

**MID-OCTOBER SOWING: AN ECO-FRIENDLY STRATEGY FOR MANAGING
ALTERNARIA BLIGHT AND IMPROVING YIELD IN RAPESEED (*Brassica napus* L.)
UNDER NAWALPUR, SARLAHI CONDITIONS OF NEPAL**

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ABSTRACT

Alternaria blight, caused by *Alternaria* spp., is a major constrain to rapeseed production and often leads to reliance on chemical pesticides, which may cause health and environmental problems. A two-year field study (2023-2024) was conducted under natural epiphytotic conditions at the Oilseed Research Program, Sarlahi, Nepal to evaluate sowing date adjustment as an eco-friendly approach for disease and yield management. The experiment was conducted in a randomized complete block design using rapeseed variety Nawalpur Tori-4 and nine sowing dates from mid-September to mid-November. Disease scores and yield attributes were recorded and analyzed. Sowing date significantly affected disease severity and grain yield. Sowing on October 15 resulted in the lowest percent disease index (PDI, 28%) and the highest grain yield (1424.50 kg/ha), followed by October 23 (32% PDI and grain yield 1319.17 kg/ha). Early sowing in September resulted in lower disease severity but comparatively lower yield (1165 kg/ha), whereas late sowing from late October to November resulted in severe disease severity and reduced yield (841.67 kg/ha). Regression analysis showed that weather conditions 35 days after sowing explained 90% of the variation in disease severity. Higher temperature and relative humidity during this critical period increased disease severity ($p < 0.01$). Mid-October sowing therefore offers an effective strategy for reducing *Alternaria* blight and improving yield without fungicides.

Keywords: Crop growth, disease management, epidemiology, weather variables, yield optimization

INTRODUCTION

Rapeseed (*Brassica napus* L.) is a vital oilseed crop in Nepal and plays a significant role in edible oil production, food security, and rural livelihoods (Subedi, 2023). However, its productivity is greatly affected by several biotic stresses, among which diseases and insect pests are major constraints. *Alternaria* blight, caused primarily by *Alternaria brassicae* and *A. brassicicola*, is a destructive disease of rapeseed globally, including Nepal (Saharan & Chand, 1988). Under Nepalese conditions, the disease can cause yield losses ranging from 32% to 57% (Shrestha et al., 2010). In addition to reducing yield, *Alternaria* blight detrimentally affects seed size, seed colour, and oil content (Singh et al., 2013). Seed infection alone may reduce oil yield by 15-36% (Ansari et al., 1989).

The development and spread of *Alternaria* blight are strongly influenced by environmental conditions, particularly temperature and humidity during critical crop growth stages (Shrestha et al., 2010; Uloth et al., 2018). Management of the disease largely depends on chemical fungicides. Although fungicides may provide effective control, their repeated use increases production costs and poses hazards to human health and the environment, including soil degradation, water pollution, and loss of biodiversity, particularly beneficial organisms (Subedi et al., 2025; Lamichhane et al., 2016). Furthermore, climate change is expected to intensify disease pressure by creating environmental conditions favourable for pathogen development and disease outbreaks (Chapman et al., 2012). Therefore, sole reliance on chemical control is becoming increasingly unsustainable.

In this context, the development of eco-friendly, climate-resilient disease management strategies is therefore imperative. Adjustment of sowing date is a promising, low-cost, and non-chemical approach that can modify the crop microclimate and disrupt the disease cycle. Sowing the crop at a time less favourable for pathogen development during critical infection periods can substantially reduce disease severity (Dixon, 1981; Meena et al., 2020). Although the importance of sowing time has been recognized, the optimum sowing window for effective management of *Alternaria* blight and improved rapeseed yield under the subtropical conditions of Nepal has not been adequately quantified. Moreover, limited information is available on the relationship between local weather conditions during critical crop stages and disease development.

This study was conducted to evaluate the effect of different sowing dates on *Alternaria* blight severity and yield performance of rapeseed under field conditions. We hypothesize that strategically timed sowing can synchronize the crop's most vulnerable period with weather conditions less conducive for *Alternaria* blight development. The study also aimed to develop a predictive model linking major agro-climatic factors with disease progression. Based on field observations and model analysis, the study sought to identify an appropriate sowing window that could minimize disease and maximize yield through a sustainable and chemical-free management approach for Nepalese farmers.

MATERIALS AND METHODS

Experimental site and design

The study was conducted at the Oilseed Research Programme (ORP), Sarlahi, Nepal (27.03°N, 85.35°E; 144 m elevation) during the winter seasons of 2023 and 2024. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Nine sowing dates at 7-day intervals, from September 17 to November 13, were included as treatments. The recently released rapeseed cultivar Nawalpur Tori-4, which is susceptible to *Alternaria* blight, was used in the study. Each plot measured 2 m × 3 m, and seeds were sown at a spacing of 30 cm × 5 cm. Recommended agronomic practices (ORP, 2022) were followed uniformly in all plots, including fertilizer application at the rate of 80:40:20 kg/ha N:P₂O₅:K₂O, irrigation, and hand weeding, to minimize the influence of non-treatment factors.

Disease assessment

Disease scoring was done once during the late flowering to pod-filling stage when *Alternaria* blight symptoms were well developed across all sowing date treatments. Five plants were randomly selected and tagged from each plot for disease scoring using a 0-5 scale (Conn et al., 1990) (Table 1). The percent disease index (PDI) was calculated following the method of Wheeler (1969) as follows:

$$\text{PDI} = \frac{\Sigma (\text{Individual plant ratings})}{\text{Number of plants examined} \times \text{Maximum disease scale}} \times 100$$

Table 1. Rating scale for *Alternaria* blight severity

Rating	Symptom description	Reaction category
0	No visible symptoms	HR (Highly resistant)
1	1–10% leaf/pod area with pinhead spots	R (Resistant)
2	11–25% leaf/pod area with small spots	MR (Moderately resistant)
3	26–50% leaf/pod area with coalescing spots	MS (Moderately susceptible)
4	51–75% leaf/pod area with coalescing lesions	S (Susceptible)
5	76–100% leaf/pod area with blighting	HS (Highly susceptible)

Yield and yield attributing traits, including days to flowering, days to maturity, plant height (cm), number of siliquae per plant, number of seeds per siliqua, grain yield (kg/ha), and thousand-seed weight (g) were recorded. These parameters were used to assess the effect of disease severity on crop performance and yield.

Weather-based disease modeling

A multiple linear regression model was developed to determine the relationship between weather variables and percent disease index (PDI) during the critical 35 days post-sowing. In the model, average PDI for each sowing date was considered as the dependent variable, daily maximum temperature (°C), daily minimum temperature (°C), and daily relative humidity (%) during the 35-day post-sowing period were used as independent variables. Meteorological data were obtained from the Department of Hydrology and Meteorological (DHM).

The regression model was expressed as:

$$\text{PDI} = \beta_0 + \beta_1 (\text{Avg. Max Temp}) + \beta_2 (\text{Avg. Min Temp}) + \beta_3 (\text{Avg. RH}) + \epsilon$$

Where, β_0 = intercept, β_1 – β_3 = coefficients, and ϵ = error term.

Statistical analysis

Data were analyzed using Microsoft Excel 2021 and GENSTAT 18th edition. Analysis of variance (ANOVA) was performed to determine the significance of treatment effects. Regression coefficients and model diagnostic parameters, including coefficient of determination (R^2), adjusted R^2 , standard

error, and root mean square error (RMSE) were computed. Pearson's correlation was performed to examine the relationship between PDI and grain yield. Significance was determined at $p \leq 0.05$.

RESULTS

During 2023, at the Oilseed Research Programme, Sarlahi, sowing date had a significant effect ($p < 0.001$) on percent disease index (PDI), plant growth, and yield parameters of rapeseed. Earlier sowings from mid-September to early October resulted in lower disease severity with PDI ranging from 20% to 28%, and percent disease control (PDC) ranging from 65% to 75%. However, these sowings produced comparatively lower grain yields (1132-1232 kg/ha).

October 15 sowing produced the highest grain yield (1434 kg/ha) with a moderate PDI (28%). This sowing date also produced the tallest plants (119.5 cm), highest number of siliquae per plant (166), highest number of seeds per silique (17), longest silique length (5 cm), and higher thousand-seed weight (4 g). In contrast, late sowings from late October onwards showed progressively higher disease severity, with PDI increasing up to 80% and PDC decreasing to 25%, along markedly reduced growth and yield attributes (Table 2). The results showed that mid-October was the optimal sowing period for maximizing yield while minimizing disease severity during 2023.

Table 2. Effect of sowing dates on Alternaria blight severity, yield and yield-attributing traits of rapeseed at the Oilseeds Research Programme, Nawalpur, Sarlahi, Nepal during 2023

Sowing dates	FL_D	Mat_D	Pht (cm)	Sil/PL	S/Sil	Sil_L (cm)	PDI%	GY (kg/ha)	TSW (g)	PDC %	YI%
September 17	26	83	101	100	12	4	20	1132	3	75	31
September 24	29	85	106	102	12	5	24	1193	4	70	38
October 1	29	87	112	115	13	5	27	1205	4	67	40
October 8	29	90	116	128	13	5	28	1232	4	65	43
October 15	32	96	119	166	17	5	28	1434	4	65	66
October 22	37	101	113	142	13	5	32	1335	4	60	55
October 29	43	105	91	90	10	4	44	1096	3	45	27
November 6	57	109	83	45	8	4	60	913	2	25	6
November 13	59	112	68	25	6	4	80	863	2		
Grand mean	38	96	101	101	11	5	38	1156	3		
Min.	26	83	68	25	6	4	20	863	2		
Max.	59	112	119	166	17	5	80	1434	4		
P-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001		
LSD (0.05)	3.03	3.06	4.08	3.99	0.45	0.19	3.53	16.13	0.14		
CV %	4.60	1.80	2.30	2.30	2.30	2.40	5.30	0.80	2.40		

FL_D - Days to 50% flowering, Mat_D - Days to 75% maturity, Pht - Plant height, Sil/PL - Number of siliquae per plant, S/Sil - Number of seeds per silique, Sil_L - Silique length, GY - Grain yield, TSW - Thousand seed weight, PDI - Percent disease index, PDC - Percent disease control, YI - Yield increase

Similarly, during 2024, showing date significant affected ($p < 0.001$) all disease, plant growth, and yield parameters. The results followed a trend similar to that observed in 2023. Sowing on October 15 produced the highest grain yield (1415 kg/ha) along with superior growth and yield attributes, including tallest plants (117 cm), highest number of siliquae per plant (161), highest number of seeds per siliqua (16), longest siliqua length (5 cm), and highest thousand-seed weight (4 g). Disease severity remained at a moderate level (28% PDI and 65% PDC).

Table 3. Effect of sowing dates on *Alternaria* blight severity, yield and yield-attributing traits of rapeseed at Oilseeds Research Programme, Nawalpur, Sarlahi, Nepal during 2024

Sowing dates	FL D	Mat D	Pht (cm)	Sil /PL	S /Sil	Sil_L (cm)	PDI %	GY (kg/ha)	TSW (g)	PDC %	YI %
September 17	25	80	99	97	12	4	20	1062	3	75	29
September 24	28	83	104	100	12	4	24	1077	3	70	31
October 1	28	85	109	112	12	5	28	1182	4	65	44
October 8	29	89	111	123	13	5	28	1203	4	65	47
October 15	30	93	117	161	16	5	28	1415	4	65	73
October 22	35	98	109	135	13	5	32	1303	4	60	59
October 29	42	103	88	87	10	4	48	1078	3	40	32
November 6	56	106	79	42	8	4	66	867	2	18	6
November 13	58	109	66	24	5	4	80	820	2		
Grand mean	37	94	98	98	11	4	39	1112	3		
Minimum	25	80	66	24	5	4	20	820	2		
Maximum	58	109	117	161	16	5	80	1415	4		
P-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	
LSD (0.05)	2.09	2.10	2.15	4.02	0.36	0.12	2.31	17.30	0.10		
CV %	3.30	1.30	1.30	2.40	1.90	1.50	3.40	0.90	1.70		

FLD - Days to 50% flowering, Mat_D - Days to 75% maturity, Pht - Plant height, Sil/PL – Number of siliquae per plant, S/Sil – Number of seeds per siliqua, Sil_L - Siliqua length, GY - Grain yield, TSW - Thousand seed weight, PDI - Percent disease index, PDC - Percent disease control, YI - Yield increase

Earlier sowings from mid-September to early October) resulted in relatively lower disease severity (20-28% PDI, 65-75% PDC), but produced lower grain yields (1062-1203 kg/ha). Late sowings from late October to November gave progressively higher disease severity with PDI reaching up to 80%, PDC decreasing to 18%, resulting in substantially reduced growth and yield components. The lowest grain yield (820 kg/ha) was recorded in the November 13 sowing (Table 3). These findings further confirmed that mid-October was the optimum sowing period for reducing disease severity and maximizing rapeseed yield under the conditions of Sarlahi in 2024. The combined analysis of 2023 and 2024 showed that sowing date had a highly significant effect ($p < 0.001$) on disease severity, plant growth, and yield parameters. Among the tested sowing dates, October 15 consistently produced the highest grain yield (1424.50 kg/ha), along with optimum plant height (118.01 cm),

number of siliquae per plant (163.33), highest number of seeds per silique (16.56), longest silique length (5.46 cm), and highest thousand-seed weight (3.90 g). Disease severity at this sowing date remained moderate, with 28 % PDI and 65% PDC (Table 4).

Both earlier sowings in September and late sowing in late October and November resulted in lower yields and poorer growth performance, accompanied by increased disease severity, with PDI reaching up to 80%. Significant variations ($p < 0.05$) between years were also observed. In general, the 2023 season had slightly higher growth and yield values, including mean grain yield (1156 kg/ha), compared to 2024 (1112 kg/ha), while disease pressure was comparatively lower (mean PDI 38.07%) in 2023 than in 2024 (mean PDI 39.33%). The interaction effect between sowing date and year was non-significant ($p > 0.05$) for all parameters except grain yield ($p < 0.001$), indicating that the performance of optimum sowing dates remained stable across years despite annual variation in yield levels (Table 4). These results confirm mid-October as a reliable sowing window for minimizing *Alternaria* blight and maximizing rapeseed productivity under Sarlahi conditions.

The relationship between *Alternaria* blight severity (PDI) and grain yield showed a strong negative linear trend (Fig. 1). The regression equation: $Y = -7.0293x + 1406$ indicated that for every 1% increase in PDI, grain yield decreased by approximately 7.03 kg/ha. The coefficient of determination ($R^2 = 0.60$) showed that disease severity explained 60% of the variation in grain yield. Under field conditions, where PDI ranged from 20 to 80, grain yield declined substantially with increasing disease severity. Overall, *Alternaria* blight caused an estimated yield reduction of about 421 kg/ha within this disease range).

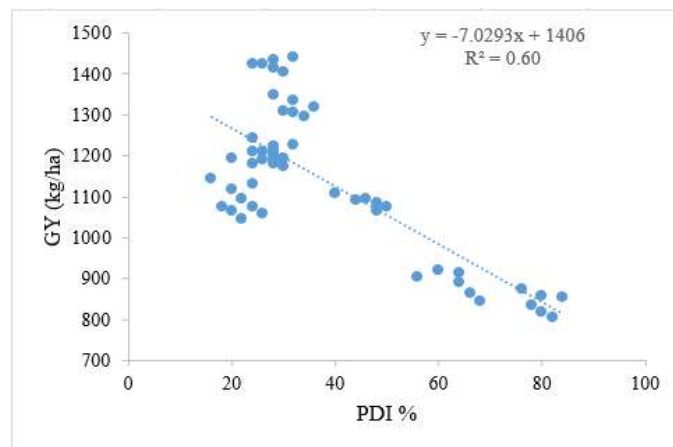


Fig. 1. Relationship between *Alternaria* blight disease index (PDI) and grain yield (kg/ha) of rapeseed sown on different dates, Nawalpur, Sarlahi, Nepal during 2023 and 2024.

Table 4. Sowing dates × year interaction effect on *Alternaria* blight severity, yield and yield-attributing traits of rapeseed at the Oilseeds Research Programme, Nawalpur, Sarlahi, Nepal during 2023 and 2024

Treatments	Fl D	Mat D	Pht (cm)	Sil /Pl	S /Sil	Sil_L (cm)	PDI %	GY (kg/ha)	TSW (g)	PDC %	YI%
Sowing dates											
September 17	25.50	81.33	100.12	98.63	11.69	4.37	20.00	1097.00	3.23	75.00	30.34
September 24	28.33	84.17	105.18	100.95	12.08	4.51	24.00	1135.00	3.49	70.00	34.85
October 1	28.17	85.67	110.82	113.57	12.54	4.61	27.33	1193.33	3.72	65.83	41.78
October 8	28.83	89.83	113.69	125.49	12.88	4.84	28.00	1217.83	3.76	65.00	44.69
October 15	31.33	94.33	118.01	163.33	16.56	5.46	28.00	1424.50	3.90	65.00	69.25
October 22	35.83	99.50	110.90	138.72	12.97	4.85	32.00	1319.17	3.78	60.00	56.73
October 29	42.67	103.83	89.85	88.72	9.97	4.18	46.00	1087.00	3.07	42.50	29.15
November 6	56.33	107.17	81.00	43.12	7.92	3.94	63.00	889.67	2.36	21.25	5.70
November 13	58.33	110.50	67.14	24.58	5.47	3.58	80.00	841.67	2.20		
Grand mean	37.26	95.15	99.63	99.68	11.34	4.48	38.70	1133.91	3.28		
P-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001		
LSD (0.05)	1.77	1.79	2.48	2.93	0.289	0.109	2.39	11.53	0.08		
Year											
2023	37.89	96.33	101.16	101.48	11.50	4.53	38.07	1155.96	3.32		
2024	36.63	93.96	98.11	97.88	11.19	4.43	39.33	1111.85	3.24		
Grand mean	37.26	95.15	99.63	99.68	11.34	4.48	38.70	1133.91	3.28		
P-value	0.004	<.001	<.001	<.001	<.001	<.001	0.03	<.001	<.001		
LSD (0.05)	0.83	0.84	1.17	1.38	0.1363	0.05	1.13	5.44	0.04		
Year × Sowing dates											
2023 × Sep. 17	26.00	82.67	101.32	100.21	11.81	4.41	20.00	1132.33	3.27		
2023 × Sep. 24	28.67	85.33	106.05	102.04	12.13	4.53	24.00	1193.33	3.50		
2023 × Oct. 1	28.67	86.67	112.18	115.23	12.64	4.64	26.67	1205.00	3.77		
2023 × Oct. 8	29.00	90.33	115.95	128.00	13.12	4.88	28.00	1232.33	3.83		
2023 × Oct. 15	32.33	95.67	119.50	165.72	16.76	5.48	28.00	1434.00	3.94		
2023 × Oct. 22	37.00	100.67	113.18	142.26	13.24	4.95	32.00	1335.00	3.86		
2023 × Oct. 29	43.33	105.00	91.33	90.18	10.07	4.21	44.00	1095.67	3.09		
2023 × Nov. 6	57.00	108.67	82.82	44.72	8.16	4.03	60.00	912.67	2.40		
2023 × Nov. 13	59.00	112.00	68.12	24.93	5.56	3.62	80.00	863.33	2.24		
2024 × Sep. 17	25.00	80.00	98.92	97.06	11.57	4.32	20.00	1061.67	3.20		
2024 × Sep. 24	28.00	83.00	104.31	99.86	12.04	4.49	24.00	1076.67	3.47		

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Treatments	Fl D	Mat D	Pht (cm)	Sil /Pl	S /Sil	Sil_L (cm)	PDI %	GY (kg/ha)	TSW (g)	PDC %	YI%
2024 × Oct. 1	27.67	84.67	109.45	111.90	12.43	4.58	28.00	1181.67	3.68		
2024 × Oct. 8	28.67	89.33	111.44	122.97	12.64	4.79	28.00	1203.33	3.69		
2024 × Oct. 15	30.33	93.00	116.53	160.94	16.37	5.43	28.00	1415.00	3.86		
2024 × Oct. 22	34.67	98.33	108.63	135.18	12.70	4.75	32.00	1303.33	3.70		
2024 × Oct. 29	42.00	102.67	88.38	87.26	9.88	4.15	48.00	1078.33	3.05		
2024 × Nov. 6	55.67	105.67	79.17	41.52	7.67	3.85	66.00	866.67	2.32		
2024 × Nov. 13	57.67	109.00	66.16	24.23	5.38	3.53	80.00	820.00	2.16		
Grand mean	37.26	95.15	99.63	99.68	11.34	4.48	38.70	1133.91	3.28		
Minimum	25.00	80.00	66.16	24.23	5.38	3.53	20.00	820.00	2.16		
Maximum	59.00	112.00	119.50	165.72	16.76	5.48	80.00	1434.00	3.94		
P-value	0.98	0.98	0.94	0.598	0.72	0.81	0.12	<.001	0.84		
LSD (0.05)	2.50	2.53	3.51	4.14	0.4088	0.15	3.38	16.31	0.12		
CV, %	4.00	1.60	2.10	2.50	2.20	2.10	5.30	0.90	2.20		

FLD - Days to 50% flowering, Mat_D - Days to 75% maturity, Pht - Plant height, Sil/PL - Number of siliquae per plant, S/Sil - Number of seeds per siliqua, Sil_L - Siliqua length, GY - Grain yield, TSW - Thousand seed weight, PDI - Percent disease index, PDC - Percent disease control, YI - Yield increase

Disease severity prediction model

The developed prediction model for disease severity was:

$$\text{PDI} = -160.28 - 4.38 \times (\text{Average maximum temperature}) - 5.44 \times (\text{Average minimum temperature}) + 5.28 \times (\text{Average relative humidity}).$$

The regression model showed that relative humidity had a significant positive effect on disease severity, whereas maximum and minimum temperatures were negatively associated with PDI. The coefficient estimates indicated that an increase in maximum temperatures (coefficient = -4.38, $p = 0.05^*$) and minimum temperatures (coefficient = -5.44, $p = 0.002$) was associated with a reduction in disease severity. In contrast, relative humidity had a significant positive effect on disease development (coefficient = +5.28, $p = 0.006$), indicating that higher humidity levels increased disease severity (Table 5). The model uses maximum temperature, minimum temperature, and relative humidity as predictor variables for estimating PDI. It showed a high level of accuracy with an adjusted R^2 value of 0.91, root mean square error (RMSE) value is 6.25 and residual standard error is 6.21 ($n=54$).

The overall model was highly significant ($p < 0.001$), indicating that at least one of the predictor variables contributed significantly to the prediction of disease severity. An adjusted R^2 value of 0.89 further indicated that the approximately 89% of the variance in PDI was explained by the weather variables included in the model (Fig. 2).

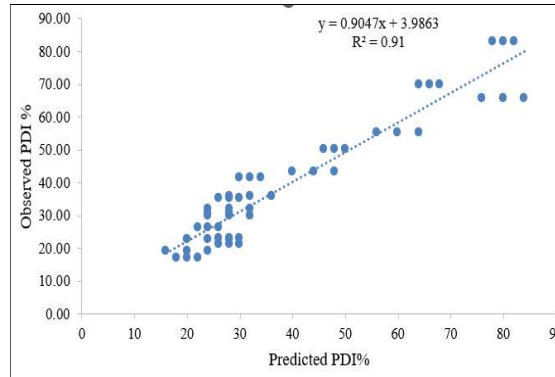


Fig. 2. Observed versus predicted PDI of rapeseed *Alternaria* blight as influenced by meteorological factors under different sowing dates, Nawalpur, Sarlahi, Nepal during 2023 and 2024.

Weather parameters

The weather data represent the average climatic conditions recorded during the crop growth period for different rapeseed sowing dates during the 2023 and 2024 growing seasons. The parameters evaluated included total rainfall (RF), average maximum temperature, average minimum temperature, and average relative humidity (RH).

The graphical representation (Fig. 3) illustrated clear trends across sowing dates. Both maximum and minimum temperatures declined progressively with delayed sowing; rainfall decreased sharply after early October, and relative humidity showed a gradual reduction over successive sowing windows.

Table 5. Summary output of the regression model of rapeseed *Alternaria* blight by linking sowing-date-driven microclimatic variations to disease progression

Regression Statistics	
Multiple R	0.951
R Square	0.905
Adjusted R Square	0.899
Standard Error	6.212
Observations	54

ANOVA

	df	SS	MS	F	Significance F
Regression	3	18399.58	6133.19	158.92	1.483E-25
Residual	50	1929.68	38.59		
Total	53	20329.26			

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	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-160.28	183.56	-0.87	0.39	-528.97	208.40
avgMaxTemp (°C)	-4.38	2.22	-1.97	0.05 *	-8.85	0.09
avgMinTemp (°C)	-5.44	1.74	-3.12	0.002**	-8.95	-1.94
avgRH (%)	5.28	1.84	2.87	0.006**	1.58	8.97

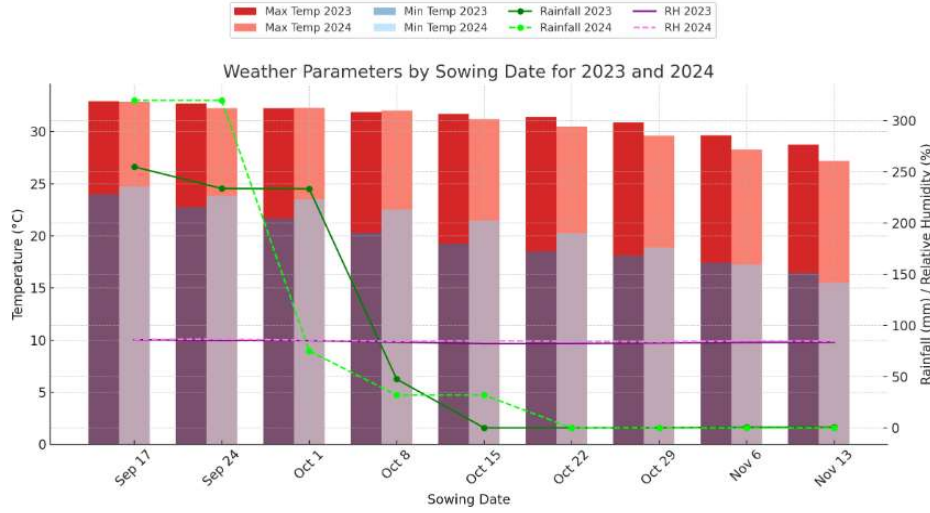


Fig. 3. Weather parameters (average maximum temperature, °C; average minimum temperature, °C; total rainfall, mm; and average relative humidity, %) recorded during the 35-day period after sowing under different sowing dates, Nawalpur, Sarlahi during 2023 and 2024.

Total rainfall showed a marked decline with delayed sowing. Crops sown on 17 September and 24 September received the highest rainfall, averaging 287.24 mm and 276.64 mm, respectively. Rainfall decreased considerably with later sowing, reaching 154.18 mm for 1 October, 39.76 mm for 8 October, and only 16.00 mm for 15 October. There was almost no rainfall from 22 October onward, indicating that later-sown crops experienced much drier conditions during the early stages of growth. Average maximum temperature gradually decreased from 32.90 °C for the 17 September sowing to 27.97 °C for the mid-November sowing, reflecting the transition from late monsoon to early winter conditions. Similarly, average minimum temperature declined from 24.36 °C in mid-September to 15.96 °C by November, indicating progressively cooler night temperatures with delayed planting. Relative humidity remained high during the September sowings (86.16-85.95%), but gradually declined to approximately 83-84% during October and November sowings.

DISCUSSION

The present study demonstrates that sowing date induced microclimatic variation strongly influences the development of *Alternaria* blight in rapeseed, particularly during the early crop growth stages. The weather data indicated that early sowing periods experienced higher rainfall, relatively warm temperatures, and elevated relative humidity, conditions that are generally favourable for the survival and spread of *Alternaria brassicae*. The pathogen is known to perpetuate through seeds, infected plant debris, soil, and weed hosts, enabling continuous inoculum availability within the cropping environment (Ansari et al., 1989). Initial infection typically appears on cotyledonary leaves, from which the disease progresses to other plant parts (Humpherson-Jones and Maude, 1983). Subsequent lesions on foliar tissues produce abundant sporulation, which acts as a source of secondary infection and facilitates rapid disease spread within the crop canopy (Kolte, 1985).

The biology of the pathogen further explains its strong dependence on prevailing weather conditions. *Alternaria* species produce conidia that readily germinate in the presence of moisture, forming germ tubes from any cell and initiating infection under favorable conditions. High atmospheric humidity plays a crucial role in pathogen development; sporulation of *A. brassicae* and *A. brassicicola* requires relative humidity levels of 91.5% and 87%, respectively. Moreover, successful infection requires free water combined with optimum temperatures of approximately 15 °C for *A. brassicae* and 25 °C for *A. brassicicola* (Humpherson-Jones and Maude, 1983). Previous studies have also indicated that the optimum temperature for sporulation ranges from 18-24 °C, while temperatures above 24 °C inhibit sporulation in *A. brassicae*. Similarly, Mehta (2014) reported that maximum temperatures of 20-25 °C, minimum temperatures around 15°C, morning relative humidity above 90%, and evening humidity above 70% create highly conducive conditions for *Alternaria* blight development.

The prediction model suggests that the period around 35 days post-sowing is critical for disease development. However, the most suitable sowing window may vary across locations in Nepal, and further studies are required to determine the effects of such adjustments on disease reduction and yield improvement. Early sowing dates were characterized by higher rainfall, warmer temperatures, and higher humidity, creating a more humid microclimate, whereas later sowing dates experienced cooler and relatively drier conditions. When these weather patterns are considered together with disease development, sowing during October to early November generally exposed the crop to lower rainfall, cooler temperatures, and slightly lower humidity levels. These conditions are likely to be less favorable for pathogen development and disease spread, resulting in reduced disease severity. Consequently, crops sown during this period may maintain healthier foliage and achieve higher grain yield, provided that sowing is not delayed excessively and the crop growth period is not substantially shortened.

These environmental requirements support the observed relationship between temperature, humidity, and disease severity, where favorable moisture conditions and moderate temperatures enhance pathogen establishment and disease progression. The pathogen infects all green tissues of the plant and may reach the seeds through pod infection, further contributing to disease persistence and potential yield loss (Kavita et al., 2013). The influence of sowing date on disease severity observed in this study is consistent with earlier findings. Wagle et al. (2024) reported that early sowing on 7 October resulted in lower *Alternaria* blight severity and higher yield, indicating that appropriate

adjustment of sowing time can help avoid highly favorable environmental conditions for the pathogen. Similarly, Singh et al. (2013) observed that *Alternaria* blight severity on leaves tends to be higher under late-sown conditions, although the trend may differ for pod infection where earlier sowing sometimes increases pod blight incidence.

The implications of *Alternaria* blight on crop productivity are important. Previous reports have indicated yield losses ranging from 32% to 57% in rapeseed due to *Alternaria* blight, highlighting the economic significance of this disease in oilseed production systems (Shrestha et al., 2010). Therefore, adjusting sowing dates to escape highly favorable environmental conditions for the pathogen represents an important cultural management strategy. Such agronomic interventions can help reduce disease severity and protect yield potential, particularly under the subtropical climatic conditions prevalent in rapeseed-growing regions of Nepal.

CONCLUSIONS

The study identified mid-October (15-20 October) as the optimal sowing window for rapeseed in Nepal, minimizing *Alternaria* blight severity (PDI 25-30%) while achieving higher grain yield (1425 kg/ha). The developed disease simulation model ($R^2 = 0.89$) demonstrated a strong relationship between weather variables and disease progression, providing a reliable basis for predictive disease management. Adjusting sowing time can therefore reduce reliance on chemical control measures, thereby lowering environmental risks and production costs. Future research should focus on validating the model across multiple locations and agro-ecological zones of Nepal, integrating weather-based disease risk forecasting, and evaluating cultivar-specific sowing windows to develop region-specific management strategies for sustainable rapeseed production.

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REFERENCES

- Ansari, N.A., Khan, M.W., & Muheet, A. (1989). Survival and perpetuation of *Alternaria brassicae* causing *Alternaria* blight of crucifers. *Mycopathologia*, 105, 67-70.
- Conn, K.L., Tewari, J.P., & Awasthi, R.P. (1990). A disease assessment key for *Alternaria* black spot in rapeseed and mustard. *Canadian Plant Disease Survey*, 70, 19-22.
- Chapman, S.C., Chakraborty, S., Dreccer, M.F., & Howden, S.M. 2012. Plant adaptation to climate change-opportunities and priorities in breeding. *Crop & Pasture Science*, 63, 251.
- Dixon, G. R. (1981). Pathogens of crucifer crops. In *Vegetable crop diseases*. Westport, CT: AVI Publishing Company. pp. 119-123.

- Humpherson-Jones, F.M., & Maude, R.B. (1983). The seed borne source of *Alternaria brassicae* and *Leptosphaeria maculans* in oilseed rape in the United Kingdom: Prospects for control. In *Proceedings of the 6th International Rapeseed Conference*. Groupe Consultatif International de Recherche sur le Colza, France. Vol. 2. pp. 916-921.
- Kavita, H.K., Singh, H.K., & Singh, R.B. (2013). *Survival and management of Alternaria blight in Indian mustard*. Saarbrücken, Germany: LAP LAMBERT Academic Publishing.
- Kolte, S.J. (1985). *Diseases of Annual Edible Oilseed Crops: Vol. II. Rapeseed-Mustard and Sesame Diseases*. Boca Raton, FL: CRC Press.
- Lamichhane, J.R., Dachbrodt-Saaydeh, S., Kudsk, P., & Messéan, A. (2016). Toward a reduced reliance on conventional pesticides in European agriculture. *Plant Disease*, 100(1), 10-24. <https://doi.org/10.1094/PDIS-05-15-0574-FE>
- Meena, P.D., Kumar, S.M.S., Meena, H.S., Jambhulkar, S., Taj, G., Pathak, D., Srivastava, S., Gupta, R., Singh, D., Gurung, B., & Rai, P.K. (2020). Confirmation of induced tolerance to *Alternaria* blight disease in Indian mustard (*Brassica juncea* L.). *Applied Biochemistry and Biotechnology*, 192, 965-978.
- Mehta, N. (2014). Epidemiology and forecasting for the management of rapeseed-mustard diseases. *Journal of Mycology and Plant Pathology*, 44, 131-147.
- ORP, 2022. *Annual Report 2078/79 (2021/22)*. Oilseed Research Program, Nepal Agricultural Research Council, Nawalpur, Sarlahi, Nepal.
- Saharan, G.S., & Chand, J.N. (1988). *Diseases of Oilseed Crops*. Hisar, India: Haryana Agricultural University.
- Shrestha, S.K., Munk, L., & Mathur, S.B. (2010). Role of weather on *Alternaria* leaf blight disease and its effect on yield and yield component of mustard. *Nepal Agricultural Research Journal*, 6, 62-72.
- Singh, R., Singh, D.D., & Singh, H. (2013). Variability in *Alternaria brassicae* incitant of *Alternaria* blight of oilseed brassica. *Research on Crops*, 14, 1082-1088.
- Subedi, S., Sah, S.K., Neupane, S., & Shrestha, J. (2025). Fungicidal management of *Alternaria* blight in rapeseed. *Agronomy Journal of Nepal*, 9(1), 90–94. <https://doi.org/10.3126/ajnv9i1.90918>
- Subedi, S. (2023). Research achievements, prospects and future strategies of winter oilseed crops in Nepal. In S. Shrestha et al. (Eds.), *Proceedings of the 32nd Winter Crops Workshop*. pp. 22–42. Nepal Agricultural Research Council, Kathmandu, Nepal.
- Uloth, M.B., You, M.P., & Barbetti, M.J. (2018). Plant age and ambient temperature: Significant drivers for powdery mildew (*Erysiphe cruciferarum*) epidemics on oilseed rape (*Brassica napus*). *Plant Pathology*, 67, 445-456. <https://doi.org/10.1111/ppa.12740>
- Wagle, P., Yadav, B.P., Rasaily, S., Chaudhary, A., Mishra, A., & Subedi, S. (2024). Screening of rapeseed genotypes against *Alternaria* leaf blight resistance at Nawalpur, Sarlahi. *International*

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Journal of Scientific and Research Publications, 14(1), 171-180.
<https://doi.org/10.29322/IJSRP.14.01.2024.p14515>

Wheeler, B.E.J. (1969). *An Introduction to Plant Diseases*. New York, NY: John Wiley & Sons.