Environment Conservation Journal 25 (1):33-40, 2024

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Epidemiological study of Alternaria blight of cabbage in Jorhat district of Assam, India

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ARTICLE INFO

Received : 07 May 2023
Revised : 10 October 2023
Accepted : 20 October 2023

Available online: 02 February 2024

Key Words:
Alternaria brassicicola
Area under disease progress curve
Disease severity
Epidemiology
Regression
PDI

ABSTRACT

The field experiment conducted during the period of 2021-2022 at the Department of Horticulture, AAU, Jorhat, has shown that the timing of transplantation significantly impacts the severity of Alternaria blight in cabbage. The study revealed that the timing of transplanting significantly affects disease severity. The crop transplanted in the month of December exhibited the highest disease intensity (maximum and minimum temperatures 24.76°C and 10.58°C, morning and evening relative humidity 98.41% and 57.13% respectively). The disease intensity was the lowest in October transplanted crops (maximum and minimum temperature 26.94°C and 12.22°C, relative humidity morning 96.12% and evening 55.13% respectively). The December transplanted crop had the highest AUDPC at 1317.75, followed by the February transplanted crop at 1037.85. With respect to the correlation matrix, rainfall and relative humidity showed a strong positive correlation with PDI whereas BSSH and temperature (maximum and minimum) all revealed a negative correlation. The multiple regression analysis revealed a substantial relation between disease intensity and meteorological conditions. The multiple regression equation indicated that the overall influence of all environmental parameters, namely (maximum and minimum) temperature, (morning and evening) relative humidity, rainfall, and BSSH on disease development ranged from 63.19% to 82.94%.

Introduction

The most common winter vegetable in India is cabbage (*Brassica oleracea* L var. *capitata*), which is profitable for farmers and belongs to the family Brassicaceae. Cabbage is most likely a native of Western Europe and the Northern Mediterranean region (Thompson and Kelly, 1957). This introduced vegetable crop has now thrived and spread throughout the Indian subcontinent. China is the largest producer of cabbage followed by India (Chadha, 2003). West Bengal, Orissa, Gujarat, MP, Bihar, and Assam are India's top cabbage-producing states. As per the data of Horticultural Statistics at a Glance (2018), Assam produced 640.13 thousand MT of cabbage in an area of 33.24 thousand ha during the year 2017-18 with a productivity of 19.26 MT/ha. The productivity was much less as compared to the country as a whole (22.7 MT/ha). The most prevalent and harmful disease of cabbage and Brassicas in the world are thought to be Alternaria leaf blight which is caused by *Alternaria brassicicola* (Meah *et al.,* 2002). The Pathogen infects the cabbage plant during the entire development stage of the crop (Valkonen and Koponen, 1990). Small brown patches on the leaves are the first signs, which progressively grow into larger lesions with concentric circles where spores

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Doi:https://doi.org/10.36953/ECJ.23422608

are formed. The disease initiates in the lower part of leaves and gradually progresses to the upper shoots, leaves, petioles, pods, and heads. On severely infected plants, defoliation of the outer leaves may occur. Aside from yield, susceptible varieties may experience a significant quality loss due to this disease. The pathogen needs free water for spore germination and the ideal temperature for spore germination, mycelial development and plant infection is 20°C to 30°C (Humpherson and Phelps, 1989), heavy dew and regular rains promote conidia formation (Nowicki *et al.,* 2012). Alternaria leaf blight development is primarily governed by environmental factors. The climatic factors, including temperature (maximum and minimum), humidity, rainfall and BSSH are crucial in the development of disease (Selvamani, 2014). As a result, it is important to examine critically how various epidemiological variables contribute to the emergence of crucifer disease in order to create efficient management strategies (Kumar and Kolte, 2001). Moreover, a mathematical model for predicting the correlation between climatic variables and disease intensity is urgently needed for successful management.

Material and Methods

The Randomised Block Design (RBD) with four replications for each treatment was used for the experiment. The entire experiment was conducted in the experimental field of the Department of Horticulture AAU, Jorhat. Twenty plots with the dimension 2.4 X 2.4 m^2 were prepared for the experiment for the following treatment combinations consisting of five dates of transplanting (DOT)- T1: 30th October, T2: 30th November, T3: 30th December, T4: 30th January, T5: 28th February. Throughout the experiment, the cabbage variety "Pride of India" was used. One month old seedlings were transplanted into each plot at a distance of 60 X 45 cm^2. The other cultivation techniques were used in accordance with the package of practice prepared by AAU, Jorhat, except for the management of the disease. Observations of Percent Disease Intensity (PDI) were recorded every fortnight in each treatment on 10 randomly selected plants from each plot (Selvamani *et al.,* 2014). The disease rating scale of 0-5 (Conn *et al.,* 1990) was used to record the data of disease severity, where 0 indicates no symptoms on the leaf; 1 indicates that less than 5% of the leaf surface is affected; 2 indicates circular grey spots, with concentric rings covering 6-10% of the leaf surface; 3 indicates enlarged lesions, grey circular spots with a black border and concentric rings covering 11-25% of the leaf surface; 4 indicates spots covering 26-50% of the leaf surface; and 5 indicates lesions with concentric rings and a black border which covers 50% or more of the leaf surface. The following method for determining disease intensity (McKinney, 1923) was used to compute the per cent disease intensity:

$$\textit{Disease intensity}\ (\%) = \frac{\text{Sum of all the disease ratings}}{\text{Total number of ratings x Maximum disease grade}}\ X\ 100$$

The Area Under Disease Progress Curve (AUDPC) was calculated using the method proposed by Campbell and Madden (1990).

$$AUDPC = \sum_{i=1}^{n-1} \frac{y_i + y_{i+1}}{2} X(t_{i+1} - t_i)$$

Where, y_i= Cumulative intensity of disease at i^{th}observation; ti= Time (number of days after transplanting) at i^{th}observations
n = Total no of observations.

The weather parameters, maximum and minimum temperature, rainfall, morning and evening relative humidity, and BSSH were recorded during the crop-growing period of October 2021 to May 2022 in order to assess the effects of various weather factors on the development of the disease. To determine the correlation between disease intensity and meteorological conditions, multiple regression analysis and correlation with disease intensity were also conducted. The forecasting formula shown below was employed (Gupta *et al.,* 2003; Jha *et al.,* 2013).

$$Y = a + b1A1 + b2A2 + b3A3 + b4A4 + b5A5 + b6A6$$

Where, Y= Disease severity (predicted); a= Intercept; b1 to b6= Partial regression coefficients; A1: Temperature (maximum) (°C); A2: Temperature (minimum) (°C); A3: Relative humidity (morning) (%); A4: Relative humidity (evening) (%); A5: Total rainfall (mm) and A6: BSSH (Sunshine/day)

Results and Discussion

Knowledge of disease intensity concerning meteorological parameters can help ensure successful and environmentally friendly control of cabbage leaf blight. This will allow them to forecast the emergence of the disease and assist producers in taking appropriate management action. The severity of Alternaria leaf blight of cabbage is heavily influenced by the weather (Table 1 and Fig 1). The crops transplanted in the month of October showed the lowest per cent disease intensity (PDI= 4.42, 8.96, 9.53, 10.5 and 12.21 in 1st, 2nd, 3rd, 4th and 5th fortnight respectively), whereas crop transplanted in the month of December showed the per cent disease intensity (PDI= 14.47, 16.73, 20.42, 22.44 and 27.33 in 1st, 2nd, 3rd, 4th and 5th fortnight respectively) in the field experiment. Notably, each fortnight of 30th October transplanted crops exhibited significantly lower disease intensity compared to the significantly higher disease intensity observed in cabbage transplanted on 30th December. During the month of October the average maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening), rainfall and the BSSH were 26.94°C, 12.22°C, 96.12%, 55.13%, 0.34 mm, 7.18 h respectively (Fig. 2). The meteorological parameters viz. the average maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening), rainfall and the BSSH were respectively during the month of December 24.76 °C, 10.58°C, 98.41%, 57.13%, 0.90 mm, and 5.8 h respectively. The combination of fairly low temperatures and moist, humid weather may be responsible for the development of Alternaria blight disease. Bart and Thomma, (2003) also reported the temperature between 20 to 27°C and relative humidity of 95-100% as essential parameters for developing the disease on crucifers caused by *Alternaria brassicicola*. Humpherson and Phelps (1989) similarly found that *Alternaria brassicicola* is responsible for Alternaria disease on cabbage. They observed that the severity of the disease increased when the pathogen generated spores in 12 to 14 hours, under optimal temperatures ranging from 18 to 24°C and 20 to 30°C. The pathogen requires free water for spore germination and the ideal temperature for spore germination, mycelial development, and plant infection. The severity of Alternaria blight rises with an average temperature between 13.5°C and 19.3°C and the disease intensity gradually increases with the days after sowing. This occurrence might be attributed to the delayed sowing resulting in the plant's vulnerable growth stage coinciding with the warm temperatures and high humidity as mentioned by Mahapatra *et al*. (2022). The plots transplanted in December had the highest average AUDPC (1317.75), followed by those transplanted in February (1037.85), January (983.25), November (728.4), and October (592.73) (Fig 3). The outcomes of this experiment were consistent with those of Hossain and Mian (2005) they observed that the severity of *Alternaria* blight increased with delay in planting. The crops planted in October had the lowest severity and those planted in December had the greatest. The seed yield per hectare was higher in October and November plantings than in December. According to Fagodiya *et al.* (2022), the severity of Alternaria leaf spot in soybean crops, as measured by the variance of AUDPC, is influenced by both the month of sowing and weather conditions. They found that various weather parameters and sowing dates play a significant role in the onset of the disease, affecting the infection process and pathogen spread. Yield and other growth parameters (numbers of loose leaves /plant, plant spread, diameter of head and head weight/plant) were found to be significantly better in early transplanted crops except for the plant height which was found non-significant in entire treatments (Table-2). The early transplanted crop on October 2021, had the highest yield (16.25 kg per plot or 28.21 t/ha), whereas the late transplanted crop on February 2022, had the lowest yield (10.52 kg per plot) (Table 2). Differences in the intensity of Alternaria blight may be one of the factors behind the different performance of transplanting dates on yield and other yield parameters. Similar findings were also reported by Lavanya *et al.* (2015) on cabbage they found that early transplanted crops gave better results in the case of yield and other attributes as compared to the latter transplanted crops. The figures followed by the same letters in the superscript are not significantly different at 5% significance level. The correlation coefficient depicted in Table 3 showed that there was a significant negative correlation with the maximum temperature on all the treatments except in the crop transplanted on 28th February (-0.835) where a non-significant negative correlation was recorded.

Table 1: Effect of date of transplanting on per cent disease intensity (PDI) of Alternaria blight under field conditions

Date of transplanting	PDI				
	1st fortnight	2nd fortnight	3rd fortnight	4th fortnight	5th fortnight
30th October	4.42d	8.96c	9.53d	10.50c	12.21d
30th November	8.80c	9.51c	10.31d	11.29c	17.54c
30th December	14.77a	16.73a	20.42a	22.44a	27.33a
30th January	10.62b	12.55b	14.24c	18.08b	20.52b
28th February	8.34c	14.28b	17.31b	18.92b	20.98b
SEd (±)	**0.61**	**1.08**	**1.28**	**0.91**	**1.28**
CD at 0.05	**1.33**	**2.36**	**2.80**	**1.98**	**2.79**

The figures followed by the same letters in the superscript are not significantly different at 5% significance level

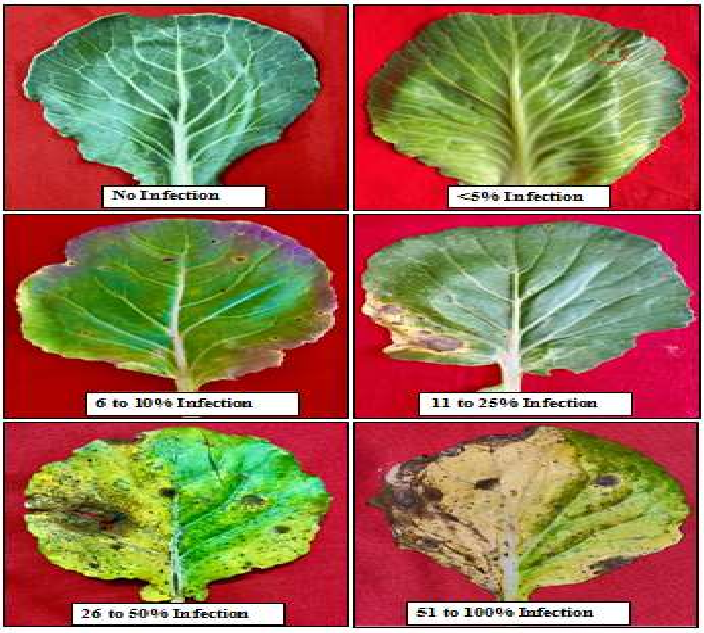

Figure 1: Scoring of disease infected leaves from 0-5 scale according to Conn *et al*. (1990)

Table 2: Effect of different transplanting dates on growth parameters and yield of Cabbage

Treatments	Plant height (cm) at 75 DAT	No. of lose leaves /plant	Plant spread (cm)	Dia. of head (cm)	Head weight (kg)/plant	Yield/plot (kg)	Yield (t/ha)
30th Oct, 2021	29.5	14.54a	54.34a	18.26a	0.818a	16.25a	28.21a
30th Nov, 2021	29.4	13.47b	53.33a	18.09a	0.807a	16.03a	27.84a
30th Dec, 2021	28.5	13.38bc	51.73a	16.16b	0.741a	14.62ab	25.37ab
30th Jan, 2022	28.4	12.57cd	47.52b	13.54c	0.581b	11.95bc	20.79bc
28th Feb, 2020	27.3	11.75d	45.64b	13.08c	0.477c	10.52c	18.27c
SEd (±)	**NS**	**0.39**	**1.89**	**0.76**	**0.045**	**1.54**	**2.23**
CD at 0.05	**NS**	**0.86**	**4.11**	**1.66**	**0.098**	**3.36**	**4.86**

Table 3: Correlation matrix between weather parameters with PDI on different transplanting dates

Date of transplanting	Correlation coefficient (r)					
	Weather factors					
	A_1	A_2	A_3	A_4	A_5	A_6
30th Oct, 2021	-0.970(**)	-0.923(*)	0.973(**)	-0.987(**)	0.929(*)	-0.795
30th Nov, 2021	-0.971(**)	-0.862	0.944(*)	0.965(**)	0.990(**)	-0.917(*)
30th Dec, 2021	-0.967(**)	-0.867	0.928(*)	0.954(*)	0.862	-0.955(*)
30th Jan, 2022	-0.979(**)	-0.929(*)	0.932(*)	0.970(**)	0.906(*)	-0.930(*)
28th Feb, 2022	-0.835	-0.859	0.930(*)	0.932(*)	0.921(*)	-0.948(*)

(*) correlation is significant at 0.05 level. (**) correlation is significant at 0.01 level.

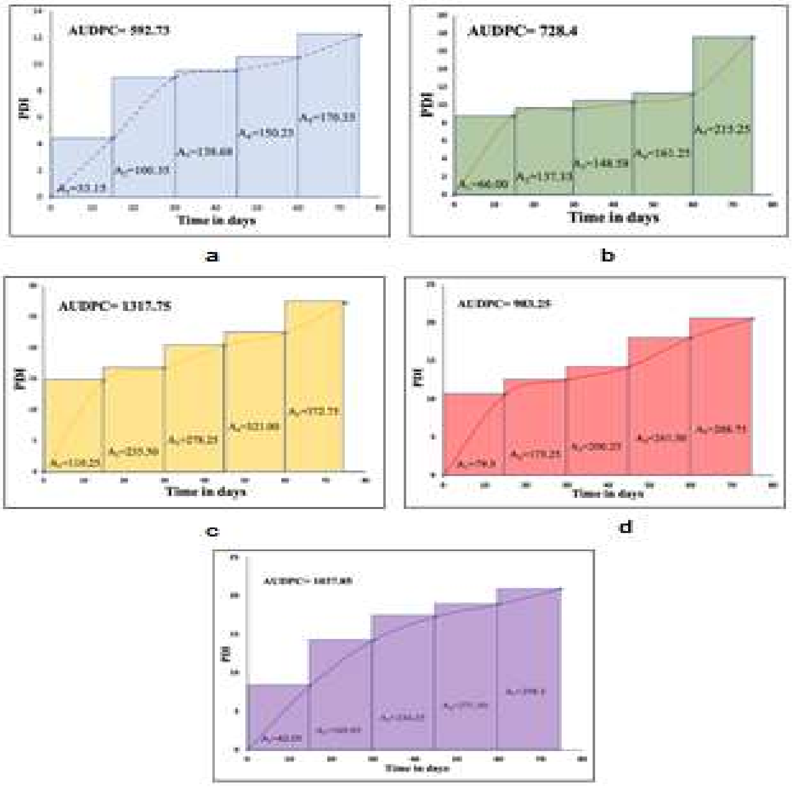

Figure 2: Effects of different dates of transplanting on AUDPC in relation to the Per cent disease intensity (PDI) of leaf spot of cabbage. a) 30st October 2021, b) 30st November 2021 c) 30st December 2021 d) 30st January 2022 and e) 28th February 2022

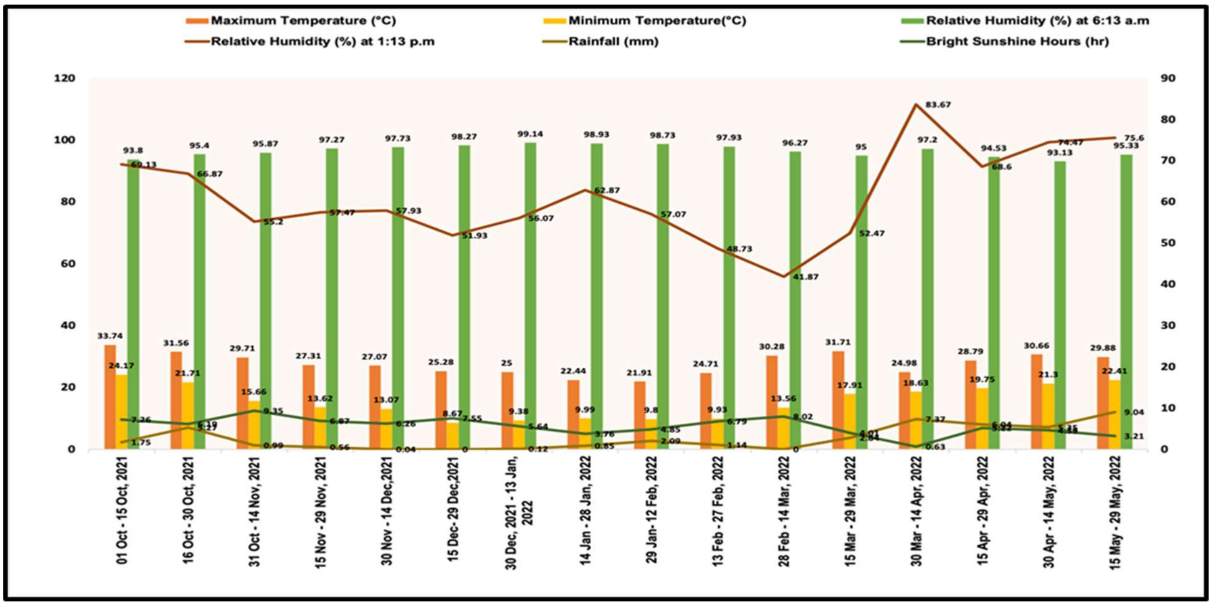

Figure 3: Weather data of Jorhat during the period of experiment taken from Meteorological Observatory, AAU, Jorhat (1st Oct, 2021 to 29th May, 2022)

With regard to the relative humidity recorded in the morning and evening, a significant positive correlation was obtained in all the treatments except for a significant negative correlation in the 30th October (-0.987**) evening relative humidity. A similar positive and significant correlation was obtained in the case of rainfall except in the crop transplanted on 30th December (0.862) where a non-significant positive correlation was found. A significant negative correlation was obtained with respect to the bright sunshine hours (BSSH) except for the crop transplanted on 30th October (-0.795), it showed a non-significant negative correlation. A high correlation was seen in the results of multiple regression analysis between PDI and meteorological variables during the crop season (Table 4). The total influence of all meteorological elements in the changing disease development was shown by the coefficient of multiple determinations (R^2), which ranged from 63.19% to 82.94% for the crop transplanted in October, November, December, January and February, respectively. The prediction equations for all treatments collectively demonstrated that weather factors had a combined influence to the extent of 82.94%, 63.19%, 72.70%, 76.32%, and 70.33%. Specifically, the multiple regression equations used to forecast the disease severity of Alternaria leaf blight in cabbage transplanted from 30th October to 28th February are as follows:

For 30th October transplant: $Y1 = 17.1708 - 0.2833A1 - 1.024A2 + 0.1924A3 + 0.0003A4 + 0.0037A5 - 0.6603A6$
For 30th November transplant: $Y2 = 23.1324 - 0.9045A_1 - 0.6160A_2 + 0.2430A_3 - 0.1080A_4 + 0.3639A_5 - 0.3787A_6$
For 30th December transplant: $Y3 = 15.1262 - 0.7080A_1 - 0.8312A_2 + 0.2981A_3 - 0.0240A_4 + 0.1794A_5 - 0.5203A_6$
For 30th January transplant: $Y4 = 10.5681 - 0.6536A_1 + 0.5426A_2 + 0.2552A_3 + 0.0726A_4 - 0.1356A_5 - 0.4153A_6$
For 28th February transplant: $Y5 = 32.4017 - 0.8132A_1 + 1.0248A_2 + 0.3525A_3 + 0.2167A_4 - 0.0708A_5 + 0.7338A_6$

Table 4: Multiple regression equation for prediction of percent disease index (PDI) of Alternaria leaf spot at five different dates of transplanting of the cultivar Pride of India using different combinations of weather factors

Date of transplanting	Intercept (a)	Regression coefficient (b)						R^2
		Weather factors						
		A_1	A_2	A_3	A_4	A_5	A_6	
30th October	17.1708	-0.2833	-1.024	0.1924	0.0003	0.0037	-0.6603	0.8294
30th November	23.1324	-0.9045	-0.616	0.2430	-0.108	0.3639	-0.3787	0.6319
30th December	15.1262	-0.7080	-0.8312	0.2981	-0.024	0.1794	-0.5203	0.7270
30th January	10.5681	-0.6536	0.5426	0.2522	0.0726	-0.1356	-0.4153	0.7632
28th February	32.4017	-0.8132	1.0248	0.3525	0.2167	-0.0708	0.7338	0.7033

A greater incidence of Alternaria leaf blight of mustard was also noted by Shrestha *et al.* (2005) in meteorological conditions with maximum temperatures of 18°C to 25°C, lowest temperatures of 10°C to 14°C, and relative humidity of more than 80%. Similar findings on the disease caused by *Alternaria brassicae* in the Brassica crop were also reported by Sinha *et al.* (1992) they reported that the disease intensity increases along with the plant age when the temperature ranges between 8-12°C minimum temperature to 21-26°C maximum temperature and 90% RH. According to Gemawat and Prasad (1972), high humidity >90% for around 3 days and a temperature of 23°C to 28°C increase the severity of *Alternaria* causing cumin blight. In their study on the Alternaria leaf spot of safflower, Murumkar *et al.* (2008) also observed that temperatures between 21°C to 33°C, high rainfall, and high humidity >80% had a significant impact on the disease development. During the study, it was observed that relative humidity (morning), relative humidity (evening) and rainfall had a positive correlation with the intensity of Alternaria leaf blight, while the temperature (maximum and minimum), and bright sunshine hours all had a negative correlation. The findings of Gupta *et al.* (2003) were in conformity with our findings. They also observed that the relative humidity (morning and evening) showed a significant positive correlation with disease intensity while the temperature (maximum and minimum) showed a significant negative correlation in the disease intensity of Alternaria blight on rapeseed mustard. In the cluster bean leaf blight, Sharma *et al.* (2020) also found the same kind of correlation matrix. Early studies on the various diseases caused by Alternaria also revealed a negative correlation between temperatures (maximum and minimum) and disease severity, while a positive correlation existed between relative humidity and rainfall (Bajaya *et al.,* 2022; Fagodiya *et al.,* 2022). It might be due to the favourable temperature for spore germination of Alternaria is the temperature in the range of 18°C and 24 °C and relative humidity levels above 90% (Nowicki *et al.,* 2012). The ideal temperature for spore germination of Alternaria, according to Selvamani (2014), was between 20°C and 24°C, with a relative humidity of at least 90%.

Conclusion

The time of transplanting had a considerable impact on the per cent disease intensity of Alternaria leaf blight. In the experimental year, crop transplanted in October had the lowest PDI and AUDPC, whereas the crop transplanted in December had the highest. Early transplanting was found to be beneficial for the farmers for the reduction of Alternaria leaf blight incidence. The development of the disease is significantly influenced by weather variables such as (maximum and minimum) temperatures, (morning and evening) relative humidity, rainfall, and BSSH. Development of a disease forecasting model for Alternaria blight of cabbage based on epidemiological factors becomes the need of the hour for a successful environment friendly disease management strategy.

Acknowledgement

The author acknowledges the Director of Post Graduate Studies, Head of the Department of Plant Pathology and all the faculties in the Department, Assam Agricultural University, Jorhat for the entire necessary help during the study.

Conflict of interest

The authors declare that they have no conflicts of interest.

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