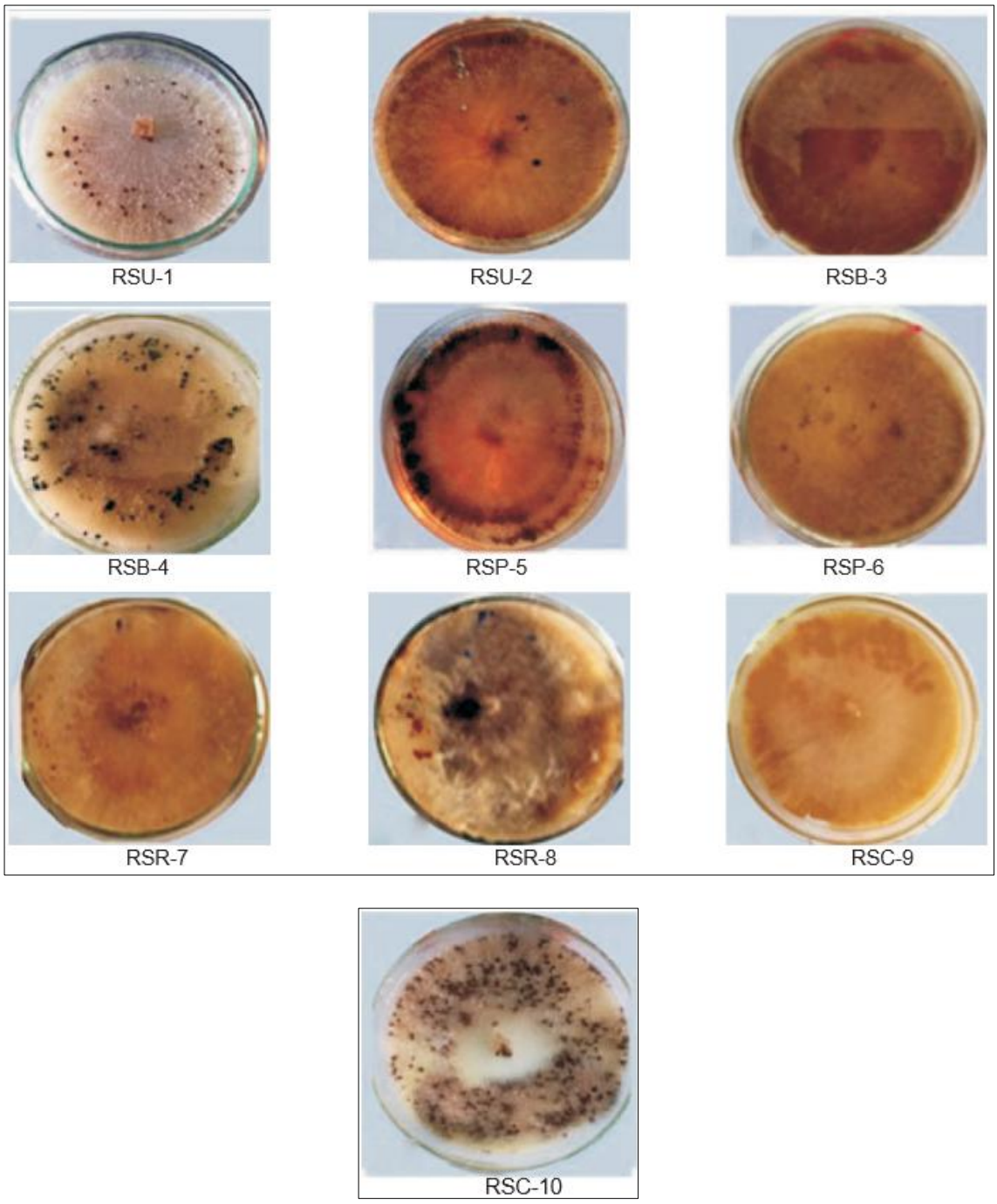

Plate 2: Cultural Variability of different isolates of *R. Solani* on Potato Dextrose Agar (PDA) medium

B. Mycelial Characteristics

Microscopic examination revealed significant differences in hyphal morphology. Hyphal width ranged from 2.73 to 7.69 µm. The maximum hyphal width was recorded in RSR-7 (7.69 µm), followed by RSU-2 (6.98 µm) and RSB-3 (5.80 µm), whereas the minimum was observed in RSP-6 (2.73 µm). The number of septa between two adjacent branches varied from 1 to 7. Isolate RSR-7 showed the highest number of septa (7), followed by RSB-3 (6), while RSP-6 exhibited only one septum. Characteristic right-angle branching with constriction at the branch point and a septum near the branch origin was consistently observed in all isolates, confirming their identity as Rhizoctonia solani. Similar variability in microscopic characters of R. solani isolates has been reported by Guleria *et al.* (2007) and Mishra *et al.* (2014) [3, 7], who observed differences in hyphal diameter, septation and branching pattern among isolates collected from different agro-ecological regions.

C. Sclerotial Characteristics: All isolates produced sclerotia on PDA; however, pronounced variation was observed in their size, shape, colour, distribution pattern, and abundance. Sclerotia were either round or oblong in shape. Round sclerotia were produced by RSU-1, RSB-3, RSB-4, RSP-5, RSP-6, and RSR-7, whereas oblong sclerotia were observed in RSU-2, RSR-8, RSC-9, and RSC-10.

The number of sclerotia ranged from 5 to 60 per microscopic field (mm²). The highest sclerotial density was recorded in RSR-7 (60), followed by RSB-3 (50) and RSC-9 (45), while the lowest was observed in RSP-6 (5). Based on sclerotial abundance, isolates were grouped as producing few (1-20), several (21-40), or abundant (>40) sclerotia. Sclerotial size varied from 0.20 to 2.70 mm. The largest sclerotia were produced by RSP-6 (2.70 mm), whereas the smallest were recorded in RSR-7 (0.20 mm).

The pattern of sclerotial development exhibited marked variation among the isolates, with sclerotia arranged in scattered, centrally aggregated, aerial surface, peripheral ring, and embedded forms. The colour of sclerotia also varied considerably, ranging from light brown and brown to dark brown and whitish brown. Such pronounced differences in sclerotial arrangement and pigmentation indicate a high degree of morphological variability among the isolates of Rhizoctonia solani associated with chilli root rot.

Similar variability in sclerotial characteristics and production has been documented by Gurav *et al.* (2018) and Singh *et al.* (2014), who reported substantial differences in sclerotial formation and colony morphology among isolates collected from different geographical locations. Comparable findings were also recorded by earlier investigators, who observed significant variation in radial growth, colony characteristics, hyphal features, and sclerotial development among isolates of R. solani, influenced by host source and geographical origin (Guleria *et al.*, 2007; Singh *et al.*, 2018; Raghunandana and Prashanthi, 2023) [3, 8, 9].

Table 3 Morphological variability in different isolates of Rhizoctonia solani at 40X

S. No.	Isolates	Hyphal width (µm)		Sclerotia size (mm)**	Pattern of sclerotia formation	No. of sclerotia (mm²)	Shape of sclerotia	Colour of sclerotia
		Mean	Range					
1	RSU-1 (Udaipur)	5.20±0.18	4.20-6.20	2.45	Scattered and irregular with aerial surface	20	Round	Light brown
2	RSU-2 (Udaipur)	6.98±0.30	5.60-8.35	2.60	Embedded	12	Oblong	Light brown
3	RSB-3 (Banswara)	5.80±0.39	4.55-7.05	0.25	Embedded	50	Round	Light brown
4	RSB-4 (Banswara)	3.92±0.28	2.80-5.04	1.35	Embedded	25	Round	Dark brown
5	RSP-5 (Pratapgarh)	3.76±0.42	2.90-4.62	2.65	Embedded	9	Round	Light blackish
6	RSP-6 (Pratapgarh)	2.73±0.58	1.90-3.56	2.70	Centre with aerial surface	5	Round	Light brown
7	RSR-7 (Rajsamand)	7.69±0.75	5.90-9.48	0.20	Centre and scattered with aerial surface	60	Round	Brown
8	RSR-8 (Rajsamand)	4.56±0.34	3.50-4.62	1.40	Embedded	23	Oblong	Dark brown
9	RSC-9 (Chittorgarh)	5.18±0.56	4.20-6.16	0.25	Peripheral ring and central with aerial surface	45	Oblong	Brown whitish
10	RSC-10 (Chittorgarh)	4.70±0.67	3.65-5.75	1.30	Scattered with aerial surface	27	Oblong	Light brown to whitish
	SEm±	0.017		0.08				
	CD at 5%	0.039		0.23				
	C.V. (%)	1.27		1.87				

** Mean number of ±50 sclerotia and S.D. of mean value

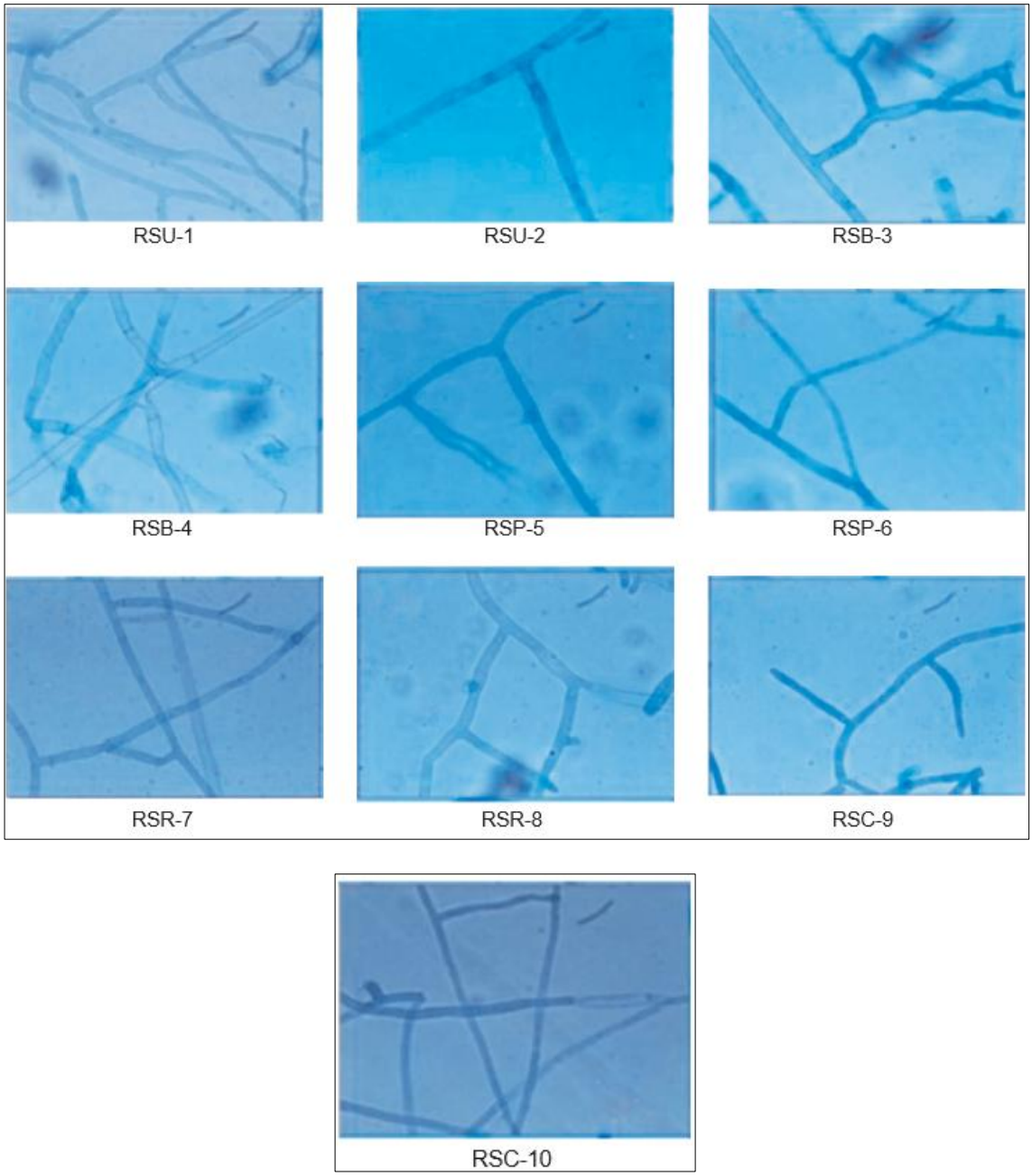

Plate 3: Morphological Variability in different isolates of *R. Solani* at 40× magnification

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