



RESEARCH ARTICLE

Deciphering temperature-driven epidemiology of collar rot (*Sclerotium rolfsii*) in soybean under different sowing windows

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Received: 25 November 2025; Accepted: 16 April 2026; Available online: Version 1.0: 31 May 2026

Cite this article: Ganga NS, Amrate PK, Lokhande KK, Kurmi S, Barfa P, Chouksey V, Raghuwanshi P, Shrivastava MK. Deciphering temperature-driven epidemiology of collar rot (*Sclerotium rolfsii*) in soybean under different sowing windows. Plant Science Today. 2026; 13(sp2): 1-9. <https://doi.org/10.14719/pst.12926>

Abstract

Collar rot, caused by *Sclerotium rolfsii*, significantly reduces soybean yield, especially under variable environmental conditions. This comprehensive field study investigated the interactive effects of three sowing dates, seven varietal responses and various meteorological variables, including soil temperature, on the incidence of collar rot during the 2024 *khari*f season at JNKVV, Jabalpur. The weekly percentage increase in collar rot and the corresponding influencing variables were analysed to draw a relation. Collar rot severity peaked at 34.0 % on the first sowing date and decreased significantly with delays, suggesting that temporal disease escape could be an effective management strategy. The seedling stage coincided with dry spells/scattered rainfall, along with warmer soil temperatures (> 30 °C) and RH ranging from 69.3 to 90.4 %, which were the most conducive field conditions for the rapid development of collar rot in soybean. Atmospheric minimum (0.803**), maximum (0.519*) and soil temperature (0.740**) exhibited significant positive associations and morning RH (-0.576*) exhibited a significant negative association with collar rot development in soybean in the pooled analysis. In contrast, rainy days, rainfall and evening RH were not significantly related. The multiple regression model (genotype-independent effects) with an R² of 0.824 (82.4 % of the variance explained) underscored the critical roles of weather variables in the development of collar rot epidemics in soybean. The findings advance current epidemiological understanding and establish a robust foundation for weather-based forecasting models, offering practical tools for integrated, climate-adaptive collar rot management in soybean cultivation.

Keywords: collar rot; correlation; regression; sowing date; soybean; weather

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the world's premier oilseed crops grown worldwide. It contains 38 % to 44 % protein and 18 % to 23 % edible oil, as well as essential amino acids, vitamins and minerals and is highly valued for its utility as both a food and an industrial crop (1, 2). India is a significant soybean-producing country, ranking among the top five in the world, along with Brazil, the United States, Argentina and China (3, 4). India's soybean production is concentrated in the states of Maharashtra, Madhya Pradesh, Rajasthan, Gujarat and Karnataka. Madhya Pradesh continues to be the spine of this belt, producing close to 40 % of the national production, with Ujjain and Indore as major centres (5). Soybeans are exposed to extreme weather shocks and frequent disease outbreaks and farmers need to battle these abiotic and biotic stresses. The weather conditions of central India favour the profitable and sustainable cultivation of soybean. However, in recent years, several diseases have become major constraints on soybean cultivation in this region (6-9). Collar rot, caused by *Sclerotium rolfsii* Sacc. (teleomorph: *Athelia rolfsii* (Curzi) Tu and Kimbrough) is a soilborne disease that has evolved from a sporadic to a regular menace on most soybean farms.

Sclerotium rolfsii has a very broad host range of over 500 plant species in different agroecosystems worldwide (10-12). Collar rot in soybean is a common problem that may appear at any growth stage of plants, but the seedling and vegetative growth phases are most sensitive to collar rot development in India (6, 13-15). Collar-rot-affected plants exhibit yellowing and leaf drop and subsequently die (6). In the affected plant, necrotic constriction around the collar region is the most diagnostic symptom, which is often accompanied by a whitish fungal growth of the pathogen (6). Infected plants initially exhibit premature yellowing of leaves, with subsequent wilting and collapse. Prominent white mycelial mats at the collar area are interspersed with many tanned brown sclerotia, are the classic symptom. Sclerotia are the overwintering structures and allow survival under adverse environmental conditions (12). The disease cycle begins with the germination of soil-borne sclerotia, usually under warm, moist conditions and fungal germ tubes attack the plant at the collar region near the soil surface (10, 12). The pathogen then colonises by causing rotting at the collar region of the plant, hydrolysing the pectate in the plant's cell wall with enzymes and oxalic acid (14, 15). Current field observations in central India also indicate the frequent appearance of collar in the majority of the cultivating varieties, a definite indication of its increased stronghold (6, 7). Due to weather variability and changing cropping patterns,

collar rot in soybean has become a challenging soil-borne disease that seriously affects the plant stand during the early stages of crop development (6, 7, 11). This increase can be largely explained based on climate variability, changed agronomic management and pathogens' developed adaptability. Amongst abiotic stresses, environmental factors have a significant influence on collar rot infection. It has been found in earlier studies that excessive soil moisture, temperature and rainfall are the primary factors in disease progression (16, 17). Soil-borne pathogens in legumes are significantly influenced by soil temperature; however, variations in the soil atmosphere can also enhance plant defence responses against pathogenic fungi (18, 19). Hence, it is worthwhile to determine which atmospheric and soil conditions most favour the development of collar rot in soybeans. Timely adjustments to the planting schedule, coupled with appropriate varietal selection and manipulation of temperature-related variables, could help formulate an effective cultural management strategy for the disease.

By modifying the crop's exposure to beneficial pathogen conditions, the date of sowing is a cultural practice that can potentially control disease. Such temporal differences can play an important role in disease development patterns since environmental conditions differ significantly throughout the crop growth season. The interactions between environmental conditions and sowing date on collar rot development are not well understood. Hence, considering all these, the present investigation was undertaken with the following objectives to identify the effects of different sowing dates on collar rot incidence in different soybean varieties and their interaction, to elucidate the relationships between weather and disease patterns and (3) to formulate a probable disease predication equation for collar rot. This comprehensive approach could provide critical insights for developing integrated management strategies combining cultural practices with varietal selection.

Materials and Methods

Isolation, identification and Pathogenicity of the causal agent

Symptomatic soybean plants exhibiting collar rot were collected from the experimental soybean field at JNKV in Jabalpur (latitude 23°12'42" N and longitude 79°56'53" E) during experimentation to confirm the pathogenicity of the causal agent (Fig. 1 and 2). Thereafter, to isolate the causal agent, the infected collar region was cut into small pieces, surface-sterilised with sodium hypochlorite (1.0 %) for 30 sec, rinsed with sterile water 3 times and dried on sterile blotter paper. The bits were subsequently inoculated into sterile *potato dextrose agar* medium in petri plates and incubated at 26 ± 2 °C for 4 days to promote fungal growth. The fungus was further purified and maintained using the single-sclerotial transfer method and identified as *Sclerotium rolfsii* based on the cultural and morphological keys, as shown in Fig. 3 (13). Pathogenicity of the isolated fungus was confirmed by the agar disc method (16), in which actively growing mycelial bits from a 5-day-old culture were affixed to the basal stem region of the test plant (JS 335) (16).

Experimental details

A field experiment was undertaken to derive the relation between weather and collar rot development at the experimental field of Plant Pathology, BSP (Field crop unit), JNKV, Jabalpur (latitude 23° 12'42" N and longitude 79°56'53" E), during the *kharif* of 2024. The experimental field had well-levelled, well-drained loamy clay soil. Climatic conditions in Jabalpur are hot and humid, which favour the

development of collar rot disease in soybean and other crops. The weather conditions during *kharif* 2024 were also most suitable for collar rot disease development (Table S1). In the present experiment, seven soybean varieties, i.e. JS 97-52, JS-20-94, JS 93-05, JS 20-29, JS 335, JS 95-60 and JS 20-34, were sown on three different dates of sowing (D1- 25/06/24, early; D2- 05/07/24, mid; D3- 15/07/24, Late). Each variety was grown in two replications, with a plot size of 0.8 × 3 m² per replication. No fungicidal or biocontrol agent seed treatments were applied at the time of sowing. The field chosen for the experiment had a history of regular collar rot in soybean and the subsequent chickpea crop. To facilitate a higher incidence, mass-multiplied partially crushed sorghum grains were placed in the rows at the time of sowing.

Observations on collar rot incidence

Variety-wise collar rot incidence from experimental plot rot was recorded at standard meteorological weekly (SMW) intervals up to 50 days after sowing (DAS). For this purpose, 50 plants of each variety were selected and regularly monitored throughout the observation period. At each observation, collar-rot-symptomatic plants were counted and recorded. After recording the observations, the diseased plants were removed from the plot to avoid repeated counting in subsequent observations. Thus, each week, only the newly infected plants in the remaining healthy population were considered for recording disease incidence. The % disease incidence was calculated using the following formula (17).

$$\% \text{ disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100 \quad (\text{Eqn. 1})$$

Monitoring of soil temperature and other parameters

Standard meteorological week (SMW) - wise average weather variables such as atmospheric temperature, RH, rainfall and rainy days, sunshine hours, etc., for the experimental site during the cropping season were obtained from the Meteorological Observatory, Department of Physics and Agrometeorology, College of Agricultural Engineering, JNKV, Jabalpur (M.P.). A detailed account of these weather variables is presented in the Fig. 4 and Table S1. Soil temperature at the experimental site was recorded daily at a depth of 10-12 cm using a mercury-based soil thermometer during the morning hours (10.00 to 10.30 AM) (Fig. 5)

Correlation and regression analysis

The Pearson correlation coefficient was calculated to assess the relationship between SMW-wise weather parameters and collar rot incidence. In addition, multiple linear regression analysis was performed to develop prediction models for collar rot incidence for each variety. Pooled data from the three sowing dates were utilised for this purpose. In the regression analysis, the % disease incidence (PDI) of collar rot was the dependent variable and the recorded weather parameters were the independent variables. All statistical analyses, including the calculation of correlation coefficients and the development of regression equations, were conducted using SPSS. The multiple linear regression model used for predicting collar rot incidence is expressed as:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 \quad (\text{Eqn. 2})$$

Where Y = Collar rot incidence, b_0 = Intercept (constant), b_1 to b_6 = Regression coefficient,

X_1 = Maximum temperature, X_2 = Minimum temperature, X_3 = Rainfall (mm), X_4 = Morning RH, X_5 = Evening RH and X_6 = Soil temperature



Fig. 1. Symptoms of collar rot in soybean: A. Yellowing and dropping of plant, B.-C. death of growing plants and emerging seedlings, along with the presence of fungal mycelial mat, D. girdling and shredding of the collar region due to infection, respectively.

Results

Symptoms and causal agent of collar rot

The collar-rot-infected plants exhibited characteristic symptoms, such as chlorotic leaves, which gradually led to patchy wilting and eventual plant death in the field. In addition, white mycelial growth on the necrotic lesions covering the collar region and mustard-coloured sclerotia along the soil line were observed in most of the collar rot-infected soybean seedlings (Fig. 1). The fungus *Sclerotium rolfsii*, isolated on *Potato Dextrose Agar* medium, exhibited snow-white, fluffy and dense mycelial growth spreading radially. Brownish-coloured, hard sclerotia were formed after 14 days of inoculation. Mature sclerotia, measuring 0.5-1.5 mm in diameter, initially appeared as white dots and later developed into dark brown structures (Fig. 3). The fungal colony attained full growth of about 90

mm on the Petri plate within approximately five days. Agar disc inoculation during the pathogenicity test induced typical collar rot symptoms in healthy soybean seedlings, thereby fulfilling Koch's postulates.

Collar rot progression

The first crop planted on 25 June 2024 recorded the highest disease intensity. The weekly mean incidence reached a maximum of 7.9 % during SMW 28 (9-15 July), followed by another peak of 6.3 % in SMW 29 (16-22 July) (Table 1 and Fig. 4). Thereafter, a sharp decline in disease incidence was observed, which may be attributed to changes in environmental conditions that were less favourable for the pathogen. The overall collar rot incidence among varieties ranged from 11.0 % in JS 20-34 to 34.0 % in JS 20-29 under the first sowing date. The second sowing (5 July 2024) recorded



Fig. 2. Experimental view of growing seven soybean varieties on three dates of sowing with two replications.



Fig. 3. Cultural plate of *Sclerotium rolfsii*, the inciting agent of collar rot of soybean.

comparatively lower disease intensity, with the peak weekly mean incidence of 5.7 % during SMW 29 (Table 2). The overall collar rot incidence among varieties ranged from 9.0 % in JS 93-05 to 22.0 % in JS 20-29 under this sowing date. The later sowing (15 July 2024) was found to be the most effective in reducing the disease, where the highest incidence recorded was only 4.0 % during SMW 29. By mid-August, disease activity had almost ceased (Table 3). Under this sowing date, the overall collar rot incidence among varieties ranged from 7.0 % in JS 95-60 and JS 97-52 to 12.0 % in JS 93-05. This trend in disease occurrence suggests a possible disease escape phenomenon, in which delayed sowing enabled the crop to avoid the most favourable period for pathogen development. A gradual decline in overall disease incidence across the cropping season was observed, decreasing from 21.7 % in the earliest sowing to 14.9 %

and 9.1 % in the subsequent sowings, indicating an inverse relationship between sowing date and disease incidence.

Among the three sowing dates, the maximum overall incidence of collar rot was recorded in JS 20-29 (34 %) under the first sowing date, whereas the minimum incidence (7 %) was observed in JS 97-52 and JS 95-60 under the third sowing date (Tables 1-3 and Fig. 4). Briefly, the month of July, particularly the period from 9–22 July, was found to be the most favourable for disease development across all sowing dates and varieties (Fig. 4). This may be attributed to favourable environmental conditions prevailing during this period. During this time, the maximum temperature was around 33 °C, the minimum temperature ranged from 25.8 to 26.1 °C and the soil temperature was approximately 32 °C (Fig. 5). Irregular rainfall ranging from 22.8 mm to 174.2 mm, persisting for 2–4 days, was also recorded. The morning and evening relative humidity ranged between 85.6–90.4 % and 69.3–70 %, respectively. In addition, the highest disease incidence was observed in plants less than 30 days old, whereas no apparent disease symptoms were recorded once the plants approached the early reproductive stage.

Varietal performance statistics

Significant variation was observed among the seven varieties concerning their response towards collar rot infection (Table 4). Statistical analysis revealed that variation among sowing dates ($CD = 0.450, p \leq 0.05$), varieties ($CD = 0.687, p \leq 0.05$) and their interaction ($CD = 1.190, p \leq 0.05$) was significant. Among the pooled data, the variety JS 20-29 possessed the greatest mean PDI (3.55 %), which was followed by JS 335 at 3.21 % and the lowest was in the case of JS 20-34 (1.83 %) (Table 4). This confirmed the relative susceptibility of JS 20-29, while JS 20-34 consistently showed the lower incidence across sowing dates (1.83 % to 2.21 %), indicating partial tolerance to the disease. JS 93-05 and JS 95-60 also exhibited good performance with disease incidences of 2.22 % each. JS 97-52 and JS 20-94 yielded the middle values for responses with the mean PDI values of 2.38 % and 2.33 %, respectively.

Table 1. Weekly incidence of collar rot in soybean varieties under the first date of sowing (25.06.2024)

SMW	Duration	Collar rot incidence (%)							Avg
		JS 335	JS 20-29	JS 97-52	JS 93-05	JS 20-94	JS 95-60	JS 20-34	
27	July 2-8	3.0	7.0	3.0	6.0	3.0	3.0	0.0	3.6
28	July 9-15	11.0	13.0	7.0	6.0	9.0	5.0	4.0	7.9
29	July 16-22	8.0	9.0	6.0	5.0	5.0	6.0	5.0	6.3
30	July 23-29	4.0	3.0	3.0	2.0	0.0	4.0	2.0	2.6
31	July 30- Aug 5	1.0	2.0	2.0	0.0	0.0	3.0	0.0	1.1
32	Aug 6-12	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.3
Overall incidence		27.0	34.0	22.0	19.0	17.0	22.0	11.0	21.7

Table 2. Weekly incidence of collar rot in soybean varieties under the second date of sowing (05.07.2024)

SMW	Duration	Collar rot incidence (%)							Avg
		JS 335	JS 20-29	JS 97-52	JS 93-05	JS 20-94	JS 95-60	JS 20-34	
28	July 9-15	6.0	4.0	2.0	0.0	2.0	2.0	4.0	2.9
29	July 16-22	9.0	8.0	4.0	2.0	5.0	6.0	6.0	5.7
30	July 23-29	4.0	7.0	5.0	4.0	4.0	2.0	3.0	4.1
31	July 30- Aug 5	2.0	3.0	2.0	3.0	2.0	1.0	0.0	1.9
32	Aug 6-12	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.3
33	Aug 13-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overall incidence		21.0	22.0	14.0	9.0	14.0	11.0	13.0	14.9

Table 3. Weekly incidence of collar rot in soybean varieties under the third date of sowing (15.07.2024)

SMW	Duration	Collar rot incidence (%)							Avg
		JS 335	JS 20-29	JS 97-52	JS 93-05	JS 20-94	JS 95-60	JS 20-34	
29	July 16-22	4.0	3.0	4.0	6.0	4.0	2.0	5.0	4.0
30	July 23-29	3.0	5.0	3.0	4.0	4.0	2.0	3.0	3.4
31	July 30- Aug 5	2.0	0.0	0.0	1.0	1.0	3.0	0.0	1.0
32	Aug 6-12	1.0	0.0	0.0	1.0	2.0	0.0	1.0	0.7
33	Aug 13-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	Aug 20-26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overall incidence		10.0	8.0	7.0	12.0	11.0	7.0	9.0	9.1

**Fig. 5.** Measurement of soil temperature at the experimental field.**Table 4.** Weekly average incidence of collar rot in varieties under different dates of sowing

Varieties	Collar rot (%)			Mean PDI %
	D ₁	D ₂	D ₃	
JS 335 (V ₁)	4.500	3.495	1.66	3.21
JS 20-29 (V ₂)	5.665	3.665	1.33	3.55
JS 97-52 (V ₃)	3.660	2.33	1.165	2.38
JS 93-05 (V ₄)	3.160	1.500	1.995	2.22
JS 20-94 (V ₅)	2.83	2.330	1.830	2.33
JS 95-60 (V ₆)	3.665	1.830	1.160	2.22
JS 20-34 (V ₇)	1.83	2.165	2.218	1.83
Mean PDI %	3.61	2.48	1.52	-
DOS (A)	CD ($p=0.05$) = 0.450, SEM = 0.151			
Variety (B)	CD ($p=0.05$) = 0.687, SEM = 0.231			
A × B	CD ($p=0.05$) = 1.190, SEM = 0.401			

Disease-weather correlation matrix

The correlation matrix between collar rot incidence and environmental factors, including soil temperature, showed that parameters associated with the first sowing date were significantly related to disease development (Table 5). In the first sowing, maximum temperature (0.922**), minimum temperature (0.934**) and soil temperature (0.934**) showed a significant positive relationship with collar rot incidence, whereas morning RH (-0.876*) showed a significant negative relationship. In the second and third sowing dates, none of the environmental parameters showed a significant association with disease development.

Pooled analysis of all three sowing dates indicated that minimum atmospheric temperature (0.832**–JS 335, 0.696**–JS 20-29, 0.698**–JS 97-52, 0.569*–JS 93-05, 0.702**–JS 20-94, 0.693**–JS 95-60, 0.864**–JS 20-34, 0.803**–Average) and soil temperature (0.772**–JS 335, 0.679**–JS 20-29, 0.631**–JS 97-52, 0.529*–JS 93-05, 0.664**–JS 20-94, 0.556*–JS 95-60, 0.782**–JS 20-34, 0.740**–Average) had a strong and significant positive relationship with collar

Table 5. Correlation matrix between disease-influencing factors and average collar rot incidence in soybean varieties under different dates of sowing

	First date	Second date	Third date
Max temperature (°C)	0.922**	0.355	0.175
Min temperature (°C)	0.934**	0.738	0.724
Sunshine hrs	0.801	0.358	0.216
Rainfall (mm)	-0.290	0.508	0.660
Max RH (%) (morning)	-0.876*	-0.247	-0.223
Min RH (%) (eve)	-0.787	-0.088	0.127
Rainy days	-0.272	0.573	0.566
Soil temperature (°C)	0.934**	0.564	0.597

** . Correlation is significant at the 0.01 level, * . Correlation is significant at the 0.05 level.

rot incidence across all soybean varieties and their average (Table 6). Maximum temperature (0.606**–JS 335, 0.490*–JS 20-94, 0.663**–JS 20-34, 0.519*–Average) and sunshine hours (0.641**–JS 335, 0.520*–JS 20-94, 0.673**–JS 20-34, 0.513*–Average) also showed a significant positive association with increasing collar rot incidence in most varieties and their average. In contrast, morning RH (-0.664**–JS 335, -0.566*–JS 20-29, -0.573*–JS 20-94, -0.552*–JS 20-34, -0.576*–Average) exhibited a significant negative relationship with disease incidence across sowing dates. However, other parameters, such as rainfall, rainy days and evening RH, did not show a significant relationship with collar rot incidence in soybean.

Regression equations

To develop forecasting models for collar rot development in soybean, multiple linear regression was performed using combined data from all three sowing dates, including significant meteorological parameters such as maximum and minimum temperatures, rainfall, morning and evening relative humidity and soil temperature (Table 7). The coefficient of determination (R^2) ranged from 0.614 in JS 20-94 to 0.963 in JS 20-34, indicating variability in the models' explanatory power across varieties. The regression model for JS 20-34 showed the highest prediction accuracy ($R^2 = 0.963$), followed by JS 335 ($R^2 = 0.848$) and JS 97-52 ($R^2 = 0.736$), while JS 20-94 showed comparatively lower model fitness. The pooled average model for all varieties ($Y = -26.873 - 0.388X_1 + 1.660X_2 + 0.009X_3 - 0.374X_4 + 0.153X_5 + 0.725X_6$) explained about 82.4 % variation ($R^2 = 0.824$) in collar rot incidence, indicating the combined influence of these weather parameters on disease development. The statistical validity of the models was supported by highly significant F-test values ($p < 0.05$), confirming their suitability in explaining the relationship between weather variables and collar rot incidence in soybean.

Discussion

Changes in standard weather parameters influence the occurrence and severity of crop diseases and alter management practices (20). Recent observations in central India reveal that collar rot is increasingly affecting cultivated soybean varieties, damaging plant stand during early crop development amidst changing weather and cropping patterns (6, 7). The symptoms observed in the present study, including chlorosis and wilting of soybean plants in patches, along with a whitish mycelial mat at the constricted collar region, due to the attack of *Sclerotium rolfsii*, agree with previous research findings (6, 10). The rapid radial, whitish, fluffy mycelial growth of the isolated pathogen on Potato Dextrose Agar and the later formation of brown, hard sclerotia are also consistent with earlier descriptions of the pathogen (12, 21). Furthermore, the successful reproduction of disease symptoms in healthy soybean seedlings also confirms the isolate's pathogenicity.

In our investigation, the month of July, particularly the period from 9–22 July, was found to be the most favourable for disease development across all sowing dates and varieties. This may be attributed to favourable environmental conditions, i.e. warm temperature, high relative humidity and intermittent rainfall prevailed during the month for the development of collar rot. This kind of weather promotes higher germination of sclerotia and helps in developing infection by colonising pathogens on host tissues easily. Further, the plant in the early stage, below 30 days of age, has greater infection ability, indicating that young seedlings are more vulnerable to collar rot infection than plants at later growth stages. As far as the literature is concerned, there are no publications on the influence of sowing date on collar rot incidence in soybean. However, similar findings were reported in previous research for delayed planting and lower incidence of collar rot in chickpea, where the highest mean incidence of collar rot of 18.76 %

Table 6. Correlation matrix between disease-influencing factors and collar rot incidence in soybean varieties and their average (pooled of three sowing dates)

	JS 335	JS 20- 29	JS 97-52	JS 93-05	JS 20-94	JS 95-60	JS 20-34	Average
Max temperature (°C)	0.606**	0.442	0.400	0.260	0.490*	0.366	0.663**	0.519*
Min temperature (°C)	0.832**	0.696**	0.698**	0.569*	0.702**	0.693**	0.864**	0.803**
Sunshine hrs	0.641**	0.411	0.398	0.168	0.520*	0.371	0.673**	0.513*
Rainfall (mm)	0.049	0.024	0.184	0.151	-0.019	0.322	0.176	0.115
Max RH (%) (morning)	-0.664**	-0.566*	-0.450	-0.333	-0.573*	-0.363	-0.552*	-0.576*
Min RH (%) (eve)	-0.415	-0.303	-0.196	-0.169	-0.341	-0.219	-0.379	-0.334
Rainy days	0.080	0.182	0.276	0.336	0.041	0.338	0.124	0.200
Soil temperature (°C)	0.772**	0.679**	0.631**	0.529*	0.664**	0.556*	0.782**	0.740**

Number of observations = 18, **. Correlation is significant at the 0.01 level, *. Correlation is significant at the 0.05 level.

Table 7. Multiple linear regression equations for increasing weekly collar rot incidence with current week independent variables (pooled of three dates of sowing)

Varities	Multiple linear regression equations	R^2	Standard error of the estimate of the model summary	F	Sig
JS 335	$Y = 10.085 + 0.209 (X_1) + 2.227 (X_2) + 0.017 (X_3) - 1.036 (X_4) + 0.300 (X_5) + 0.047 (X_6)$	0.848	1.62491	10.230	0.001 ^a
JS 20-29	$Y = 86.589 - 1.310 (X_1) - 0.992 (X_2) + 0.023 (X_3) - 0.938 (X_4) + 0.132 (X_5) + 1.896 (X_6)$	0.710	2.599	4.494	0.015 ^a
JS 97-52	$Y = -41.399 - 0.229 (X_1) + 1.370 (X_2) + 0.006 (X_3) - 0.241 (X_4) + 0.198 (X_5) + 0.763 (X_6)$	0.736	1.38910	5.101	0.010 ^a
JS 93-05	$Y = -33.389 - 1.658 (X_1) + 0.749 (X_2) + 0.006 (X_3) + 0.219 (X_4) - 0.101 (X_5) + 1.853 (X_6)$	0.629	1.79190	3.104	0.050 ^a
JS 20-94	$Y = -49.920 - 0.102 (X_1) + 2.877 (X_2) + 0.001 (X_3) - 0.392 (X_4) + 0.199 (X_5) + 0.133 (X_6)$	0.614	1.91000	2.918	0.059 ^a
JS 95-60	$Y = -17.974 - 0.726 (X_1) + 2.236 (X_2) + 0.013 (X_3) - 0.251 (X_4) - 0.015 (X_5) + 0.313 (X_6)$	0.693	1.38883	4.138	0.020 ^a
JS 20-34	$Y = -150.851 + 1.155 (X_1) + 3.095 (X_2) - 0.003 (X_3) + 0.088 (X_4) + 0.365 (X_5) + 0.117 (X_6)$	0.963	0.51965	47.851	0.000 ^a
Average	$Y = -26.873 - 0.388 (X_1) + 1.660 (X_2) + 0.009 (X_3) - 0.374 (X_4) + 0.153 (X_5) + 0.725 (X_6)$	0.824	1.24672	8.573	0.001 ^a

Number of observations = 18, Y= Collar rot (%), X_1 = Maximum temp, X_2 = minimum temp, X_3 = Rainfall (mm), X_4 = Morning RH, X_5 = Evening RH and X_6 = Soil temperature

was recorded when sowing was performed in the first fortnight of November, followed by sowing in the second fortnight of November (14.38 %). The lowest incidence of collar rot of 8.77 % was seen under the sowing date during the first fortnight of December (22). Early sowing (15-Nov) in chickpea facilitates a higher incidence of collar rot (21.37 %) than late sowing (15-Dec) (11.19 %) (23). It corroborates our findings that a high-temperature regime promotes high disease, as in the early stage, soil and atmospheric temperatures remained high (23). Our findings indicate that collar rot development during the seedling and vegetative stages is corroborated by reports of collar rot in other legumes, as this stage is most suitable for the pathogen's attack (24). In our findings, soil temperature greatly contributed to the development of collar rot in soybeans. This is also similar to the findings, which showed that soil temperatures ranging from 25 to 30 °C were most suitable for the development of collar rot in chickpea (25). The reduced disease incidence in later sowing may therefore be attributed to a disease escape mechanism, where the crop avoids the most favourable environmental window for pathogen activity. According to the above results, it can be concluded that both the factors, sowing date and varieties, as well as the interaction between them, are very important in disease occurrence. Thus, both timely variation in planting schedule and appropriate varietal selection act as major factors in collar rot control.

The correlation analysis indicated that temperature-related parameters, particularly minimum atmospheric temperature and soil temperature, had a strong positive association with collar rot incidence caused by *Sclerotium rolfsii*. All these trends combined meant that hot and slightly drier environments favour collar rot in soybeans. Varietal reactions showed particular genotype × environment interactions in these microclimatic regimes, although overall, higher temperatures of air and soil and lower humidity emerged as prime influential factors for collar rot development. The previous findings agreed with our results, indicating that moderate atmospheric temperature and high humidity favour the development of collar rot in soybean (16, 26). However, their observation that rainfall significantly and positively influences collar rot incidence was contradictory to our findings (16). Whereas soil moisture significantly influences collar development in chickpeas, with incidence directly proportional to increases in soil moisture (25). In conclusion, increased soil temperatures supported pathogen survival and increased infection efficiency through increased enzymatic activity for host tissue invasion. While high relative humidity during the morning is usually considered conducive to fungal pathogens, in this study, there were strong negative correlations with collar rot severity, suggesting that waterlogging of the aerial environment could impede pathogen survival or interrupt the process of infection.

In regression analysis, the high R^2 values obtained for most varieties suggest that the selected meteorological variables were effective in explaining the variability in disease incidence. In previous findings, the contribution of parameters such as maximum temperature, soil moisture (SM) and minimum relative humidity in the development of collar rot was also indicated through a binary logistic model (27). These results highlight the potential usefulness of weather-based regression models for forecasting collar rot incidence and supporting timely disease management strategies. These findings show that weather-related relationships with soybean collar rot vary by cultivar and highlight the usefulness of regression models for predicting and managing this significant disease.

Conclusion

The findings revealed that high atmospheric and soil temperatures, coupled with scattered rainfall, play a significant role in the development of collar in soybean at the early seedling stage. The selection of comparatively tolerant varieties, i.e., JS 20-34 and delayed sowing could significantly reduce the incidence of collar rot. Hence, proper plant protection measures should be adopted in timely-sown conditions to minimise collar rot as much as possible.

Acknowledgements

Authors truly acknowledge the valuable support and guidance of HoD, Plant Pathology and HoD, Genetics and Plant Breeding, JNKVV, Jabalpur.

Authors' contributions

NSG carried out the experiment, data compilation and initial draft preparation. PKA did the data compilation, data analysis and final draft preparation. KKL conducted trial and data collection; SK did data analysis and draft preparation. PB did data collection, data analysis and draft preparation; VC contributed to data analysis and draft preparation. PR contributed to data analysis and draft preparation. MKS supervised and guided the research. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Hymowitz T, Richard MS, James EH, Richard FW, Randy CS. Soybeans: improvement, production and uses. Speciation and cytogenetics. 2004;16:97–136. <https://doi.org/10.2134/agronmonogr16.3ed.c4>
2. Banerjee J, Shrivastava MK, Singh Y, Amrate PK. Estimation of genetic divergence and proximate composition in advanced breeding lines of soybean (*Glycine max* (L.) Merrill). Environ Ecol. 2023;41(3C):1960–68. <https://doi.org/10.60151/envec/VYWE5744>
3. Amrate PK, Shrivastava MK, Borah M, Routhu GK, Sharma S, Nataraj V, et al. Molecular characterization of soybean yellow mosaic virus isolates and identification of stable resistance sources in central India. Australas Plant Pathol. 2023;52:165–79. <https://doi.org/10.1007/s13313-022-00902-8>
4. Anand KJ, Shrivastava MK, Amrate PK, Patel T, Singh Y. Morphological characterization-based optimal trait selection for improving yield and stability of soybean (*Glycine max* L. Merrill). Int J Bioresour Stress Manag. 2024;15(10):1–12. <https://doi.org/10.23910/1.2024.5604>
5. Directorate of Economics and Statistics. Area, production and yield reports [Internet]. New Delhi: Ministry of Agriculture & Farmers Welfare, Government of India; 2024 [cited 2026 Apr 23]. Available from: <https://data.desagri.gov.in/website/crops-apy-report-web>
6. Amrate PK. Survey and present status of soybean diseases in central India. Int J Bioresour Stress Manag. 2024;15(5):1–10. <https://doi.org/10.23910/1.2024.5299>
7. Ramteke R, Rajput LS, Nataraj V, et al. Evaluation of soybean genotypes for resistance to collar rot (*Sclerotium rolfsii*) under field and glasshouse condition. Trop Plant Pathol. 2024;49:714–25. <https://doi.org/10.1007/s40858-024-00652-6>

8. Amrate PK, Nataraj V, Shivakumar M. BLUP-based models aided in selection of high yielding charcoal rot and yellow mosaic resistant soybean genotypes. *Genet Resour Crop Evol.* 2025;72:5593–5611. <https://doi.org/10.1007/s10722-024-02289-5>
9. Mishra R, Pandey A, Payasi DK, Tripathi MK, Singh Y, Sharma S, et al. Resistance profiling of soybean RILs against yellow mosaic virus and charcoal rot under field conditions. *Plant Sci Today.* 2025;12(sp4). <https://doi.org/10.14719/pst.9379>
10. Patra GK, Acharya GK, Panigrahi J, Mukherjee AK, Rout GR. The soil-borne fungal pathogen *Athelia rolfsii*: past, present and future concern in legumes. *Folia Microbiol.* 2023;68(5):677–90. <https://doi.org/10.1007/s12223-023-01086-4>
11. Wrather A, Shannon G, Balardin R. Effect of diseases on soybean yield in the top eight producing countries in 2006. *Plant Health Prog.* 2010;11:1. <https://doi.org/10.1094/PHP-2010-0102-01-RS>
12. Gupta GK, Nair RM. Soybean diseases in India. In: Hartman GL, Rupe JC, Sikora EJ, et al., editors. *Compendium of Soybean Diseases and Pests.* Minnesota: APS Press; 2015. p.201–2.
13. Punja ZK. The biology, ecology and control of *Sclerotium rolfsii*. *Annu Rev Phytopathol.* 1985;23(1):97–127. <https://doi.org/10.1146/annurev.py.23.090185.000525>
14. Hiremath IG, Jahagirdar S, Krishnaraj PU, Ashtaputre SA, Kambekar DN, Priyanka K. Diversity studies of *Sclerotium rolfsii* isolates associated with collar rot of soybean. *Legume Res.* 2024;47(10):1809–14. <https://doi.org/10.18805/LR-5221>
15. Kirtzman G, Chet I, Henis Y. The role of oxalic acid in the pathogenic behaviour of *Sclerotium rolfsii*. *Exp Mycol.* 1977;1:280–85. [https://doi.org/10.1016/S0147-5975\(77\)80003-0](https://doi.org/10.1016/S0147-5975(77)80003-0)
16. Borah M, Saikia H. Influence of weather parameters on development of collar rot of soybean caused by *Sclerotium rolfsii*. *Int J Curr Microbiol Appl Sci.* 2019;8(10):1667–75. <https://doi.org/10.20546/ijcmas.2019.810.194>
17. Sharma M, Pande S. Effects of temperature and soil moisture stress on dry root rot development in chickpea. *Am J Plant Sci.* 2013;4:584–89. <https://doi.org/10.4236/ajps.2013.43076>
18. Sinha R, Gupta A, Senthilkumar M. Impact of drought on bacterial pathogen stress in chickpea. *Front Plant Sci.* 2016;7:902. <https://doi.org/10.3389/fpls.2016.00902>
19. Shokes FM, Rozaiski K, Gorbet DW, Brenneman TB, Berger DA. Techniques for inoculation of peanut with *Sclerotium rolfsii*. *Peanut Sci.* 1996;23:124–28. <https://doi.org/10.3146/10095-3679-23-2-11>
20. Kaur G, Singh H, Maurya S, Kumar C, Kumar A. Climate change and its impact on plant diseases. *Plant Sci Today.* 2023;10(4):163–71. <https://doi.org/10.14719/pst.2479>
21. Mishra S, Mishra P, Mishra AK, Singh J. Evaluation of inoculation techniques for *Sclerotium rolfsii*. *Pharma Innov.* 2021;10:758–59. <https://doi.org/10.22271/tpi.2021.v10.i3k.5876>
22. Tiwari P, Gautam V, Shivramakrishnan R, Sharma RS, Parmar P, Kharte S. Effect of sowing time and seed treatment in management of collar rot of chickpea. *Biol Forum.* 2023;15(1):169–73.
23. Kumar A, Singh VK, Khan A. Impact of soil types and sowing times on collar rot of chickpea in Bundelkhand region. *Bhartiya Krishi Anusandhan Patrika.* 2026. <https://doi.org/10.18805/BKAP884>
24. Tamang S, Saha P, Rizal S. Effects of sowing dates on yield and collar rot of chickpea (*Cicer arietinum* L.). *Bangladesh J Bot.* 2022;51(4):721–27. <https://doi.org/10.3329/bjb.v51i4.63491>
25. Tarafdar A, Rani TS, Chandran USS, Ghosh R, Chobe DR, Sharma M. Combined effect of abiotic and biotic stress on collar rot development in chickpea. *Front Plant Sci.* 2018;9:1154. <https://doi.org/10.3389/fpls.2018.01154>
26. Gandhi V, Taya RS, Kumar A. Epidemiology of collar rot of sunflower caused by *Sclerotium rolfsii*. *Int J Curr Microbiol Appl Sci.* 2019;8(10):762–71. <https://doi.org/10.20546/ijcmas.2019.810.088>
27. Garain PK, Mondal B, Dutta S. Influence of weather factors, soil temperature and moisture on collar rot of betelvine. *J Agrometeorol.* 2021;23(4):428–34. <https://doi.org/10.54386/jam.v23i4.148>

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