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Impacts of Integrated Nutrient Management on Epidemiology, Seed Yield and Severity of *Alternaria* blight Disease in Indian Mustard (*Brassica juncea* L.)

Sunita Mahapatra[1], Sunanda Chakraborty[2], Malay Samanta[3] and Srikanta Das[4]

[1]Dept. of Plant Pathology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, W.B. (741 252), India
[2]Subject Matter Specialist (Horticulture), Nadia, Kishi Vigyan Kendra , BCKV, Nadia, W.B. (741 252), India

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Corresponding sunitamahapatra@yahoo.co.in

0000-0002-8476-0490

ABSTRACT

The field studies were conducted at the research farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India during rabi seasons of 2017–18 and 2018–19. The objective of the research was to establish a relationship between disease severity of Alternaria blight with epidemiological factors in Indian mustard under Integrated Nutrient Management. Severity of disease in the specified time intervals was measured under 10 different nutrient management treatments combinations. Results showed that the highest intensity of *Alternaria* blight was observed with a mean maximum temperature of 19.3 to 24.4°C, mean minimum temperature of 7.6 to 14.1°C, average temperature of 13.5 to 19.3°C and an average relative humidity of more than 70%. The nutrient management in different combinations resulted different disease severity on leaves and pods and with increase in the age of the plant, significant increase in disease severity was observed. Maximum increase in disease severity was observed on 95 days after sowing (DAS) (44.77%) followed by 80 DAS (38.99%) and 65 DAS (32.99%) irrespective of their different treatments. Minimum disease severity was observed (13.83%) when the plots were treated with Azotobacter @ 250 g kg^{-1} seed, Phosphobacteria @ 250 g kg^{-1} seed along with FYM @ 7.5 t ha^{-1}. Empirical relationship was established between different weather factors and Alternaria blight under different nutrient management practices which will be useful to forecast the first appearance of the disease accurately.

KEYWORDS: *Alternaria* blight, epidemiology, integrated nutrient management, mustard

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1. INTRODUCTION

India is the third largest producer of rapeseed-mustard in the World after China and Canada, with a global share of 17.99% in acreage and 13.13% in production (Shekhawat et al., 2012; Anonymous, 2020). The crop accounts for nearly one-third of the oil produced in India and play a vital role in supporting the livelihood of marginal and small farmers in rain fed areas and resource scarce areas. It is, however, prone to a number of biotic and abiotic stresses, which reduces its productivity significantly (Singh et al., 2021; Rayanoothala, 2021). Among diseases, leaf blight of Indian mustard, incited by *Alternaria brassicae* and *A. brassicicola* is a major threat to mustard cultivation in India and is responsible for yield reduction of up to 70% under favorable conditions (Gupta et al., 2020; Singh et al., 2017; Sharma et al., 2018). The disease development is dependent upon a number of factors, viz., age of plant, soil nutrients, environmental factors like temperature, relative humidity and rainfall etc. (Sinha et al., 1992; Meena et al., 2011; Biswas, 2013; Kumar et al., 2013). The role of environmental factors in disease development as well as suitable chemical measures for disease control have been previously studied by many workers (Jagana et al., 2013; Mahapatra and Das, 2014; Kumar et al., 2014; Mahapatra and Das, 2016; Mahapatra et al., 2014; Mahapatra et al., 2018).

Although, soil nutrition plays an important role in the development of *Alternaria* leaf blight (Mahapatra and Das, 2013) but their role as a primary component of disease control has not been reported so far. Generally, plants are more prone to a number of diseases under nutrient stress, and certain nutrients are highly capable of alleviating the susceptibility of the plant to the disease (Rathi et al., 2015; Singh et al., 2017a). Previous studies reported the role of temperature, relative humidity (RH) and sunshine hours on occurrence of blight on rapeseed and mustard (Dang et al., 1995; Mahapatra and Das, 2014a; Jha et al., 2016; Dhaliwal and Singh, 2020). Keeping the above points in view, the present study was conducted to identify the effective nutrient combinations to minimize the incidence of the leaf blight disease in Indian mustard and to enhance the seed yield. The present investigations also aimed at studying the effect of weather on the development of Alternaria blight (epidemiology) and disease progression with age of the plant under different integrated nutrient management treatments.

These reports also predicted relationships between different weather factors and Alternaria blight occurrence through empirical models. However, there was a need to accurately forecast the age of crop at first appearance of the disease, so as to avoid unnecessary pesticide application. Hence, in this study empirical relationships were established between different weather factors and Alternaria blight under different nutrient management practices which would be useful to accurately forecast the first appearance of the disease and guide the farmers to decide the optimum time for spraying of fungicide and to avoid unnecessary pesticide application and cost of cultivation.

2. MATERIALS AND METHODS

The field experiments were conducted at the research farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India during October to March of 2017–18 and 2018–19. The mustard cultivar 'Binoy' was sown at 40×15 cm^2 but all the data analyzed and represented in the tables are on the basis of two years pooled mean. As host nutrition is an important factor for disease progression, experiment was conducted to find out the suitable application of organic, inorganic, bio-fertilizers and their combinations on disease progression to maximize seed yield of mustard. The integrated nutrient management treatment consisted of: T_1-No fertilizer (untreated control); T_2-Normal dose of fertilizer N:P:K @ 80:40 :40; T_3- N:P:K @ 121:33:56, T_4-N:P:K @ 60.5:33:56+Azotobacter, T_5-N:P:K @ 60.5:16.5:56+Phosphobacteria; T_6-N:P:K @ 60.5:16.5:56+Azotobacter+Phosphobacteria; T_7-N:P:K @ 60.5:33:56+Green manure; T_8-N:P:K @ 60.5:16.5:56+Green manure+Azotobacter+phosphobacteria; T_9-N:P:K @ 60.5:16.5:28+FYM @ 7.5 t ha^{-1}; T_{10}-Azotobacter+Phosphobacteria+FYM @ 7.5 t ha^{-1}. The experiment was laid out in randomized block design replicated thrice.

Recommended agronomic practices and intercultural operations were adopted and natural epiphytotic development was allowed in field condition. The onset of time for disease was monitored, first appearance of lesion and disease severity were recorded at 10 days interval. Disease rating was done by using the 0-5 scale according to Sharma and Kolte (1994), where, 0=no visible symptoms; 1=1–10% disease severity; 2=11–25% disease severity; 3=26–50% disease severity; 4=51–75%; 5=>75% disease severity. 10 randomly selected plants were tagged and disease severity was assessed till 15 days before harvesting. The disease severity was calculated using standard methods (Dhingraand Sinclair, 1993). The plants in border rows were not considered for disease assessment.

The Percent Disease Index (PDI) was calculated using the formula (Wheeler, 1969).

PDI=(Total Sum of individual rating/Number of leaves examined×Maximum disease grade)×100

Weather data with respect to maximum and minimum temperature, relative humidity I (7.22 IST or 7.00 LMT) and II (2.22 IST or 2.00 LMT) and rainfall were obtained and averaged for seven days. Simple correlation was done with the maximum temperature, minimum temperature, relative humidity (RH) I, II and rainfall.

The weather parameters were maximum (T_{max}) and minimum temperature (T_{min}); maximum (RHmax) and minimum relative humidity (RH_{min}); total rainfall (RT); wind velocity (km/h) evening ($WV_{evening}$) and morning ($WV_{morning}$); vapour pressure (millibar) noon (VPnoon) and morning(VP morning); and bright sunshine hour (BSH) were continuously recorded at the adjacent meteorological observatory. The averages of 10 days data of these variables, except for 10 days cumulative rainfall for the specific period of disease prediction were worked out for statistical analysis. The step wise multiple regression analysis was carried out and the prediction equation used was following:

$v= b_o+b_1x_1+b_2x_2 \ldots\ldots\ldots\ldots b_nx_n$

Where v = predicted disease severity; bo = intercept; $b_1b_2 \ldots\ldots\ldots b_n$ = Regression co-efficient; $x_1x_2 \ldots\ldots\ldots x_n$ = independent variables, The goodness of fit of multiple regression model was evaluated by coefficient of determination (R2), adjusted co-efficient of determination (R^2), standard error (SE), and residual sum of squares (RSS) (Cornell and Berger, 1987).

3. RESULTS AND DISCUSSION

3.1. *Disease progression under different nutrient status*

Efficient, economical and environment friendly control of the blight may be obtained through knowledge of its timing of attack in relation to weather factors, which may enable prediction of its occurrence so as to allow growers to take timely action in an efficient manner for crop management. Weather is an exceptionally important factor in the severity of *Alternaria* blight of oilseed *Brassica*. The data on the severity of *Alternaria* blight as affected by different weather parameters is presented in Table 1. The characteristic symptoms of *Alternaria* blight as small round, brown to black necrotic spots became visible on the leaves after sixty-one days of sowing. During this period (9th week after sowing), the mean maximum and minimum temperatures were 13.7 and 7.2°C respectively, with an average relative humidity of more than 90%. Total rainfall during this week was 13.8 mm, which provided the required leaf wetness and helped in disease development and led to gradual increase in disease severity. The maximum increase in the disease severity was observed during 18th week during which the mean maximum and minimum temperatures were 28.8°C and 13.4°C with an average relative humidity of more than 70% (Figure 1, 2, 3). There was a negative correlation between PDI of *Alternaria* blight and the mean maximum and minimum temperatures while, disease severity was positively correlated with rainfall and relative humidity (Table 2). The highest intensity of Alternaria blight was noticed with a mean maximum temperature of 27.0 to 28.5°C, mean minimum temperature of 8.0 to 13.4°C, average temperature of 13.5 to 19.3°C and an average relative

Table 1: Effect of weather factors on development and severity of *Alternaria* blight of mustard under different nutrient management

SMW	T Max (°C)	T Min (°C)	Rainfall (mm)	RH Max (%)	RH Min (%)	Accumulated increase in diseases incidence under nutrient management treatments									
						T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
51	25.2	10.7	13.8	95	63.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	23.5	7.5	0	98.7	50.7	6.23	9.15	13.12	6.65	8.83	6.85	3.61	4.11	2.92	1.51
1	25.3	7.8	0	97.6	48.1	9.39	11.05	18.14	9.78	12.56	10.95	10.57	9.77	8.84	11.28
2	24.6	7.5	0	97.7	46.4	12.54	12.95	23.15	12.91	16.28	15.05	17.52	15.43	14.75	21.05
3	25.9	7.9	0	96.7	47.3	29.18	30.15	36.66	22.36	27.42	23.98	21.44	16.28	18.08	21.14
4	26.1	10	0	92.7	48	45.81	47.35	50.16	31.81	38.55	32.91	25.35	17.12	21.41	21.22
5	27	8	0	93.4	39.1	48.19	48.30	54.89	34.13	42.68	35.26	28.78	21.67	23.91	22.44
6	27	9.5	0	93.6	45.7	50.56	49.25	59.62	36.45	46.81	37.61	32.21	26.21	26.41	23.66
7	29.4	11.2	62.7	93.6	43.9	53.85	54.28	62.42	40.34	49.81	41.66	36.81	30.62	27.06	27.00
8	28.5	13.4	0	95.1	61.9	57.13	59.31	65.21	44.23	52.81	45.71	41.41	35.02	27.71	30.33

Table 2: Correlation coefficients between meteorological parameters and PDI of *Alternaria* blight disease in mustard

Meteorological parameters	PDI of *Alternaria* blight
T_{max}	-0.107
T_{min}	-0.262
RH_{max}	0.465
RH_{min}	0.324
Rainfall (mm)	0.339

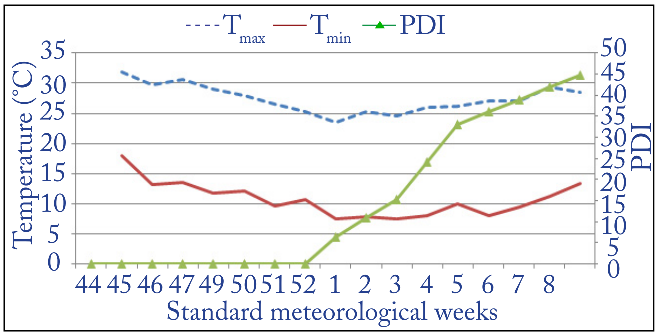

Figure 1: Weekly pattern of temperature and disease severity of *Alternaria* leaf blight

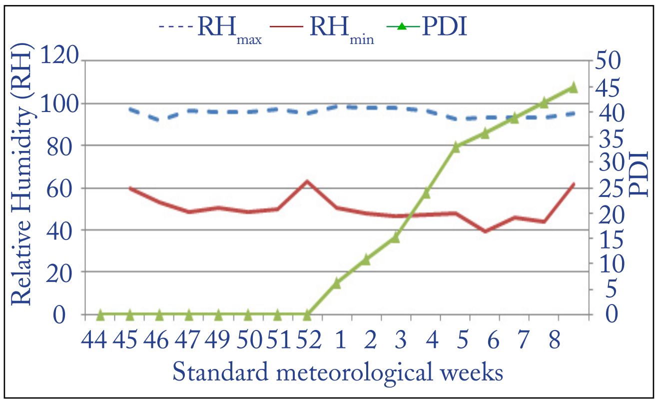

Figure 2: Weekly pattern of relative humidity and disease severity of *Alternaria* leaf blight

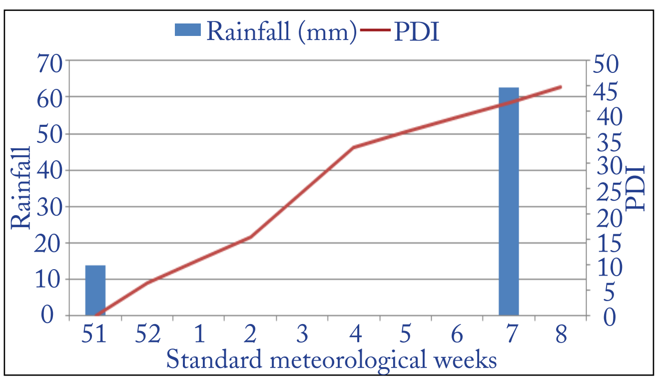

Figure 3: Weekly rainfall pattern and disease severity of *Alternaria* leaf blight

humidity of more than 70%. This is in keeping with the studies of Gupta et al. (2003), who reported that the week with maximum temperature ranging of 20.4 to 31.6°C and minimum temperature of 4.9 to 14.4°C had the highest disease severity. Biswas (2013) had previously reported that the development of *Alternaria* blight was maximum during the period when daily minimum temperature was between 10 to 14°C, daily maximum temperature was between 18 to 29°C and average relative humidity ranged between 60 to 96%, which was also observed in our study. Chandel (2016) found a positive correlation between rainfall and disease severity, indicating the influence of rainfall on disease development.

A multiple regression model has been developed based on study of epidemic leaf blight in relation to different meteorological factors (Chattopadhyay et al., 2005; Sangeetha and Siddharamiha, 2007). Severity of *Alternaria* blight on leaves (Meena et al., 2004) and pods (Sandhu et al., 1985) were found be higher in late sown crops. A delayed sowing results in coincidence of the vulnerable growth stage of plants as indicated earlier with warm (maximum temperature: 18-26°C; minimum temperature: 8–12°C) and humid (mean RH >70%) weather. Severity of *Alternaria* blight disease on leaves was favored by a maximum temperature of 18–27 the preceding week, minimum temperature of 8- 12°C, mean temperature >10°C, >92% morning relative humidity (RH), >40% afternoon RH and mean RH of >70%. Disease severity on pods was positively influenced by 20–30°C maximum temperature, >14°C mean temperature, >90% morning RH, >70% mean RH, >9 h sunshine and >10 h of leaf wetness. The regional and crop specific models devised thereby could predict the crop age at which *Alternaria* blight first appears on the leaves, pods, the peak blight severity on leaves, pods and the crop age at peak blight severity on leaves, pods at least one week ahead of first appearance of the disease on the crop, thus allowing growers to take necessary action (Chattopadhyay et al., 2005).

3.2. Predictive equations for Alternaria blight diseases on mustard under different nutrient management

Nine treatments were applied in field to boost up yield of mustard as well as on *Alternaria* blight under natural field condition and it was compared with untreated control (without fertilizers). The weather factors like maximum temperature (T_{max}), minimum temperature (T_{min}), average temperature (T_{avg}), maximum relative humidity (RH_{max}), minimum relative humidity (RH_{min}), average relative humidity (RH_{avg}), wind velocity (W_v), Vapour pressure (Vp), total rainfall (Rt), bright sunshine hours (BSH), were collected from nearby observatory during the experimentation and correlated with the *Alternaria* leaf blight disease severity. Step down multiple regression analysis was conducted in every treatment to determine the effect of individual as well as the combined effect of weather factors on disease development. Significance of the co-efficient of multiple determinations (R^2) and partial regression co-efficients were tested at p>0.05 (Syndecor and Cochran, 1967).

The results showed that in every treatment average temperature, average relative humidity and wind velocity positively or negatively and significantly influenced on disease severity. In control (T_1) treatment (no fertilizer), the equation was:

$\hat{Y}$=-24.474–10.659 T_{avg}+3.797 RH_{avg}–14.726 W_v

The equation indicated that average temperature and wind velocity negatively correlated where as average relatively humidity correlated positively and significantly with disease severity. The multiple correlation co-efficient (R^2) between disease severity and group of independent variable was found to be 0.97 suggesting that 97.0% change in disease severity is caused by average temperature, average relative humidity and wind velocity. The multiple regression equation derived from the data revealed that the disease severity is influenced by average temperature (10.658 units), average relative humidity (3.797 units) and wind velocity (14.726 units). It indicated with increase average relative humidity and decrease in average temperature and wind velocity there was a significant increase in disease severity. It was confirmed by high R^2 and adj. R^2 values (0.98 and 0.91 respectively). Similarly, predictive equations were obtained for all the treatments which are depicted in Table 3.

Table 3: Predictive equations for forecasting severity of *Alternaria* blight diseases on mustard with prevalent weather parameters under different nutrient management

Treatments	Prediction equations
T_1: No fertilizer (untreated control)	-24.474–10.659 avg.Temp+3.797 avg. RH–14.726 WV R^2=0.977 Adjusted R^2=0.910
T_2: Normal dose of fertilizer N:P:K @ 80:40 :40	-97.637–10.639 avg.Temp+4.666 avg.RH–16.024 WV R^2=0.973 Adjusted R^2=0.891
T_3: N:P:K @ 121:33:56	-116.561–10.587avg.Temp+4.840 avg. RH–10.608 WV R^2=0.975 Adjusted R^2=0.951
T_4:N:P:K @ 60.5:33:56+ Azotobacter	-23.636–7.529 avg.Temp+2.735 avg.RH–5.409 WV R^2=0.966 Adjusted R^2=0.865
T_5: N:P:K @ 60.5:16.5:56+ Phosphobacteria	-31.845–8.330 avg.Temp+3.126 avg.RH–5.850 WV R^2=0.956 Adjusted R^2=0.825
T_6: N:P:K @ 60.5:16.5:56+Azotobacter+Phosphobacteria	-18.118–7.548 avg.Temp+2.686 avg.RH–5.538 WV R^2=0.945 Adjusted R^2=0.780
T_7: N:P:K @ 60.5 :33:56+Green manure	66.390– 6.388 avg.Temp+1.206 avg.RH+1.378 WV R^2=0.844 Adjusted R^2=0.376
T_8:N:P:K @ 60.5:16.5:56+Green manure+Azotobacter+phosphobacteria	86.479–4.534 avg.Temp+ 0.401avg.RH–3.804 WV R^2=0.924 Adjusted R^2=0.695
T_9:N:P:K @ 60.5:16.5:28+FYM @ 7.5 t ha^{-1}	32.242–6.963 avg. Temp+1.815 avg. RH–0.755 WV R^2=0.905 Adjusted R^2=0.620
T_{10}: Azotobacter+ Phosphobacteria+ FYM @ 7.5 t ha^{-1}	78.113–4.200 avg. Temp+0.401 avg. RH–2.522 WV R^2=0.879 Adjusted R^2=0.516

The present experiment suggested that disease incidence and severity was observed irrespective of the treatments, but the disease progress is dependent on average temperature (average of maximum and minimum temperature), average relative humidity (average of maximum and minimum relative humidity) and wind velocity. The partial regression co-efficient of these three variables were different in each treatment (Table 3). However, the average temperature and wind velocity correlated negatively while average relatively humidity positively correlated in all treatments except T_7 and T_8, where wind velocity was found to have a positive influence on disease progression. Further, with increase in average relative humidity and decrease in average temperature and wind velocity there was significant increase in disease severity. This was also reflected in the studies of Neog et al. (2015), who reported that cloudy weather along with rainfall is ideal for development of Alternaria blight. Manjhi et al. (2018) reported that high relative humidity with intermittent rains greatly favored the disease development. This may be due to the fact that temperature, humidity and rainfall has a major impact on spore germination, growth, penetration, infection and spore production. Further, wind velocity has been known to influence spore liberation, dispersal, deposition which in turn determines the intensity of the disease, particularly for air borne pathogens (Singh et al., 2021).

3.3. Disease response of mustard in organic and inorganic sources

The results showed that application of manures, fertilizers, bio-fertilizers in different combinations resulted in different disease severity on leaves. An increase in disease severity was observed with increase in age of the plants, irrespective of the treatment used. Maximum disease severity was observed at 95 days after sowing (DAS) (44.77%) followed by 80 DAS (38.99%) and 65 DAS (32.99%) and their differences were statistically significant, irrespective of the treatments. Similarly, minimum disease severity was noticed on 35 DAS (6.33%) followed by 50 DAS (15.35%) irrespective of their different treatments and their difference was statistically significant (Table 3).

Among the treatments studied, minimum disease severity was observed (13.83%) when the plots are treated with a combination of Azotobacter @ 250 g kg^{-1} seed, Phosphobacteria @ 250 g kg^{-1} seed and FYM @ 7.5 ton ha^{-1}. No significant difference in disease severity was observed between treatments T_2 (Normal dose of fertilizer N:P:K @ 80:40:40) (35.67 %) and T_5 (N:P:K @ 60.5:16.5:56+Phosphobacteria) (32.66%) with untreated control (34.45%). T_3 (N:P:K @ 121:33:56) recorded the highest mean disease severity among the treatments used (Table 4).

The interaction between age of the plant and the treatment was also statistically significant with respect to disease severity on leaves. Maximum disease severity was observed on application of NPK @ 121:33:56 kg ha^{-1} (65.21%) at 95 DAS followed by NPK @ 80:40:40 at 95 DAS (59.31%) and their difference was not statistically significant.

Table 4: Disease progression with days after sowing under different integrated nutrient management

Treatments	PDI at different days after sowing					
	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS	Mean
T_1: No fertilizer (untreated control)	6.23 (14.42)	12.54 (20.70)	45.81 (42.59)	50.56 (43.34)	57.13 (49.20)	34.45 (34.45)
T_2: Normal dose of fertilizer N:P:K @ 80:40 :40	9.15 (17.95)	12.95 (21.05)	47.35 (43.51)	49.25 (44.60)	59.31 (50.36)	35.67 (35.49)
T_3: N:P:K @ 121:33:56	13.12 (21.22)	23.15 (29.00)	50.16 (45.11)	59.62 (50.53)	65.21 (53.85)	42.25 (39.94)
T_4:N:P:K @ 60.5:33:56+Azotobacter	6.65 (15.00)	12.91 (21.05)	31.81 (34.33)	36.45 (37.17)	44.23 (41.67)	26.41 (29.41)
T_5: N:P:K @ 60.5:16.5:56+Phosphobacteria	8.83 (17.26)	16.28 (23.81)	38.55 (37.82)	46.81 (43.17)	52.81 (46.61)	32.66 (33.73)
T_6: N:P:K @ 60.5:16.5:56+Azotobacter+Phosphobacteria	6.85 (15.23)	15.05 (22.87)	32.91 (35.00)	37.61 (37.82)	45.71 (42.53)	27.63 (30.69)
T_7: N:P:K @ 60.5 :33:56+Green manure	3.61 (10.94)	17.52 (24.73)	25.35 (30.26)	32.21 (34.57)	41.41 (40.05)	24.02 (28.11)
T_8:N:P:K @ 60.5:16.5:56+Green manure+Azotobacter+ phosphobacteria	4.11 (11.68)	15.43 (23.11)	17.12 (24.43)	26.21 (30.79)	35.02 (36.27)	19.58 (25.26)
T_9:N:P:K @ 60.5:16.5:28+FYM @ 7.5 t ha^{-1}	2.92 (9.80)	14.75 (22.63)	21.41 (27.56)	26.41 (29.41)	27.71 (31.44)	20.38 (25.55)
T_{10}: Azotobacter+Phosphobacteria+FYM @ 7.5 t ha^{-1}	1.51 (7.03)	12.95 (21.05)	13.11 (21.22)	16.05 (23.66)	25.53 (30.33)	13.83 (20.66)
Mean	6.33 (14.05)	15.35 (23.00)	32.99 (34.57)	38.99 (38.39)	44.77 (41.84)	
		SEm±		CD (p=0.05)		
Date		0.67		1.99		
Treatment		0.87		2.58		
Date×Treatment		1.47		4.37		

(The value within the paranthesis are angular transformed value)

In case of black spot disease on siliqua, disease appeared on 70 DAS when the plant was in seed forming stage and data was recorded at 10 days interval up to 100 DAS (harvesting stage) (Table 5). Statistically significant differences in disease severity were observed in plants treated with different treatments. The interactions between the age of the plant and treatment were also statistically significant with respect to black spot severity on siliqua of mustard. The disease was found to be more severe on leaves as compared to siliqua, which was confirmatory to the findings of Al-Lami et al. (2019).

With increase in age of siliqua, the disease severity increased significantly with maximum value being observed at 110 DAS (28.69%). Among the different treatments, minimum black spot disease severity on siliqua of mustard was observed in the plots treated with T_{10} (Azotobacter @ 250 g kg^{-1} seed+Phosphobacteria @ 250 g kg^{-1} seed+FYM @ 7.5 ton ha^{-1}) (9.43%) which was statistically at par with T_9 (NPK @ 60.5:16.5:28 kg ha^{-1}+FYM @ 7.5 t ha^{-1}) (9.87%) (Table 5). Maximum disease severity was observed in T_3 (NPK @ 121:33:56 kg ha^{-1})(22.55%) followed by T_5 (NPK @ 60.5:16.5:56 kg ha^{-1}+Phosphobacteria @ 250 g ha^{-1} seed)

Table 5: Effects of integrated nutrient management against black spot disease on mustard on siliqua

Treatments	PDI at different days after sowing			
	70 DAS	80 DAS	90 DAS	100 DAS
T_1: No fertilizer (untreated control)	1.31 (6.47)	8.14 (16.54)	12.13 (20.36)	10.63 (17.64)
T_2: Normal dose of fertilizer N:P:K @ 80:40 :40	1.01 (5.74)	8.15 (16.64)	12.25 (20.44)	15.38 (20.53)
T_3: N:P:K @ 121:33:56	4.61 (12.38)	15.15 (22.05)	22.13 (28.04)	22.55 (26.62)
T_4:N:P:K @ 60.5:33:56+ Azotobacter	1.15 (6.06)	5.58 (13.69)	11.81 (20.09)	11.24 (17.69)
T_5: N:P:K @ 60.5:16.5:56+ Phosphobacteria	1.35 (6.61)	8.21 (16.64)	15.18 (22.95)	14.04 (20.07)
T_6: N:P:K @ 60.5:16.5:56+Azotobacter+Phosphobacteria	1.49 (6.89)	6.29 (14.54)	12.53 (20.70)	10.78 (17.66)
T_7: N:P:K @ 60.5 :33:56+Green manure	1.58 (7.14)	1.61 (7.27)	17.12 (24.43)	11.93 (17.60)
T_8:N:P:K @ 60.5:16.5:56+Green manure+Azotobacter +phosphobacteria	1.02 (5.85)	2.11 (8.33)	14.13 (22.06)	10.64 (16.62)
T_9:N:P:K @ 60.5:16.5:28+FYM @ 7.5 t ha^{-1}	1.05 (5.79)	3.05 (10.14)	14.05 (22.06)	9.87 (16.39)
T_{10}: Azotobacter+ Phosphobacteria+ FYM @ 7.5 t ha^{-1}	1.81 (7.67)	1.91 (7.92)	11.11 (19.46)	9.43 (15.91)
Mean	1.64 (7.06)	6.02 (13.38)	14.24 (22.06)	28.69 (32.20)
	SEm±		CD (p=0.05)	
Date	0.41		1.22	
Treatment	0.69		2.05	
Date×Treatment	1.25		3.71	

The value within the paranthesis are angular transformed value

(14.04%) and their difference was statistically significant.

The age of the plant and treatment interaction on black spot disease severity on siliqua of mustard was also statistically significant (Table 5). Maximum disease severity was observed on the plots treated with T_3 (NPK application @ 121:33:56 kg ha^{-1}) (48.31%) at 100 DAS followed by normal dose of NPK @ 80:40:40 kg ha^{-1} (40.12%) at the same DAS and their difference was statistically significant. Minimum disease severity was observed in T_8 (NPK @ 60.5:16.5:56 kg ha^{-1}+Green manure @ 10 t ha^{-1}+Azotobacter @ 250 g kg^{-1} seed+Phosphobacteria @ 250 g kg^{-1} seed) (1.02%) at 70 DAS with statistically at par on all other treatment combinations except the treatment NPK @ 121:33:56 kg ha^{-1} (4.62%) on the same date of sowing.

This different inorganic, organic and bio-fertilizer and their combination treatments also produced different yield parameter i.e. seed yield, straw yield and husk yield and their differences were statistically significant (Table 6**)**.

In case of straw yield, the different treatments of organic, inorganic and bio-fertilizers also showed differential yield and their differences were statistically significant. Maximum straw yield was harvested on the treatment T_9 (NPK @ 60.5:16.5:28 kg ha^{-1}+FYM @ 7.5 t ha^{-1}) (2434 kg ha^{-1}) which was statistically at par with normal dose of fertilizer (NPK 80:40:40) (2404.67 kg ha^{-1}). Minimum straw yield was obtained in the plots treated with T_5 (NPK @ 60.5: 16.5:56 kg ha^{-1}+phosphobacteria @ 250 g kg^{-1} seed) (1730.33 kg ha^{-1}) which was statistically at par with the treatment T_6 (NPK @ 60.5:16.5:56 kg ha^{-1}+Azotobacter and phosphobacteria @ 250 g kg^{-1} seed each) (1756.67 kg ha^{-1}) (Table 6).

The different husk yield was recorded on different treatments and their differences were statistically significant. Maximum husk yield was obtained on the plots treated with T_9 (NPK @ 60.5:16.5:28 kg ha^{-1}+FYM @ 7.5 t ha^{-1}) (803.33 kg ha^{-1}) followed by the treatment T_{10} (Azotobacter and phosphobacteria @ 250 g kg^{-1} seed+FYM @ 7.5 t ha^{-1}) (699.33 kg ha^{-1}) and T_8 (NPK @ 60.5:16.5:56 kg ha^{-1}+green manure 10 t ha^{-1}+Azotobacter and phosphobacteria @ 250 g kg^{-1} seed each) (1628.67 kg ha^{-1}) and their differences were statistically significant. Minimum husk yield was obtained in the plots treated with no fertilizers (untreated control) (440.67 kg ha^{-1}) which was statistically par with the treatment T_5 (NPK @ 60.5:16.5:56 kg ha^{-1} along with phosphobacteria @ 250 g kg^{-1} seed) (488 kg ha^{-1}) (Table 6).

3.4. *Effects on the seed yield*

Disease severity significantly affected the seed yield and 1000 grain weight **(**Table 6**)**. In case of seed yield, maximum yield was recorded on the treatment T_9 (NPK @ 60.5:16.5:28 kg ha^{-1}+FYM @ 7.5 t ha^{-1}) (1375 kg ha^{-1}) followed by the treatment T_8 (NPK @ 60.5:16.5:56 kg ha^{-1}+green manure @ 10 t ha^{-1}+Azotobacter and Phosphobacteria @ 250 g kg^{-1} seed each) (1234 kg ha^{-1}) and the treatment T_{10} (Azotobacter and Phosphobacteria @ 250 g kg^{-1} seed+FYM @ 7.5 t ha^{-1}) (1205.33 kg ha^{-1}) and their difference was statistically significant. Minimum seed yield (kg ha^{-1}) was obtained

Table 6: Effect of integrated nutrient management on seed yield, straw yield and husk yield of mustard

Treatments	Seed yield kg ha^{-1}	Increase over control (%)	Straw yield kg ha^{-1}	Husk yield kg ha^{-1}
T_1: No fertilizer (untreated control)	673.67	-	2068.67	440.67
T_2: Normal dose of fertilizer N:P:K @ 80:40 :40	856.00	27.35	2404.67	534.00
T_3: N:P:K @ 121:33:56	972.00	44.12	1917.00	574.00
T_4:N:P:K @ 60.5:33:56+ Azotobacter	920.00	36.31	2219.67	560.67
T_5: N:P:K @ 60.5:16.5:56+ Phosphobacteria	1048.00	55.66	1730.33	488.00
T_6: N:P:K @ 60.5:16.5:56+Azotobacter+Phosphobacteria	992.33	47.31	1756.67	541.00
T_7: N:P:K @ 60.5 :33:56+Green manure	1044.00	54.51	2193.67	569.33
T_8:N:P:K @ 60.5:16.5:56+Green manure+Azotobacter+phosphobacteria	1234.00	83.65	2037.67	628.67
T_9:N:P:K @ 60.5:16.5:28+FYM @ 7.5 t ha^{-1}	1375.00	104.45	2434.00	803.33
T_{10}: Azotobacter+ Phosphobacteria+ FYM @ 7.5 t ha^{-1}	1205.33	79.63	1983.67	699.33
SEm±	36.26	6.62	32.34	35.46
CD (p=0.05)	76.17	14.04	67.94	74.50

on untreated control plot (675.67 kg ha^{-1}) followed by the plot treated with T_2 (NPK@ 80:40:40 kg ha^{-1}) (856 kg ha^{-1}) and T_4 (NPK @ 60.5:33:56 kg ha^{-1}+Azotobacter @ 250 g kg^{-1} seed) (920 kg ha^{-1}) and their difference was statistically significant except T_2 and T_4. The comparison between seed yield in different treatments over control was also statistically and significantly different. The maximum increase of seed yield over control was obtained in the treatment T_9 (104.45%) where NPK@ 60.5:16.5:28 kg ha^{-1} along with FYM 7.5 t ha^{-1} was used. Minimum increase in seed yield over control was recorded in the treatment T_2 (normal dose of NPK @ 80:40:40) (27.12%) which was statistically similar to the treatment T_4 (NPK @ 60.5:33:56 kg ha^{-1}+Azotobacter @ 250 g kg^{-1} seed (36.31%) (Table 6). Kolte and Awasthi (1987) reported that Alternaria blight can reduce the 1000 seed weight of mustard by 24%. Mahapatra and Das (2017) reported a 24.87% reduction in 1000 seed weight and yield loss of 31.69% due to Alternaria blight of mustard. Under favorable conditions, the pathogen is responsible for up to 70% yield loss, as mentioned by Gupta et al., 2020.

4. CONCLUSION

Highest disease severity would observed around 95 DAS, if it is accompanied by periods of high RH with intermittent rainfall, under West Bengal conditions. The forecasting system would help farmers in determining spraying schedule for disease management. Further, treatment with Azotobacter @ 250 g kg^{-1} seed, Phosphobacteria @ 250 g kg^{-1} seed along with FYM @ 7.5 ton ha^{-1} would be efficacious in disease management.

5. REFERENCES

Al-Lami, H.F.D., You, M.P., Barbetti, M.J., 2019. Incidence, pathogenicity and diversity of *Alternaria* spp. associated with alternaria leaf spot of canola (*Brassica napus*) in Australia. Plant Pathology 68(3), 492–503.

Anonymous, 2020. FAOSTAT crop statistics 2019. FAO of UN, International Fertilizer Industry Association. Available from http://www.fao.org/faostat/en/#data/QC. Accessed on 20th December, 2020.

Biswas, M.K., 2013. Influence of environmental factors on the development of *Alternaria* blight of mustard caused by *Alternaria brassicae*. The Ecoscan 4, 139–144.

Chattopadhyay, C., Agrawal, R., Kumar, A., Bhar, L.M., Meena, P.D., Meena, R.L., Khan, S.A., Chattopadhyay, A.K., Awasthi, R.P., Singh, S.N., Chakravarthy, N.V.K., 2005. epidemiology and forecasting of *Alternaria* blight of oilseed brassica in India-a case study/Epidemiologie und Prognose von Alternaria brassicae an Brassica-Ölfrüchten in Indien-Eine Fallstudie. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz. Journal of Plant Diseases and Protection 11(4), 351–365.

Cornell, J.A., Berger, R.D., 1987. Factors that influence the value of the coefficient of determination in simple linear and nonlinear regression models. Phytopathology 77, 63–70.

Dang, J.K., Kaushik, C.D., Sangwan, M.S., 1995. Quantitative relationship between Alternaria leaf blight of rapeseed–mustard and weather variables. Indian Journal of Mycology and Plant Pathology 25, 184–188.

Dhaliwal, R.S., Singh, B., 2020. Effect of weather parameters and date of sowing on intensity of Alternaria blight of rapeseed mustard. Indian Phytopathology 73(1), 89–95.

Dhingra, O.D., Sinclair, J.B., 1993. Basic methods in plant pathology. CRC press. 978-131-51-3813-8 (eBook). DOI 10.1201/9781315138138.

Gupta, R., Awasthi, R.P., Kolte, S.J., 2003. Influence of sowing dates and weather factors on development of Alternaria blight on rapeseed-mustard. Indian Phytopathology 56(4), 398–402.

Gupta, S., Didwania, N., Singh, D., 2020. Biological control of mustard blight caused by *Alternaria brassicae* using plant growth promoting bacteria. Current Plant Biology 23, 100–166.

Jagana, M., Zacharia, S., Lal, A.A., 2013. Management of *Alternaria* blight in mustard. Annals of Plant Protection Sciences 21(2), 441–442.

Jha, P., Kumar, M., Meena, P.D., Lal, H.C., 2016. Dynamics and management of Alternaria blight disease of Indian mustard (*Brassica juncea*) in relation to weather parameters. Journal of Oilseed Brassica 1(2), 66–74.

Kolte, S.J., Awasthi, R.P., 1987. Assessment of yield losses due to *Alternaria* blight in rapeseed and mustard. Indian phytopathology 40(2), 209–211.

Kumar, A., Agrawal, R., Chattopadhyay, C., 2013. Weather based forecast models for diseases in mustard crop. Mausam 64(4), 663–670.

Kumar, A., Kumar, S., Kumar, R., Chand, G., Kolte, S.J., 2014. Fungicidal effect of some non-conventional chemicals for management of alternaria blight disease of mustard. Journal of Applied and Natural Science 6(2), 913–919.

Mahapatra, S., Das, S., 2013. Evaluation of fungicides and botanicals against *Alternaria* leaf blight of mustard. Indian Journal of Plant Protection 41, 61–65.

Mahapatra, S., Saha, P., Das, S., 2018. 2018. Plant diseases forecasting in the era of climate change: Trends and applications. In: Das, S., Dutta, S., Chakroborty, B.N., Singh, D. (Eds.), Recent approaches for management of plant diseases, Indian phytopathological society, India, ISBN 81-7019-599-X (India) ISBN 1-55528-443-4 (USA)1-26.

Mahapatra, S., Das, S., 2014. Effect of meteorological factors on progression of Alternaria leaf blight of mustard and comparison of Logistic and Gompertz growth models in predicting disease severity. Indian phytopathology 67(2), 155–158.

Mahapatra, S., Das, S., 2016. Linear regression model for assessing the yield loss of mustard due to Alternaria leaf blight disease. Indian Phytopathology 69, 57–60.

Mahapatra, S., Das, S., 2017. Assessment of yield loss of mustard due to Alternaria leaf blight in Gangetic plains of West Bengal. Indian Phytopathology 70(3), 322–325.

Mahapatra, S., Saha, P., Das, S., 2014. Effect of different levels of nitrogen in field on Alternaria blight severity of mustard. Journal of Mycopathological research 52, 35–40.

Manjhi, P., Tomar, D., Srivastav, A., Nayak, M., 2018. Alternaria blight of mustard and its association with weather parameters. Annals of Plant and Soil Research 20(3), 250–253.

Meena, P.D., Meena, R.L., Chattopadhyay, C., Kumar, A., 2004. Identification of critical stage for disease development and biocontrol of Alternaria blight of Indian mustard (*Brassica juncea*). Journal of Phytopathology 152(4), 204–209.

Meena, P.D., Chattopadhyay, C., Meena, S.S., Kumar, A., 2011. Area under disease progress curve and apparent infection rate of Alternaria blight disease of Indian mustard (*Brassica juncea*) at different plant age. Archives of Phytopathology and Plant Protection 44(7), 684–693.

Neog, P., Sarma, K., Rajbonsi, R., Kalita, M.K., 2015. Development of weather based forewarning models for Downy mildew and *Alternaria* blight diseases of rapeseeds (*Brassica campestris*) in North Bank Plain zone of Assam. Mausam 66(2), 217–224.

Rathi, A.S., Singh, D., Avtar, R., Kumar, P., 2015. Role of micronutrients in defense to white rust and Alternaria blight infecting Indian mustard. Journal of environmental biology 36(2), 467.

Rayanoothala, P., Divya, M., Mahapatra, S., Das, S., 2021. Impact of elicitor seed treatment of mustard genotypes on various defense related compounds against *Alternaria* blight of indian mustard (*Brassica juncea*). Biological Forum-An International Journal, 13(2), 48–57.

Sandhu, K.S., Hari, S., Kumar, R., 1985. Effect of different nitrogen levels and dates of planting on Alternaria blight and downy mildew diseases of radish seed crop. PAU Agricultural Research Journal 22(2), 285–290.

Sangeetha, C.G., Siddaramaiah, A.L., 2007. Epidemiological studies of white rust, downy mildew and *Alternaria* blight of Indian mustard (*Brassica juncea* (Linn.) Czern. and Coss.) African Journal of Agricultural Research 2(7), 305–308.

Sharma, R., Sindhu, S., Sindhu, S.S., 2018. Suppression of *Alternaria* blight disease and plant growth promotion of mustard (*Brassica juncea* L.) by antagonistic rhizosphere bacteria. Applied Soil Ecology 129, 145–150.

Sharma, S.R., Kolte, S.J., 1994. Effect of soil applied NPK fertilizers on severity of black spot disease (*Alternaria brassicae*) and yield of oilseed rape. Plant Soil 167, 313–320.

Shekhawat, K., Rathore, S.S., Premi, O.P., Kandpal, B.K., Chauhan, J.S., 2012. Advances in agronomic management of Indian mustard (*Brassica juncea* (L.) Czernj. Cosson): An overview. International Journal of Agronomy 1–14.

Singh, B., Sran, A.S., Sohi, G.S., 2021. Innovative strategies to develop abiotic and biotic stress tolerance in mustard (Brassicaceae). In: Islam, A.K.M.A., Hossain, M.A., Islam, A.K.M.A. (Eds.), Brassica Breeding and Biotechnology. (1st Edn.) BoD–Books on Demand, 41–48.

Singh, H.K., Singh, R.B., Kumar, P., Singh, M., Yadav, J.K., Singh, P.K., Chauhan, M.P., Shakywar, R.C., Maurya, K.N., Priyanka, B.S., Srivastava, T., 2017. *Alternaria* blight of rapeseed-mustard: a review. Journal of Environmental Biology 38(6), 1405–1420.

Singh, H.K., Singh, S., Khan, N.A., Singh, R.P., Maurya, M.K., 2017a. Influence of sulphur and zinc on biochemical properties and severity of alternaria blight in indian mustard: influence of sulphur and zinc on biochemical properties of *Alternaria* blight in indian mustard. Journal of AgriSearch 4(3), 212–214.

Sinha, R.K., Rai, B., Sinha, B.B., 1992. Epidemiology of leaf spot of rapeseed mustard caused by *Alternaria brassicae*. Journal of Applied Biology 2(1/2), 70–75.

Syndecor, G.W., Cochran, W.C., 1967. Statistical methods, Oxford and IBH, Publishing company New Delhi. 593p.

Wheeler, B.E.J., 1969. An introduction to plant diseases. John Wiley and Sons Ltd., London.