



Effect of weather parameters on Alternaria leaf blight of isabgol (*Plantago ovata*) incited by *Alternaria alternata*

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ABSTRACT

Isabgol (*Plantago ovata* Forssk.) is a vital medicinal plant, highly valued for its substantial soluble fibre content and numerous health benefits. However, its cultivation is severely impacted by *Alternaria* leaf blight incited by *Alternaria alternata*, which affects both yield and quality. The present study was carried out during two winter (*rabi*) seasons of 2022–23 and 2023–24 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University Bikaner, Rajasthan to investigate the effect of various weather parameters on the progression of *Alternaria* leaf blight of isabgol. Results indicated that the highest percent disease intensity (54.38%) occurred during 29 January–04 February meteorological week in 2022–23, while in 2023–24, the peak disease intensity (51.11%) was observed during the 05–11 February week. Correlation analysis revealed that maximum and minimum temperatures, rainfall, and sunshine hours were significantly negatively correlated with disease intensity, whereas maximum and minimum relative humidity and wind velocity showed a positive correlation with disease intensity for the 2022–23 season. These findings highlight the critical role of weather attributes in the infection process and spread of *Alternaria* leaf blight in isabgol, providing essential insights for effective disease management strategies.

Keywords: *Alternaria* leaf blight, *Plantago ovata*, Parameters, Weather

Psyllium or isabgol (*Plantago ovata*) is a member of the Plantaginaceae family and holds a significant place in traditional Indian and Chinese herbal medicine. Renowned for its therapeutic properties, isabgol is utilised to treat a variety of ailments, including skin irritations, high blood pressure, constipation, intestinal ulcers, chronic diarrhoea and dysentery (Fernandez 2006). Its water-soluble and gelatinous characteristics make it an ideal candidate for drug delivery systems and enhancing absorption. Additionally, isabgol possesses cholesterol-lowering and wound-healing abilities (Taneja *et al.* 1989, Tomar *et al.* 2010).

The necrotrophic nature of *Alternaria* species often results in significant damage to plants and their harvest, with seedlings rarely surviving an attack (Humpherson-Jones 1985, Rimmer and Buchwaldt, 1995, Mamgain *et al.* 2013, Dhaka *et al.* 2022b). *Alternaria* is easily identifiable by its conidia, which are large, ovoid to obclavate, dark-coloured (melanised), and multicellular with both longitudinal and transverse septations (Barnett 1998).

These conidia are produced in chains, broadest near the base, and tapering gradually to an elongated beak (Dube 2013). In recent years, *Alternaria* leaf blight has emerged as a serious threat to isabgol cultivation. This disease, caused by *Alternaria alternata*, is particularly devastating to crops already affected by downy mildew, leading to considerable annual damage and sometimes complete yield loss. The pathogenicity of *Alternaria* is exacerbated by its production of several mycotoxins, including tenuazonic acid, alternariol, alternariol monomethyl ether, altenuene, and tentoxin (Pedras and Park 2015, Siciliano *et al.* 2017).

The natural outbreaks of *Alternaria* leaf blight are highly influenced by environmental conditions, resulting in severe disease occurrences annually in India. Most of the Indian cultivars are susceptible to *Alternaria* leaf blight disease, and there is a lack of resistant varieties available in the market. Given this susceptibility, understanding the timing of pathogen attacks, disease progression, and their relationship with weather parameters is crucial for developing effective disease management strategies. This study aimed to fill the gap in epidemiological knowledge regarding *Alternaria* leaf blight by investigating the influence of various weather attributes on the disease's development in isabgol.

MATERIALS AND METHODS

Experiment site and details: This study was carried out

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during two winter (*rabi*) seasons of 2022–23 and 2023–24 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (28.10° N, 73. 18° E; at an elevation of 223.88 m amsl), Rajasthan. The area of Bikaner is characterised by stormy southwest winds. Soils of the experiment field had sandy in texture, very low in fertility with respect to nutrients. Isabgol plants were sown before 15 November with 30 cm × 5 cm spacing. All agronomic practices were followed as per package of practices. Plants were inoculated (as of 45 days) using battery operated knapsack sprayer with a spore suspension of *A. alternata* 1×10^5 conidia/mL in both the year for disease development in isabgol plants.

Sample collection: Isabgol plants exhibiting typical leaf blight symptoms were collected from farmers' fields. Infected leaves were examined and used for pathogen isolation. The plant material belonged to a widely cultivated variety, and sample collection was carried out in accordance with the guidelines of the Government of India, therefore, no ethical approval was required.

Preparation of media, isolation and purification of the pathogen: The fungal isolation process utilised the Potato Dextrose Agar (PDA) plate method. The PDA medium was prepared by combining 200 g of peeled potatoes, 20 g of dextrose, and 15 g of agar/L of water. The pH of the medium was adjusted to 6.5 using a citrate phosphate buffer solution and verified with a digital pH meter. Once prepared, the medium was placed in a 1000 mL flask and sterilised. Subsequently, 15–20 mL of the sterilized medium was poured into each Petri dish within a laminar airflow cabinet and allowed to solidify for 15–20 min.

Diseased plant samples were cut into small pieces (2–5 mm) using a sterilised scalpel, rinsed with ultra-purified water (0 TDS), and soaked in a 0.1% mercuric chloride (HgCl₂) solution for 2 min. The pieces were then rinsed again with ultra-purified water three times. These prepared samples were placed onto the solidified PDA medium in Petri dishes under aseptic conditions. The Petri dishes were then incubated in a BOD incubator (PSI-4) at $26 \pm 1^\circ\text{C}$ to promote pathogen mycelial growth. After 3–4 days, the mycelium began to grow peripherally. The growing mycelium was then transferred using a sterilized inoculation needle for sub-culturing under similar conditions. The culture was subsequently purified using techniques as described by Sofi *et al.* (2013).

Identification of the pathogen: The cultures of *Alternaria alternata* were purified by sub-culturing the single hyphal tip method and maintained by mass transfer on potato dextrose agar medium at room temperature. After purify, these isolates of *A. alternata* were identified by observing the colony against light and later confirmed with the help of microscope (Supplementary Fig. 1). The pure culture was sent to Indian Type Culture Collection (ITCC), Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi for identification.

Inoculum preparation: The pure culture of the pathogen maintained on agar slant was multiplied on basal culture

medium (PDA) in Petri dishes. Conidial suspension (1×10^5 spores/mL) was prepared and sprayed on isabgol plant by hand sprayer.

Observation recorded: The per cent disease intensity (PDI) was assessed for each plot on a disease rating scale of 1–9 (Gugino *et al.* 2007) based on the percentage of leaf area symptomatic (1= 0% tissue symptomatic, 2= up to 1%, 3= 2–5%, 4= 6–10%, 5= 11–20%, 6= 21–30%, 7= 31–40%, 8= 41–50%, and 9= over 50%). The intensity was calculated by using the formula of Wheeler (1969):

$$\text{Per cent disease intensity} = \frac{\text{Sum of all individual disease rating}}{\text{Total no. of plants assessment} \times \text{Max. rating}} \times 100$$

The data of major meteorological factors affecting disease development and its progression were recorded from the initiation of the disease up to crop maturity at weekly intervals.

Observations on per cent disease intensity (PDI) were recorded from initiation of the disease till the maturity of the crop by examining from 10 plants randomly selected at five different locations in the field by using 1–9 scale (Gugino *et al.* 2007). Disease intensity was recorded at weekly intervals after 7 days of inoculation. Weekly meteorological data on temperature (Maximum and minimum), relative humidity (RH, Maximum and minimum), rainfall, sunshine hours and wind velocity were obtained for the period between two consecutive disease recordings to establish their correlation with disease development. Angular transformed values of per cent data were subjected to correlation and regression coefficients:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 \quad (R^2)$$

Where R^2 , Multiple correlation; Y, Per cent disease intensity; a, Constant (Intercept); b_1 to b_7 , Partial regression coefficients; X_1 , Maximum temperature ($^\circ\text{C}$); X_2 , Minimum temperature; X_3 , Max. RH (%); X_4 , Min. RH (%); X_5 , Rainfall (mm); X_6 , Sunshine hour; X_7 , Wind velocity (km/h).

RESULTS AND DISCUSSION

Effect of weather parameters on disease intensity during rabi, 2022–23: The onset of disease progression was observed between 26th November and 2nd December, with disease intensity increasing slightly from 2.15% during this period. The recorded minimum and maximum temperatures ranged from 6.6–29.3 $^\circ\text{C}$, while relative humidity fluctuated between 25.9–69.4%, accompanied by 9.3 h of sunshine. Following this initial phase, there was a gradual increase in disease intensity. A continuous rise in disease intensity was noted, ranging from 2.15–54.38% PDI, during the period from 26th November to 4th February (Table 1, Fig. 1). After 4th February, the PDI began to decline.

Correlation analysis revealed significant relationships between percent disease intensity and various weather parameters. Maximum and minimum temperatures, rainfall, and sunshine hours were found to be significantly negatively correlated with disease intensity. Conversely, maximum and

Table 1 Progression of Alternaria leaf blight disease of isabgol in relation to weather parameters under epiphytotic conditions during *rabi* 2022–23

Standard meteorological week	Temperature		Relative Humidity		Rainfall	Sunshine hour	Wind velocity	Per cent Disease Intensity (PDI)
	Max	Min	Max	Min				
	X ₁ (°C)	X ₂ (°C)	X ₃ (mm)	X ₄ (%)				
26 Nov–02 Dec	29.3	6.6	69.4	25.9	0.0	9.3	2.6	2.15
03–09 Dec	27.5	7.3	76.1	28.9	0.0	8.2	2.6	10.39
10–16 Dec	26.8	6.1	79.7	30.7	0.0	9.1	3.5	21.66
17–23 Dec	24.7	4.3	84.7	31.6	0.0	8.9	3.2	29.34
24–31 Dec	21.5	2.4	67.1	31.9	0.0	5.9	2.6	39.23
01–07 Jan	20.7	1.2	85.1	35.4	0.0	8.4	3.9	43.11
08–14 Jan	21.9	3.1	80.6	37.0	0.0	7.2	3.1	48.14
15–21 Jan	20.9	2.7	80.3	29.9	0.0	8.5	4.4	50.71
22–28 Jan	20.1	2.1	81.0	39.6	0.0	5.2	3.9	51.56
29 Jan–04 Feb	25.0	5.2	73.4	37.3	0.0	7.9	3.7	54.38
05–11 Feb	29.2	10.2	69.1	27.6	0.0	9.1	5.2	42.79
12–18 Feb	31.4	7.9	59.7	20.9	0.0	9.6	4.0	35.33
19–25 Feb	34.0	13.4	63.6	18.6	0.0	9.2	4.7	29.87
26 Feb–04 March	32.7	13.9	74.0	28.9	4.0	8.7	5.3	25.17
05–11 March	33.2	13.8	66.1	25.6	0.0	8.9	4.6	22.38
12–18 March	32.9	15.8	54.7	32.0	3.4	5.1	4.4	20.44
Mean	27.0	7.2	72.8	30.1	0.5	8.1	3.9	32.92

minimum relative humidity and wind velocity exhibited a positive correlation with disease intensity. These findings underscore the critical role of weather conditions in the progression and severity of Alternaria leaf blight in isabgol (Table 2).

Effect of weather parameters on disease intensity during rabi, 2023–24: The onset of disease progression was observed during 3rd–09th December with disease intensity increasing slightly from 8.39% PDI. The recorded minimum and maximum temperatures ranged from 6.3–25.9°C,

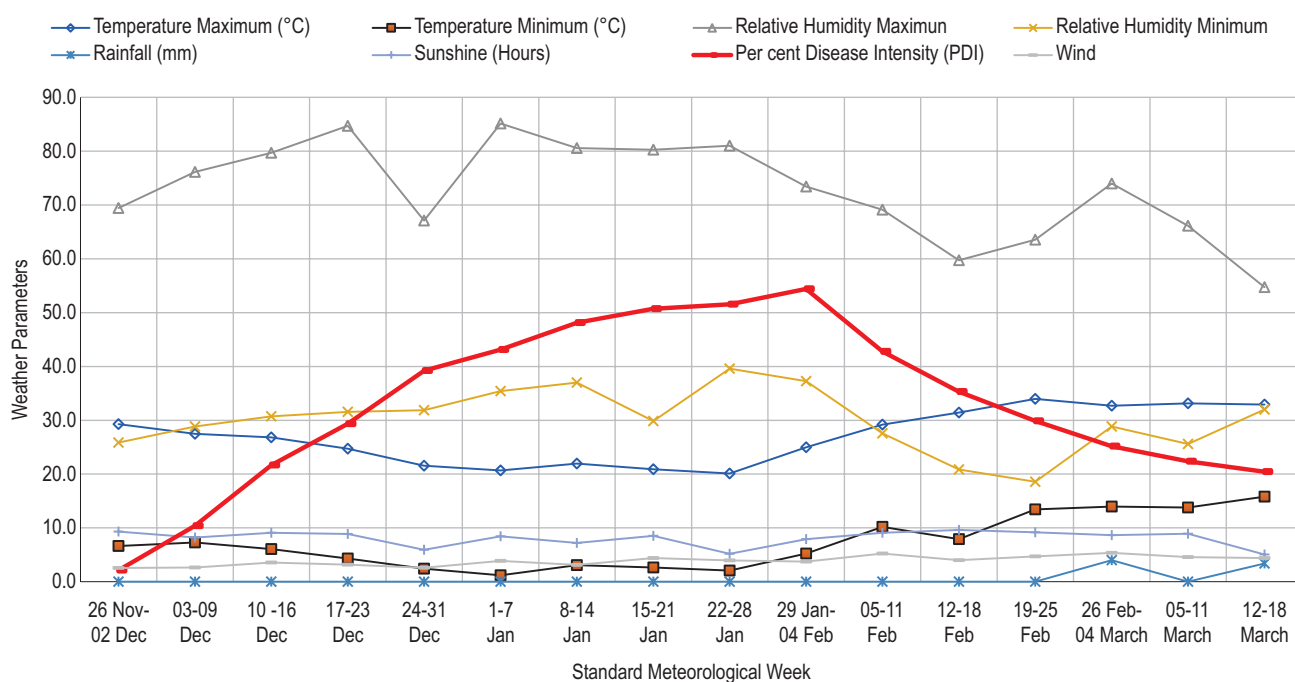
Fig. 1 Progression of Alternaria leaf blight of isabgol in relation to weather parameters under epiphytotic conditions during *rabi* 2022–23.

Table 2 Correlation matrixes and regression coefficient for Alternaria leaf blight disease per cent disease intensity progression on isabgol in relation to weather parameters under epiphytotic conditions

Season	Correlation matrixes						
	Weather parameters						
	X ₁ (°C)	X ₂ (°C)	X ₃ (%)	X ₄ (%)	X ₅ (mm)	X ₆ (h)	X ₇ (km/h)
2022–23	-0.609*	-0.497	0.319	0.504*	-0.251	-0.278	0.238
2023–24	-0.592*	-0.301	0.271	0.482	0.357	-0.668**	-0.091
Pooled	-0.540*	-0.355	0.080	0.318	-0.420	-0.277	0.110
Season	Regression coefficient						
	Weather parameters						
	X ₁ (°C)	X ₂ (°C)	X ₃ (%)	X ₄ (%)	X ₅ (mm)	X ₆ (h)	X ₇ (km/h)
Rabi 2022–23	-6.111	4.072	-0.689	-1.282	2.8288	-4.212	-0.559
Rabi 2023–24	-1.654	-1.490	-1.087	1.265	18.566	0.506	14.423
Pooled	-4.175	0.981	-0.222	-1.212	10.980	7.833	-6.334

X₁, Maximum temperature; X₂, Minimum temperature; X₃, Relative humidity (maximum); X₄, Relative humidity (minimum); X₅, Rainfall; X₆, Sunshine hours; X₇, Wind velocity. *, ** Significant at 5% and 1%, respectively.

while relative humidity fluctuated between 35.6%–89.3%, accompanied by 8.6 h of sunshine. Following this initial phase, there was a gradual increase in disease intensity. A continuous rise in disease intensity was noted, ranging from 8.39%–51.11% PDI, during the period from 3rd December to 11th February (Table 3, Fig. 2). After 11th February, the PDI began to decline.

Correlation analysis revealed significant relationships between percent disease intensity and various weather parameters. Maximum and minimum temperatures, rainfall, sunshine hours and wind velocity were found to be significantly negatively correlated with disease intensity. Conversely, maximum and minimum relative humidity showed a positive correlation with disease intensity. These

findings relate to the critical role of weather conditions in the disease progression (Table 2).

The coefficients of multiple determinations (R²) were 57.50, 86.80 and 84.50% in *rabi* 2022–23, 2023–24 and pooled, respectively, which means that 57.50–86.80% of disease intensity dependent on the weather parameters taken into consideration during both the cropping years (Table 1, 2 and 4, Supplementary Fig. 2).

$$Y = 178.127 - 6.111 X_1 + 4.072 X_2 + 0.680 X_3 - 1.287 X_4 + 2.828 X_5 - 4.212 X_6 - 0.559 X_7 \text{ (For } rabi \text{ 2022–23)}$$

$$Y = 71.424 - 1.654 X_1 - 1.490 X_2 - 1.087 X_3 + 1.265 X_4 + 18.566 X_5 + 0.506 X_6 + 14.423 X_7 \text{ (For } rabi \text{ 2023–24)}$$

$$Y = -209.689 - 4.175 X_1 + 0.981 X_2 - 0.222 X_3 - 1.212 X_4 + 10.980 X_5 + 7.833 X_6 - 6.334 X_7 \text{ (Pooled basis)}$$

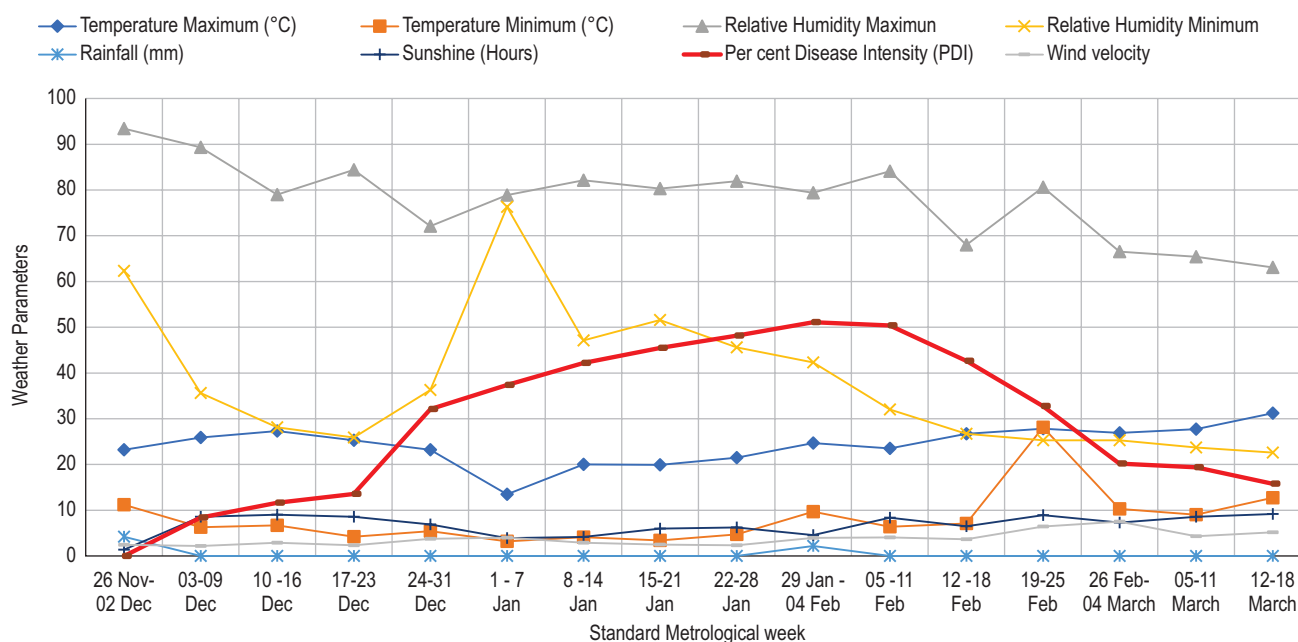


Fig. 2 Progression of Alternaria leaf blight of isabgol in relation to weather parameters under epiphytotic conditions during *rabi* 2023–24.

Table 3 Progression of Alternaria leaf blight disease of Isabgol in relation to weather parameters under epiphytotic conditions during *rabi* 2023–24

Standard meteorological week	Temperature		Relative Humidity		Rainfall	Sunshine hour	Wind velocity	Per cent Disease Intensity (PDI)
	Max	Min	Max	Min				
	X ₁	X ₂	X ₇	X ₅				
	(°C)	(°C)	(%)	(%)		(hour)	(km/hr)	
26 Nov –02 Dec	23.2	11.2	93.4	62.3	4.2	1.4	2.5	0
03–09 Dec	25.9	6.3	89.3	35.6	0	8.6	2.2	8.39
10–16 Dec	27.3	6.7	79.0	28.1	0	9.0	2.9	11.63
17–23 Dec	25.3	4.2	84.4	25.9	0	8.6	2.3	13.54
24–31 Dec	23.2	5.4	72.1	36.3	0	6.9	3.8	32.11
01–07 Jan	13.5	3.2	78.9	76.3	0	3.9	4.0	37.38
08–14 Jan	20.0	4.1	82.1	47.1	0	4.1	2.9	42.16
15–21 Jan	19.9	3.4	80.3	51.6	0	6.0	2.5	45.47
22–28 Jan	21.5	4.7	81.9	45.6	0	6.3	2.4	48.16
29 Jan–04 Feb	24.7	9.7	79.4	42.3	2.2	4.5	3.9	50.39
05–11 Feb	23.5	6.4	84.1	32.0	0	8.4	4.0	51.11
12–18 Feb	26.7	7.1	68.0	26.7	0	6.5	3.6	42.65
19–25 Feb	27.8	8.1	80.6	25.3	0	8.9	6.5	32.74
26 Feb–04 March	26.9	10.3	66.5	25.3	0	7.3	7.5	20.17
05–11 March	27.7	9.0	65.4	23.7	0	8.5	4.3	19.38
12–18 March	31.2	12.7	63.1	22.6	0	9.2	5.2	15.77
Mean	24.26	7.03	78.03	37.91	0.4	6.8	3.8	29.4

Table 4 Progression of Alternaria leaf blight disease of isabgol in relation to weather parameters under epiphytotic conditions (Pooled basis)

Standard meteorological week	Temperature		Relative humidity		Rainfall	Sunshine hour	Wind velocity	Per cent Disease Intensity (PDI)
	Max	Min	Max	Min				
	X ₁	X ₂	X ₃	X ₄				
	(°C)	(°C)	(mm)	(%)		(h)	(km/h)	
26 Nov–02 Dec	26.2	8.9	81.4	44.1	2.1	5.4	2.5	1.08
03–09 Dec	26.7	6.8	82.7	32.2	0.0	8.4	2.4	9.39
10–16 Dec	27.1	6.4	79.4	29.4	0.0	9.1	3.2	16.65
17–23 Dec	25.0	4.3	84.6	28.7	0.0	8.7	2.8	21.44
24–31 Dec	22.4	3.9	69.6	34.1	0.0	6.4	3.2	35.67
01–07 Jan	17.1	2.2	82.0	55.9	0.0	6.2	3.9	42.25
8–14 Jan	21.0	3.6	81.3	42.1	0.0	5.7	3.0	45.15
15–21 Jan	20.4	3.0	80.3	40.7	0.0	7.3	3.4	48.09
22–28 Jan	20.8	3.4	81.5	42.6	0.0	5.7	3.2	49.86
29 Jan–04 Feb	24.8	7.5	76.4	39.8	1.1	6.2	3.8	52.75
05–11 Feb	26.3	8.3	76.6	29.8	0.0	8.7	4.6	46.59
12–18 Feb	29.1	7.5	63.9	23.8	0.0	8.0	3.8	38.99
19–25 Feb	30.9	10.8	72.1	21.9	0.0	9.0	5.6	31.31
26 Feb–04 March	29.8	12.1	70.3	27.1	2.0	8.0	6.4	22.67
05–11 March	30.4	11.4	65.8	24.6	0.0	8.7	4.5	20.88
12–18 March	32.1	14.2	58.9	27.3	1.7	7.1	4.8	18.11
Mean	25.6	7.1	75.4	34.0	0.4	7.4	3.8	31.30

The analysis of independent variables individually and in combinations reported that every weather factor played a major role in *Alternaria* leaf blight disease development in Isabgol. Overall, our findings underscore the significant influence of weather conditions, particularly temperature, humidity, rainfall, sunshine hours and wind velocity on the development of the disease. Understanding these relationships can aid in the development of effective disease management strategies tailored to specific weather conditions encountered during different cropping seasons.

The analysis of all independent variables individually and in combinations reported that every weather factor played a major role in *Alternaria* leaf blight disease development in Isabgol. The findings are consistent with the results obtained by previous researchers. Gemawat and Prasad (1971) also found that prolonged exposure to high humidity (90% and above) for approximately three days, along with temperatures ranging between 23–28°C, as well as factors such as rainfall, sunshine hours, and wind speed, significantly influence the onset of cumin blight caused by *A. burnsii*. Sharma and Pandey (2013) have observed that optimal conditions for the development of cumin blight include maximum temperatures ranging between 29–35.5°C, minimum temperatures between 9.6–19.7°C, average relative humidity exceeding 60% in the morning and over 28% in the afternoon, wind speeds of 2.1–4.8 km/h, and ample bright sunshine hours. Singh and Shukla (1986) have pointed out that *Alternaria alternata* thrives in temperatures ranging from 28.7–32.2°C and relative humidity levels of 74%.

The study carried out during two winter (*rabi*) seasons of 2022–23 and 2023–24 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan investigated the impact of weather parameters on *Alternaria* leaf blight disease intensity in isabgol during the *rabi* seasons of 2022–23 and 2023–24. Correlation analysis revealed significant negative correlations between disease intensity and maximum and minimum temperatures, rainfall, and sunshine hour, while positive correlations were found with maximum and minimum relative humidity and wind velocity. Rainfall showed a positive correlation with disease intensity in 2023–24 but negative correlations in 2022–23 and overall. Multiple regression analysis confirmed the influence of weather parameters on disease development across both cropping years.

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