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Research Article

Correlation of Sowing Dates and Weather Factors on the Infection and Severity of Alternaria Blight and White Rust of Indian Mustard (*Brassica juncia* L. Czern and Coss.) in Eastern Uttar Pradesh of India

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Abstract

India is one of the world's largest producers of oilseed crops. Among the oilseed crops of India, Indian mustard (*Brassica juncia* L.) has shared the maximum account of the edible oilseed production, which is also considered the backbone of the Indian agriculture economy. Recently the production of Indian mustard is decline due to adverse climatic conditions. Hence, the changes in climatic conditions also increase the pest attacks on the crops. The present investigation documented the correlation of weather factors on the prevalence and severity of the Alternaria blight and White rust on Indian mustard. The experiment was conducted with eight dates of sowing viz. October (1, 10, 20, and 30), November (10, 20, and 30), and December (10) of the mustard crop (var. Varuna) in the field during the Rabi season at 10 days intervals. The results revealed that the maximum severity and apparent infection rate (r) of Alternaria blight and white rust were recorded on the sixth (November, 20) and eighth (December, 10) date of sowing, respectively. Among dates of sowing, the maximum seed yield was recorded at first date of sowing (20.41 q/ha) followed by second (19.99 q/ha) and third (19.16 q/ha). Overall, our findings suggested that early-sown crops escaped the disease outbreak and give higher yields compared to late-sown crops..

Keywords: Mustard; Disease Severity; PDI; Sowing Dates; Apparent Infection Rates; Weather Factor

Abbreviations

PDI: Percent Disease Index; DAS: Days After Sowing; DOS: Date of Sowing; Mha: Million Hectare; Mta: Million Tone

Introduction

Indian mustard (*Brassica juncia* L.) is one of the major edible oilseed crops in India [1], which is cultivated throughout the Indian subcontinent and other parts of the world such as Canada, China, USA, and Brazil etc., and India had an area of 6.02 mha with a production of 7.8 mt and productivity of 1324 kg/ha [2]. Indian mustard is principally cultivated in Rajasthan, Uttar Pradesh, Haryana, Gujarat and Madhya Pradesh [3]. Currently, the production of mustard crops is declining due to various kinds of biotic and weather factors. The major biotic factors are foliar diseases i.e., Alternaria blight and white rust are considered the most damaging diseases of the mustard crop by reduction of the photosynthetic area of the plants, resulting in reduced accumulation of food. Alternaria blight caused by *Alternaria brassicae* (Berk) Sacc. and *Alternaria brassicicola* (Schwein) and white rust caused by *Albugo candida* (Pers. ex Lev.) Kuntze is widely prevalent in eastern Uttar Pradesh [4] and causes enormous losses in crop productivity.

In the initial stage of the crop, the incidence of Alternaria blight is low but at a later stage of plant growth, the progression of the disease becomes very high resulting in significant crop losses or sometimes plants will diea. Mustard crops showed heavy crop losses in terms of reduced plant height, number of primary and secondary branches, number of pods and number of seeds per pod, when

the crop got an infection at an early or before flowering stage commonly known as early blight [5]. Similarly, white rust disease may appear simultaneously with downy growth of the fungus appearing on leaves, stem and stage of heads [6]. At the present time, the disease is reported throughout the country including Uttar Pradesh, Bihar, Punjab, Haryana, Rajasthan and West Bengal etc. The association of white rust and downy mildew caused a reduction of 37-41 per cent in siliqua and 17-32 per cent in seed yield may occur [7]. Both Alternaria blight and white rust caused a reduction in seed yield, seed test weight and oil content up to 34.7, 13.1 and 4.2 per cent, respectively in Indian mustard [8]. Keeping in view the economic importance of the disease, it was necessary to investigate, to find out the effect of sowing dates and weather factors on the severity of the foliar diseases.

Materials and Methods

The experiment was conducted in the field of Genetics and Plant Breeding Farm at Narendra Deva University of Agriculture and Technology, Kumarganj Faizabad (U.P.) during the Rabi season 2021-22 with different sowing dates. Total eight sowing dates viz. Oct (1, 10, 20, and 30), Nov (10, 20, and 30), and Dec (10) of the mustard (var. Varuna) crop were taken in the field during the Rabi season at 10 days intervals. The fertilizers such as nitrogen (120 kg/ha), P_2O_5 (60 Kg/ha) and K_2O (60 Kg/ha) were applied before sowing the seed. Initially, soon after levelling the field, one-third of the nitrogen dose and the combined doses of phosphorus and potash were applied. The remaining nitrogen was applied throughout the rows in two equal portions as a top dressing. With a row-to-row and plant-to-plant spacing of 30 by 10 cm, the plot was 4 by 3 m (12 m^2). The depth of the seeds in the soil was 5 cm. The experiment was conducted in a randomized block design with three replications. The observations regarding the disease rating by table 1, per cent disease index (PDI) and infection rate [9] were calculated weekly basis by the following formula.

$$\text{PDI (\%)} = \frac{\text{Sum of all disease rating}}{\text{Number of plant observed} \times \text{Maximum disease grade}} \times 100$$

$$\text{Infection rate (r)} = \frac{2.3}{t2 - t1} \log e \frac{X2(1 - X1)}{X1(1 - X2)}$$

Where,

X_1 = Disease severity at time t_1 and

X_2 = Disease severity at time t_2

t_1 = time (days) during 1st observation

t_2 = time (days) during 2nd observation

$t_2 - t_1$ = time interval between two observations

$\log_e$ = natural log.

Rating scale (0-9)	Description of scale	Host reaction
0	No visible symptoms	Free
1	< 5% leaf area covered	Highly Resistant
3	5-10% leaf or pod area covered with small pin head spots on the leaves and superficial pinhead spots on pods	Resistant
5	11-25% leaf or pod area covered with small spots on leaf and superficial pin head spots on pods	Moderately Resistant
7	26-50% leaf or pod area covered with bigger spots with initiation of coalesces on leaves and deep lesion on pods	Moderately Susceptible
9	Profusely sporulating, rapidly coalescing brown to black spots measuring more than 6mm diameter, without margins covering more than 50% leaf area.	Highly Susceptible

Table 1: Details of rating scale used for major diseases of rapeseed mustard.

Results and Discussion

Effect of date of sowing on the severity of Alternaria blight and White rust of Indian mustard under field conditions

Alternaria blight

The disease was first appeared at 33 days after sowing and maximum disease severity was recorded on the seventh date of sowing (2.54%) and the remaining dates of sowing were not found disease symptoms. At 40 DAS, the maximum disease severity was recorded on eight dates of sowing (5.39%) followed by seventh (3.37%) and minimum on sixth (1.25%). At 47 DAS, the maximum disease severity was recorded on the eighth date of sowing (8.93%), which was at par with the seventh date of sowing (8.38%) and minimum in the fifth DAS (12.91%). At 54 DAS, the maximum disease severity was recorded on the seventh date of sowing (23.17%) followed by the sixth (18.19%) and minimum in the fourth (8.26%). At 61 DAS, the maximum disease severity was recorded on the seventh date of sowing (30.27%) followed by the sixth (25.25%) and minimum in the third (5.47%). At 68 DAS, the maximum disease severity was recorded on the seventh date of sowing (41.31%) followed by the sixth (31.49%) and minimum in the third (7.13%). At 75 DAS, the maximum disease severity was recorded on the seventh date of sowing (48.29%) followed by the sixth (47.12%) and minimum at the first (5.57%). At 82 DAS, the maximum disease severity was recorded on the sixth date of sowing (59.33%) followed by the seventh (51.37%) and minimum at (12.53%). At 89 DAS, the maximum disease severity was recorded on the sixth

date of sowing (66.51%) followed by the seventh (56.67%) and minimum at first (15.20%). At 96 DAS, the maximum disease severity was recorded on the sixth date of sowing (69.51%) followed by the seventh (60.11%) and minimum at first (19.27%). At 103 DAS, the maximum disease severity was recorded on the sixth date of sowing (74.79%) followed by the fifth (53.38%) and minimum at the first (22.24%). At 110 DAS, the maximum disease severity was recorded on the fifth date of sowing (66.54%) followed by the fourth (47.54%) and minimum at the first (25.49%). At 117 DAS, the maximum disease severity was recorded on the fifth date of sowing (72.35%) followed by the fourth (50.15%) and minimum at first (27.14%). At 124 DAS, the maximum disease severity was recorded on the fourth date of sowing (67.44%) followed by the third (49.53%) and minimum at the first (30.71%).

At the first and second date of sowing (DOS) the disease progression started from 75 DAS and reached a maximum of 124 DAS. In the third and fourth DOS, the disease progression started from 61 and 54 DAS, respectively, reaching a maximum of 124 DAS. In the fifth DOS, the disease progression started from 47 DAS and reached a maximum of 117 DAS and observed no disease at 124 DAS. In the sixth, seventh and eighth DOS, the disease progression started from 33 DAS and reached a maximum of 103, 96 and 89 DAS, respectively.

The maximum mean disease severity was observed at sixth (28.51%) followed by fifth (27.76%) and minimum at first (11.29%) followed by eighth DOS (13.45%). The maximum disease appearance at days after sowing was observed at 89 (38.67%) followed by 96 DAS (37.59%) and minimum at 33 DAS (0.38%) (Table 2).

Date of sowing	Appearance of Disease	Per cent Disease Severity														
		Days after sowing (DAS)														
	(DAS)	33	40	47	54	61	68	75	82	89	96	103	110	117	124	Mean
1.10.21 (I)	72 12-12-2021	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00	0.00 (0.00)	5.57 (13.65)	12.53 (20.73)	15.20 (22.95)	19.27 (26.04)	22.24 (28.14)	25.49 (30.32)	27.14 (31.40)	30.71 (33.65)	11.29
10.10.21 (II)	72 22-12-2021	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.73 (13.85)	20.27 (26.76)	24.87 (29.91)	31.47 (34.120	40.24 (39.37)	43.41 (41.21)	46.81 (43.170	47.21 (43.40)	18.57
20.10.21 (III)	60 20-12-2021	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.47 (13.53)	7.13 (15.49)	10.47 (18.88)	15.39 (23.10)	28.74 (32.42)	35.53 (36.59)	40.57 (39.56)	45.51 (42.42)	47.27 (43.44)	49.53 (44.73)	20.40
30.10.21 (IV)	50 20-12-2021	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.26 (16.70)	10.25 (18.67)	13.31 (21.40)	15.71 (23.35)	20.81 (27.14)	31.21 (33.96)	37.74 (37.90)	45.23 (42.26)	47.54 (43.59)	50.15 (45.09)	67.44 (55.21)	24.83
10.11.21 (V)	40 20-12-2021	0.00 (0.00)	0.00 (0.00)	4.99 (12.91)	10.16 (18.59)	16.67 (24.10)	19.21 (25.99)	22.28 (28.17)	35.46 (36.55)	40.57 (39.56)	47.13 (43.35)	53.38 (46.94)	66.54 (54.66)	72.35 (58.28)	0.00 (0.00)	27.76
20.11.21 (VI)	32 22-12-2021	0.50 (4.05)	1.25 (6.42)	5.33 (13.35)	18.19 (25.25)	25.25 (30.17)	31.49 (34.14)	47.12 (43.35)	59.33 (50.38)	66.51 (54.64)	69.51 (56.48)	74.79 (59.86)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	28.51
30.11.21 (VII)	30 01-01-2022	2.54 (9.17)	3.37 (10.58)	8.38) (16.83)	23.17 (28.77)	30.27 (33.38)	41.31 (40.00)	48.29 (44.02)	51.37 (45.79)	56.67 (48.83)	60.11 (50.83)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	23.24
10.12.21 (VIII)	35 15-01-2022	0.00 (0.00)	5.39 (13.42)	8.93 (17.39)	12.35 (20.57)	20.15 (26.67)	27.11 (31.38)	29.34 (32.80)	39.41 (38.89)	45.63 (42.49)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.45
	Mean	0.38	1.25	3.45	9.01	13.50	17.44	23.06	31.82	38.67	37.59	34.55	28.56	30.46	24.36	
	C.D.	1.413	1.120	1.684	1.320	1.252	1.096	1.462	1.217	0.775	0.871	0.872	0.729	0.851	0.74	
	SEm(±)	0.461	0.366	0.550	0.431	0.409	0.358	0.478	0.397	0.253	0.284	0.285	0.238	0.278	0.24	

Table 2: Effect of date of sowing on *Alternaria blight* severity during Rabi season 2021-22.

*DAS (Days after sowing).

White rust

The disease was first appeared at 54 days after sowing and maximum disease severity was recorded on the eighth date of sowing (26.63%) followed by the seventh (5%) and the remaining dates of sowing not found disease symptoms. At 61 DAS, the maximum disease severity was recorded on eight dates of sowing (37.12%) followed by the seventh (7.54%) and the rest are not showing symptoms. At 68 DAS, the maximum disease severity was recorded on eight dates of sowing (55.49%) followed by seventh (10.57%) and minimum at sixth DAS (10.17%). At 75 DAS, the maximum disease severity was recorded on the eighth date of sowing (75.24%) followed by the sixth (35.83%) and minimum at the fifth (4.57%). At 82 DAS, the maximum disease severity was recorded on the eighth date of sowing (79.21%) followed by the seventh (41.21%) and minimum at the fourth (4.95%). At 89 DAS, the maximum disease severity was recorded on the eighth date of sowing (82.37%) followed by seventh (50.37%) and minimum at fourth (7.23%). At 96 DAS, the maximum disease severity was recorded on the eighth date of sowing (85.71%) followed by seventh (50.53%) and minimum at third (5.27%). At 103 DAS, the maximum disease severity was recorded on the fifth date of sowing (26.33%) followed by fourth (12.55%) and minimum at second (1.0%). At 110 DAS, the maximum disease severity was recorded on fourth date of sowing (18.54%) followed by third (9.98%) and minimum at second (1.25%). At 117 DAS, the maximum disease severity was recorded on fourth date of sowing (23.25%) followed by third (12.35%) and minimum at second (1.55%).

At first date of sowing, there were no disease symptoms observed. At the second, third and fourth dates of sowing (DOS) the disease progression started from 103, 96 and 82 DAS and reached a maximum of 117 DAS. In the fifth and sixth DOS, the disease progression started from 75 and 68 DAS, respectively, reaching a maximum of 103 and 96 DAS, respectively. In the seventh and eighth DOS, the disease progression started from 54 DAS and reached a maximum of 96 DAS.

The maximum mean disease severity was observed at eight (44.27%) followed by seventh (20.10%) and minimum at first (0.0%) followed by second DOS (0.38%). The maximum disease appearance at days after sowing was observed at 96 (26.87%) followed by 89 DAS (24.8%) and minimum at 110 DAS (3.72%) (Table 3). It was observed that pathogens favoured the 11.0 to 30.6°C range of temperature, 60.2% of relative humidity (RH), 7.9 km/h of wind speed, no rainfall (0.00 mm), and 5.6 sunshine hours for heavy infestation. At the 40 meteorological standard weeks, the disease severity observed minimum (11.29%), where the temperature ranged from 21.0-31.2°C, 60.9% of relative humidity, 1.7 Km/h of wind speed, no rainfall (0.00 mm), and 6.8 sunshine hours.

Date of sowing	Appearance of Disease	Per cent disease severity										
		Days after sowing (DAS)										
	(DAS)	54	61	68	75	82	89	96	103	110	117	Mean
1.10.21 (I)	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00
10.10.21 (II)	100 20.01.22	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.00 (5.74)	1.25 (6.42)	1.55 (7.15)	0.38
20.10.21 (III)	90 20.01.22	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.27 (13.27)	8.45 (16.90)	9.98 (18.42)	12.35 (20.57)	3.60
30.10.21 (IV)	80 20.01.22	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.95 (12.86)	7.23 (15.60)	10.43 (18.84)	12.55 (20.75)	18.54 (25.50)	23.25 (28.83)	6.41
10.11.21 (V)	70 20.01.22	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.57 (12.34)	18.21 (25.26)	20.41 (26.86)	22.55 (28.35)	26.33 (30.87)	0.00 (0.00)	0.00 (0.00)	7.69
20.11.21 (VI)	60 20.01.22	0.00 (0.00)	0.00 (0.00)	5.77 (13.90)	10.17 (18.60)	25.29 (30.19)	31.79 (34.32)	40.47 (39.51)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	11.34
30.11.21 (VII)	52 22.01.22	5.00 (12.92)	7.54 (15.94)	10.57 (18.97)	35.83 (36.77	41.21 (39.94)	50.37 (45.21)	50.53 (45.30)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00	20.10
10.12.21 (VIII)	52 22.01.22	26.63 (31.07)	37.12 (37.54)	55.49 (48.15)	75.24 (60.16	79.21 (62.87)	82.37 (65.17)	85.71 (67.79)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	44.27
	Mean	3.95	5.58	8.97	15.72	21.10	24.8	26.87	6.04	3.72	4.64	
	C.D.	0.346	0.731	0.990	1.042	0.886	0.982	1.078	1.032	0.889	0.712	
	SEm (±)	0.113	0.239	0.323	0.340	0.289	0.321	0.352	0.337	0.290	0.233	

Table 3: Effect of date of sowing on white rust severity during Rabi season 2021-22.
*DAS (Days after sowing).

Infection rate

Alternaria blight

The infection rate (r) was calculated on weekly basis and observed that late sown crops showed a higher infection rate than early sown crops. On the first date of sowing (DOS), the maximum infection rate was observed at 75-82 DAS (0.292) followed by 89-96 DAS (0.094) and the minimum infection rate was observed at 110-117 DAS (0.028). On the second DOS, the maximum infection rate was observed at 75-82 DAS (0.470) followed by 96 to 103 DAS (0.126) and minimum was observed at 117-124 DAS (0.023). On the third DOS, the maximum infection rate was observed at 82-89 DAS (0.262) followed by 75-82 DAS (0.145) and minimum infection rate was observed at 110-117 DAS (0.023). On the fourth DOS, the maximum infection rate was observed at 117-124 DAS (0.237) followed by 82-89 DAS (0.179) and minimum infection rate was observed at 103-110 DAS (0.031). On the fifth DOS, the maximum infection rate was observed at 47-54 DAS (0.252) followed by 75-82 DAS (0.214) and minimum at 61-68 DAS (0.057). On the sixth DOS, the maximum infection rate was observed at 40-47 DAS (0.490) followed by 47-54 DAS (0.451) and minimum at 89-96 DAS (0.045). On the seventh DOS, the maximum infection rate was observed at 47-54 DAS (0.392) followed by 40-47 DAS (0.317) and minimum was observed at 75-82 DAS (0.40). On the eighth DOS, the maximum infection rate was observed at 54-61 DAS (0.191) followed by 40-47 DAS (0.178) and minimum at 68-75 DAS (0.036). The maximum mean infection rate was observed at the sixth DOS (0.209) followed by the seventh (0.148) and the minimum was observed at the first DOS (0.094) (Table 4).

Date of sowing	Infection rate at 7 days intervals													
	33 to 40	40 to 47	47 to 54	54 to 61	61 to 68	68 to 75	75 to 82	82 to 89	89 to 96	96 to 103	103 to 110	110 to 117	117 to 124	Average
1.10.21 (I)	-	-	-	-	-	-	0.292	0.074	0.094	0.059	0.059	0.028	0.057	0.094
10.10.21 (II)	-	-	-	-	-	-	0.470	0.087	0.108	0.126	0.043	0.045	0.005	0.126
20.10.21 (III)	-	-	-	-	0.093	0.138	0.145	0.262	0.103	0.070	0.066	0.023	0.030	0.103
30.10.21 (IV)	-	-	-	0.078	0.097	0.064	0.113	0.179	0.095	0.102	0.031	0.034	0.237	0.103
10.11.21 (V)	-	-	0.252	0.187	0.057	0.061	0.214	0.071	0.088	0.082	0.181	0.090	-	0.128
20.11.21 (VI)	0.304	0.490	0.451	0.137	0.101	0.218	0.162	0.101	0.045	0.087	-	-	-	0.209
30.11.21 (VII)	0.096	0.317	0.392	0.120	0.159	0.093	0.040	0.070	0.047	-	-	-	-	0.148
10.12.21 (VIII)	-	0.178	0.119	0.191	0.127	0.036	0.147	0.084	-	-	-	-	-	0.126

Table 4: Effect of sowing dates on Infection rates ("r") of Alternaria blight in Indian mustard during Rabi season 2021-22.

White rust

The infection rate (r) was also calculated weekly and observed that late sown crops showed a higher infection rate than early sown crops. No infection was observed on the first date of sowing (DOS). On the second DOS, the maximum infection rate was observed at 103-110 DAS (0.074) and minimum was observed at 110-117 DAS (0.072). On the third DOS, the maximum infection rate was observed at 96-103 DAS (0.167) followed by 110-117 DAS (0.079) and minimum infection rate was observed at 103-110 DAS (0.059). On the fourth DOS, the maximum infection rate was observed at 103-110 DAS (0.152) followed by 82-89 and 89-96 DAS (0.132) and minimum infection rate was observed at 96-103 DAS (0.069). On the fifth DOS, the maximum infection rate was observed at 75-82 DAS (0.505) followed by 96-103 DAS (0.067) and minimum at 89-96 DAS (0.042). On the sixth DOS, the maximum infection rate was observed at 75-82 DAS (0.360) followed by 68-75 DAS (0.202) and minimum at 82-89 DAS (0.105). On the seventh DOS, the maximum infection rate was observed at 68-75 DAS (0.510) followed by 54-61 DAS (0.144) and minimum was observed at 75-82 DAS (0.75). On the eighth DOS, the maximum infection rate was observed at 47-54 DAS (0.580) followed by 68-75 DAS (0.293) and minimum at 82-89 DAS (0.067). The maximum mean infection rate was observed at the eighth DOS (0.214) followed by the sixth (0.197) and minimum was observed at the first DOS (0.0) followed by the second (0.073) (Table 5).

The infection rate (r) varied on different dates of sowing on Alternaria blight and white rust. On the average basis, the maximum infection rate 'r' (0.49) was recorded in the plots sown on dated 30th October 2021 crops, whereas, the 'r' of Alternaria blight was higher in the plot sown on 20th November (0.209) followed by in the plot sown on 30th November 2021 (0.148) and in the plot sown on 10th November 2021 (0.128). The 'r' of white rust on leaves was higher in late sown crops. On the average basis the 'r' being highest (0.214) on 10th December sown crops followed by 20th November (0.197), 10th November (0.165) and 30th November 2021 (0.162), respectively.

Date of sowing	Infection rate at 7 days intervals										
	47 to 54	54 to 61	61 to 68	68 to 75	75 to 82	82 to 89	89 to 96	96 to 103	103 to 110	110 to 117	Average
1.10.21 (I)	-	-	-	-	-	-	-	-	-	-	-
10.10.21 (II)	-	-	-	-	-	-	-	-	0.074	0.072	0.073
20.10.21 (III)	-	-	-	-	-	-	-	0.167	0.059	0.079	0.103
30.10.21 (IV)	-	-	-	-	-	0.132	0.132	0.069	0.152	0.094	0.115
10.11.21 (V)	-	-	-	-	0.505	0.046	0.042	0.067	-	-	0.165
20.11.21 (VI)	-	-	-	0.202	0.360	0.105	0.124	-	-	-	0.197
30.11.21 (VII)	-	0.144	0.122	0.510	0.075	0.122	0.002	-	-	-	0.162
10.12.21 (VIII)	0.580	0.160	0.246	0.293	0.074	0.067	0.082	-	-	-	0.214

Table 5: Effect of sowing dates on Infection rates ("r") of white rust in Indian mustard during Rabi season 2021-22.

The correlation coefficient between weather parameters, date of sowing and disease severity

Alternaria blight

Correlation studies suggested that weather parameters significantly influenced the disease of Alternaria blight. On the first, second, third, fourth and fifth DOS, the weather parameters including minimum temperature (-0.898, -0.896, -0.923, -0.920 and -0.758), maximum temperature (-0.879, -0.892, -0.898, -0.887 and -0.711), vapour pressure (-0.898, -0.896, -0.905, -0.908 and -0.741) were showed strong negative correlation, while evaporation (-0.896, -0.899, -0.936 and -0.947) showed strong negative correlation at I, II, III and IV; and negative correlation on V DOS (-0.691). Sunshine hour, showed a strong negative correlation at VI DOS (-0.711), while the negative correlation with all DOS viz. I, II, III, IV, V, VII and VIII (-0.309, -0.317, -0.381, -0.418, -0.278, -0.334 and -0.198). Wind speed was observed weak positive at I and II (0.028 and 0.041); and positively correlated at V, VI, VII and VIII (0.211, 0.297, 0.219 and 0.395), while weak negatively correlated at III (-0.069) and IV DOS (-0.087). Relative humidity (RH), strongly positive (0.804, 0.827, 0.898, 0.792 and 0.778) correlated at I, II, III, IV and V DOS; and weak positively at VI DOS (0.279), while negatively correlated at VIII DOS (-0.428) and weak negatively correlated at VII DOS (-0.077) (Table 6). Throughout the cropping period, rainfall doesn't receive, so no significant relation between Alternaria blight and rainfall was observed.

Date of sowing	Min Temp	Max Temp	RH (%)	Vapour Pressure (%)	Wind speed (Km/hr)	Total Rainfall (mm)	Evaporation	Sunshine (hours)
1.10.21 (I)	-0.898**	-0.879**	0.804**	-0.898**	0.028	0.00	-0.896**	-0.309
10.10.21 (II)	-0.896**	-0.892**	0.827**	-0.896**	0.041	0.00	-0.899**	-0.317
20.10.21 (III)	-0.923**	-0.898**	0.858**	-0.905**	-0.069	0.00	-0.936**	-0.381
30.10.21 (IV)	-0.920**	-0.887**	0.792**	-0.908**	-0.087	0.00	-0.947**	-0.418
10.11.21 (V)	-0.758**	-0.711**	0.778**	-0.741**	0.211	0.00	-0.691**	-0.278
20.11.21 (VI)	-0.240	-0.108	0.279	-0.081	0.297	0.00	0.257	-0.711**
30.11.21 (VII)	0.004	0.245	-0.077	0.124	0.219	0.00	0.078	-0.334
10.12.21 (VIII)	0.12	0.428	-0.428	0.116	0.395	0.00	0.224	-0.198

Table 6: Correlation coefficient between weather parameters, date of sowing and disease severity of Alternaria blight.

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

White rust

Correlation studies also suggested that weather parameters significantly influenced the disease of White rust. On the first DOS, no correlation was observed with weather parameters. The minimum temperature strongly negatively correlated with II (-0.771), III (-0.789) and IV (-0.875); negatively correlated with V (-0.303), VI (-0.134) and VII (-0.067); and positively correlated with VIII DOS (0.117), maximum temperature strong negatively correlated with II (-0.871) and III (-0.879); and weak negatively correlated at fourth DOS (-0.08) as well as positively correlated with V and VI (0.165), VII (0.285) and VIII (0.422) DOS. Vapour pressure strongly negatively correlated with II (-0.729), III (-0.752), IV (-0.882); and negatively correlated with V (-0.201), VI (-0.192), VII (-0.122) and positively correlated with VIII (0.071); evaporation strongly correlated with II (-0.812), III (-0.842) and IV (-0.859); and negatively correlated with V (-0.188), and weak positively correlated with VI and VII (0.08), and positively correlated with VIII DOS (0.226). were showed a strong negative correlation. Relatively humidity strongly positively correlated with II (0.878), III (0.908) and IV (0.821); and positively correlated with V (0.186); and negatively correlated with VI (-0.266), VII (-0.412) and VIII DOS (-0.542). Wind speed negatively correlated with II (-0.109) and III (-0.159); and positively correlated with IV (0.083), V (0.244), VI (0.396), VII (0.384) and VIII DOS (0.245). Sunshine negatively correlated with II (-0.304), III (-0.378), IV (-0.344), V (-0.201), VI (-0.123), VII (-0.120) and VIII DOS (-0.101) (Table 7). Throughout the cropping period, rainfall doesn't receive, so no significant relation between White rust and rainfall was observed.

Days after sowing	Min Temp	Max Temp	RH (%)	Vapour pressure (%)	Wind speed (Km/hr)	Total Rainfall (mm)	Evaporation	Sunshine (hours)
1.10.21 (I)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.10.21 (II)	-0.771**	-0.871**	0.878**	-0.729*	-0.109	0.00	-0.812**	-0.304
20.10.21 (III)	-0.789**	-0.879**	0.908**	-0.752**	-0.159	0.00	-0.842**	-0.378
30.10.21 (IV)	-0.875**	-0.882**	0.821**	-0.882**	0.083	0.00	-0.859**	-0.344
10.11.21 (V)	-0.303	-0.08	0.186	-0.201	0.244	0.00	-0.188	-0.201
20.11.21 (VI)	-0.134	0.165	-0.266	-0.192	0.396	0.00	0.008	-0.123
30.11.21 (VII)	-0.067	0.285	-0.412	-0.122	0.384	0.00	0.08	-0.12
10.12.21 (VIII)	0.117	0.422	-0.542	0.071	0.245	0.00	0.226	-0.101

Table 7: Correlation coefficient between weather parameters, date of sowing and disease severity of white rust.

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

The date of sowing influenced the test weight and yield of mustard

The interaction between the different dates of sowing and weather parameters significantly influenced the test weight (g) and yield (q/ha) of mustard. The average test weight ranged from 1.70 to 5.93g and the yield from 4.16 to 20.41q/ha. Among dates of sowing, maximum test weight and yield were recorded in I DOS (5.93 and 20.41), which was at par with II (5.86 and 19.99), III (5.70 and 19.16), IV (5.36 and 16.66), followed by V (4.90 and 14.99), VI (3.50 and 10.83), VII (2.10 and 6.24) and VIII (1.70 and 4.16), respectively (Table 8). From the observation, it was found that test weight and yield in early sown crops compared to late sown crops.

The weather parameters also influenced the disease intensity of the white mustard, which was correlated with temperatures ranging from 7.7 to 23.8°C, relative humidity of 75.8%, wind speed of 2.9 km/h, no rainfall (0.00 mm), the vapour pressure of 12.2%, evaporation of 2.4 and sunshine hours (3.2) etc., responsible for heavy infestation. The minimum disease severity was recorded in the 40th meteorological standard week concerning temperature (maximum 31.2°C and minimum 21.0°C), relative humidity (60.9%), wind speed (1.7 km/h), rainfall (0.00 mm), vapour pressure (20.1), evaporation (7.1) and sunshine hours (6.8).

The occurrence and severity of Alternaria blight and white rust of mustard were significantly influenced by weather conditions, which had a greatly impacted in terms of crop growth, development and yield. Our hypothesis suggested that the early sown crops escaped the disease or had fewer chances of infection than late sown crops [10-13]. In the present study, the occurrence and severity of

Date of sowing	Test weight (g)	Yield (q/ha)
1.10.21 (I)	5.93	20.41
10.10.21 (II)	5.86	19.99
20.10.21 (III)	5.70	19.16
30.10.21 (IV)	5.36	16.66
10.11.21 (V)	4.90	14.99
20.11.21 (VI)	3.50	10.83
30.11.21 (VII)	2.10	6.24
10.12.21 (VIII)	1.70	4.16
SEm (±)	0.37	0.17
CD (0.05)	0.920	0.424

Table 8: Effect of different dates of sowing on test weight and yield.

both diseases were observed at eight different dates of sowing, on the weekly basis. The disease progression increased gradually in crops with delay in sowing between 20th November to 5th December 2021 and decreased with early sowing from 20th October to 5th November. It has also been reported that disease severity increased with a delay in the date of sowing [14]. In October, Alternaria blight severity was observed significantly low [15]. The severity of the disease was correlated with weather conditions or environmental conditions. It means wind speed also plays a significant role in disease dispersion. The spores of both pathogens spread with high wind and cause severe damage to the crop. The severity of Alternaria blight on leaves was also positively correlated with daily maximum and minimum temperature which ranges from 18-27°C and 8–12°C, respectively and >10°C daily mean temperature, relative humidity in the morning >92% and in the evening >40%; and mean relative humidity of >70% in the preceding week. It reported maximum and minimum temperatures of 27-28°C and 14-15°C, respectively and an average relative humidity of more than 65% was found favorable for Alternaria blight development [16].

In white rust of mustard, delayed sowing, from the first week of October to the second week of December, increased disease intensity gradually from 1 to 85.71%. Overall, the maximum incidence (44.27%) was recorded on 10th December, while the minimum (0.00%) on 1st October 2021, which indicated that early sown crops escaped the disease compared to late sowing [17]. Delayed sowing of mustard crops viz., from the first week of October to the third week of November, increased the disease intensity from 4.6 to 68.5% [18]. In mustard, a mean temperature of 13-22°C with RH > 60% was most congenial for the formation of maximum stag heads [19]. Under field conditions, the disease becomes epidemic when the temperature is around 12°C, RH > 70% (mostly between 60-80%), wind velocity from 2.7-3.4 km/h and winter rains are found as the most congenial. The severity of white rust on leaves was favored by RH > 40% afternoon (minimum), > 97% morning (maximum) and 16-24°C maximum daily temperature [20].

The severity of Alternaria blight was significantly lower in October sown crop. It revealed that the disease intensity of powdery increased from 48-74% with delayed sowing [21]. The apparent infection rate (r) was also higher during mid of March sowing.

Generally, it was observed that 1000 seed weight and yield (q/ha) were higher in early sown crops than in late sown crops. Out of 8 dates of sowing (from 01, 10, 20, 30 October, 10, 20, 30 November and 10 December 2021) maximum 1000 test weight and yield (q/ha) was recorded on 01th October (20.41 and 5.95), 10th October (19.99 and 5.86), 20th October (19.16 and 5.70), 30 October (16.66 and 5.20), 2021, respectively. With a delay in sowing a drastic reduction in yield was observed.

Conclusion

The present investigation demonstrated the role of environmental factors in relation to disease progression in mustard crops under field conditions. The knowledge of the time of sowing of crops in the field is one of the major beneficiaries to avoid disease load on the agricultural crops. Therefore, crop production is greatly influenced by weather conditions with a choice of planting time. This study suggests that early sowing of the crops escaped the disease load of Alternaria blight and White rust, minimum infection rate and gives higher yields. In the future, early sowing of the other crops also avoids disease load and gives a higher yield. Besides, these early sowing practices crops could also be suggested to the farmers to get maximum yield irrespective of disease load.

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Conflict of Interest

The author(s) declare(s) that there is no conflict of interest.

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