665.334.9 : 632 (540.35)

Development of weather based forewarning models for Downy mildew and *Alternaria* blight diseases of Rapeseed (*Brassica campestris)* in north bank plain zone of Assam

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सार - डॉनी मिल्ड्यू तथा अल्टरनेरिया ब्लाइट तोरिया और सरसों की फसल को अत्यधिक प्रभावित करने वाली दो कवकीय बीमारियाँ हैं। ये आँकड़ें बी एन कृषि महाविद्यालय, असम कृषि विश्वविद्यालय, बिस्वनाथ करियाली, असम (26º 42' उ. और 93º 15' पूर्व) के फार्म की बलुआई दोम्मट मिट्टी में उगाई गई तोरिया की दो प्रजातियों टी एस. 36 एवं एम. 27 पर किए गए प्रयोग से प्राप्त किए गए हैं जो बारी-बारी से (वर्ष 2009-10 एवं 2010-11 में) रबी की फसल के लिए (बरसात के बाद) लगाई गई थी। ये फसलें 15 अक्तूबर से छः अलग-अलग तिथियों को सात दिनों के अंतराल पर लगाई गई ताकि भिन्न-भिन्न मौसमी परिस्थितियों में उस पर पड़े प्रभाव की जानकारी मिल सके। प्रत्येक खेत में 4 दिन के अंतराल पर लगाए गए 10 पूर्व चिन्हित पौधों पर डॉनी मिल्ड्यू और अल्टरनेरिया ब्लाइट की मौजूदगी देखी गई और खेतों में लिए गए प्रेक्षणों के आधार पर बीमारी सूचकांक के प्रतिशत (पी डी आई) की गणना की गई। बीमारियों की पी डी आई और औसत मौसमी परिस्थितियों (अधिकतम और न्यूनतम तापमान, सुबह और दोपहर के बाद की सापेक्षिक आर्द्रता, तेज धूप के घंटे तथा वर्षा) के सहसंबंध का अध्ययन किया गया एवं फसल की दोनों प्रजातियों की दोनों ऋतुओं में बीमारियों के रिकॉर्ड किए जाने की तिथि के पूर्ववर्ती पाँच दिनों के कुल ग्रोइंग डिग्री डेज (GDD) का पता लगाया गया। दोनों ही प्रजातियों में लगी हुई बीमारियों को पी डी आई के रूप में दर्शाया गया और इसे बीमारियों के रिकॉर्ड किए जाने की तिथि से पूर्ववर्ती पाँच दिनों में इनके औसत दैनिक न्यूनतम तापमानों (r = 0.54 से 0.90) एवं संचयित जी डी डी (r = 0.51 से 0.74) में महत्वपूर्ण रूप से कमी पाई गई है। अत: इन दोनों प्राचलों का उपयोग वास्तविक समय पर बीमारियों के लगने की पी डी आई का पूर्वानुमान करने के लिए मॉडल समीकरण विकसित करने में किया गया है जो अल्टरनेरिया ब्लाइट और डॉनी मिल्ड्यू के लगने की क्रमश: 51 से 60 और 53 से 58 प्रतिशत की परिवर्तिता को दर्शाता है।

ABSTRACT. Downy mildew and *Alternaria* blight are two economically important fungal diseases of Rapeseed and Mustard affecting the crop to a great extent. Data were generated from the field experiment conducted on sandy loam soil of the farm of B. N. College of Agriculture, Assam Agricultural University, Biswanath Chariali, Assam (26°42' N and 93°15' E) with two rapeseed cultivars TS-36 and M-27, which were grown in two consecutive rabi (post rainy) seasons (2009-10 and 2010-11). The cultivars were grown on six different dates starting from 15 October at seven-day intervals to enable the crop to get exposed to varying weather conditions. Incidence of downy mildew and *Alternaria* blight were recorded on 10 pre-labeled plants from each plot at 4-day intervals and percent disease index (PDI) were calculated based on the field observations. Correlation studies were done between PDI of diseases and average weather conditions (maximum and minimum temperature, morning and afternoon relative humidity, bright sunshine hours and rainfall) and accumulated growing-degree-days (GDD) in preceding five days of the date of record of diseases for both cultivars and seasons. Development of diseases expressed in terms of PDI in both the cultivars was significantly and negatively correlated with average daily minimum temperatures (r = 0.54 to 0.90) and accumulated GDD (r = 0.51 to 0.74) in preceding five days of the date of record of diseases. Hence, these two parameters were used to develop model equations to predict PDI of the diseases on real time basis which could explain up to 51 to 60 and 53 to 58 per cent of the variability in development of Alternaria blight and downy mildew, respectively.

Key words – *Brassica compestris* sub sp. oleifera (toria), Peronospora parasitica, *Alternaria* brassicae, Forewarning model.

1. Introduction

Rapeseed-mustard is an important oilseed crop in Assam state of India. Three ecotypes of *Brassica campestris* sub sp. *oleifera* namely yellow sarson, brown

sarson and toria as well as *Brassica juncea* are grown in an area of 300 thousand hectares in the state. The average productivity of crop in the state is 511 kg/ha which is far below than the national average of 999 kg/ha. Erratic and scanty rainfall leading to low soil moisture during crop

growth period and infestation of the crop with insect-pests and diseases are major factors causing low productivity of the crop in the state. The crop suffers from the attack of three major fungal diseases namely White rust [*Albugo candida* (Lev.) Kunze], downy mildew [*Peronospora parasitica* (Pers. Ex Fr.) Fr.] and *Alternaria* blight [*Alternaria brassicae* (Berk) Sacc.]. In general, these diseases occur regularly year after year during the crop season causing severe damage to the crop thereby reducing the seed yields to as high as 50 per cent (Kumar *et al.*, 2003). The loss occurring due to downy mildew is very high when it is accompanied by white rust and crop gets completely damaged. *Alteranaria* blight reduces 1000 seed weight causing yield loss up to 35-38 per cent (Kolte *et al.*, 1987). The damage is even more when the disease is associated with downy mildew. Weather plays very important role in the initiation and spread of plant diseases (Thind *et al.*, 2008). Intensive studies aimed at studying the relationship between important weather parameters as well as agro-meteorological indices like growing degree days with development of various diseases in different crops have been carried out (Saharan *et al.*, 1988; Saharan and Saharan, 2001; Gadre *et al.*, 2002; Sangeetha and Siddaramaiah, 2007; Mehta *et al.*, 2008; Kumar *et al.*, 2010; Bose *et al.,* 2010). Prediction of disease outbreaks enables the effective use of management of measures, such as chemical or biological treatment and also reduces the cost of disease management. Since weather has overriding effect on disease development; therefore, monitoring the weather is an important consideration in developing disease forewarning models. Many workers (Awasthi and Kolte, 1994; Dang *et al.,* 1995, 1998; Sheoran *et al.,* 1997; Sangwan *et al.,* 2000; Kumar *et al.,* 2010; Bose *et al.,* 2010) tried to exploit the relationship between weather and diseases; developed predictive models for downy mildew and other diseases based on regression analysis. Since a few or no study was conducted on the influence of weather parameters on downy mildew and *Alteranaria* blight diseases of this important oilseed crop in this part of the India. Therefore, an attempt has been made to develop forewarning model for downy mildew and *Alternaria* blight diseases in two rapeseed cultivars based on significantly related weather parameters and temperature-derived growing degree days.

2.   Materials and methods

Two rapeseed cultivars TS-36 and M-27 were sown under rainfed condition in two *rabi* (post-rainy) seasons 2009-10 and 2010-11 at weekly intervals on six dates starting from 15 October to 19 November ($D_{1 \text{ to }} D_6$) on sandy loam soil of the farm area of BN College of Agriculture, Assam Agricultural University, Biswanath Chariali, Assam (26°42' N and 93°15' E) having subtropical climate. Daily weather data during the crop

TABLE 1

Scale/description of the symptoms for downy mildew and *Alternaria* blight

Scale	Description of the downy mildew symptom	Description of the *Alternaria* blight symptom
0	Leaves free from infection	Leaves free from infection
1	Small creamy white to light brown spots on leaves covering <5% leaf area	Small irregular brown spots covering <5% leaf area
2	Small creamy white to light brown spots with cottony downy growth covering 5.1-10% leaf area	Small irregular brown spots with concentric rings covering 5.1-10% leaf area
3	Creamy white to light brown spots with cottony growth covering 10.1-25% leaf area	Lesions enlarging, irregular brown with concentric rings covering 10.1-25% leaf area
4	Creamy white to light brown spots with cottony growth covering 25.1-50% leaf area	Lesions coalesce to form irregular and appears as a typical blight symptom covering 25.1-50% leaf area
5	Creamy white to light brown spots with cottony growth covering >50% leaf area	Lesions coalesce to form irregular and appears as a typical blight symptom covering > 50% leaf area

seasons on maximum and minimum temperatures, morning and afternoon relative humidity, rainfall and bright sun-shine hours were taken from the record of agrometeorological observatory of BN College of Agriculture situated adjacent to the experimental field and used for computation of growing-degree-days (GDD). GDD were calculated following Neog *et al.* (2004) considering 5 °C as base temperatures. Incidence of downy mildew and *Alternaria* blight were recorded in 10 pre-labeled plants selected in each plot at 4-day intervals starting from the date of appearance of diseases in leaves using 0-5 scale (Table 1) [Sangeeta and Siddaramaiah (2007)]. The percent disease index (PDI) was calculated using following formula as given by Wheeler (1969).

PDI = [(Sum total of individual rating) / (No of leaves observed × maximum score)] ×100

Gravimetric soil moisture contents of upper 30 cm soil layer (0 to 15 and 15 to 30 cm) were recorded at seven-day intervals starting from 23 November to end of February in both the crop seasons and average soil moisture content of upper 30 cm soil layer.

Correlation and regression analysis was carried out between PDI of diseases and weather parameters (average maximum and minimum temperature, morning and afternoon relative humidity, bright sunshine hours and
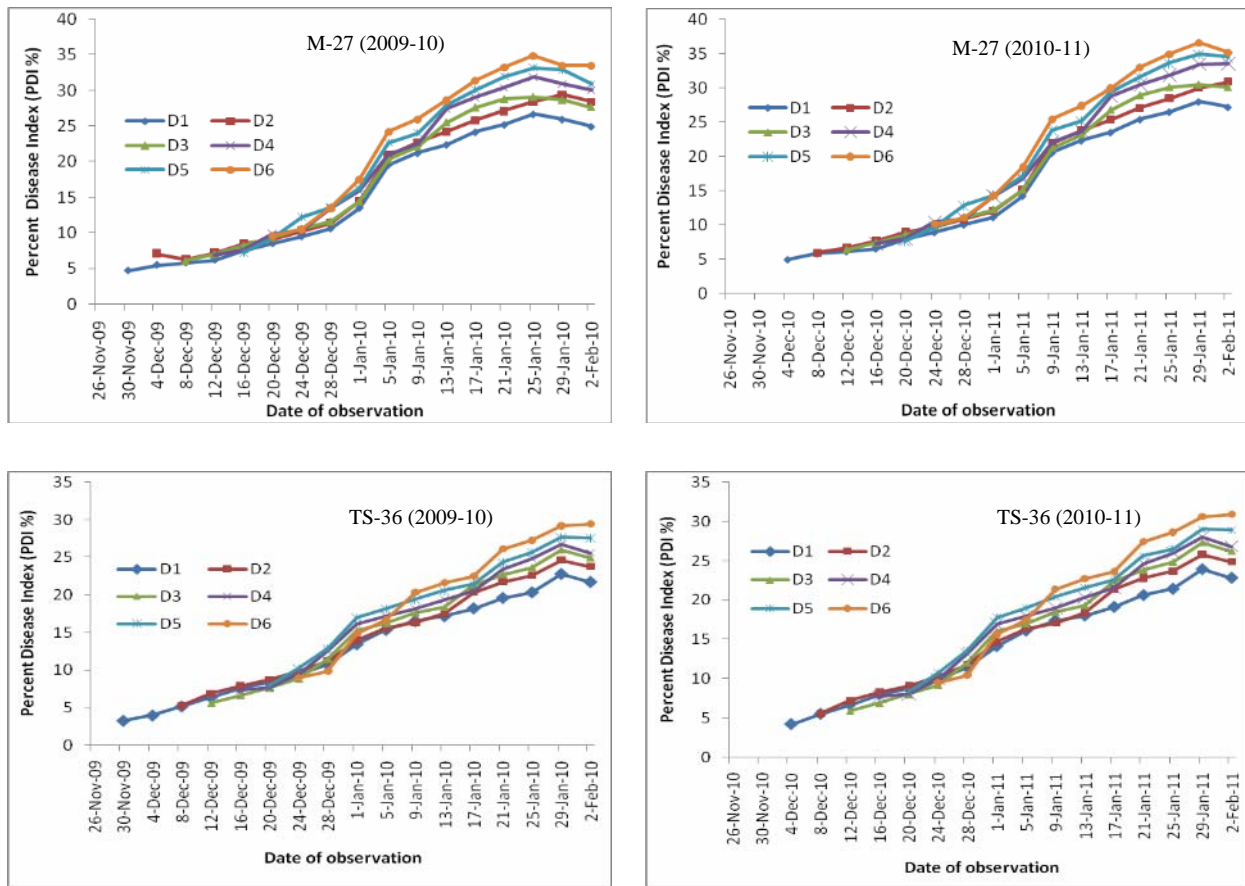
Fig. 1. Per cent disease index (PDI) of downy mildew in TS-36 and M-27 in different sowing dates during rabi (post rainy) 2009-10 and 2010-11

total rainfall) as well as GDD accumulated in preceding five days of date of record of diseases in both the cultivars and seasons. Multiple regression models were developed by clubbing significant weather parameters and agro-meteorological indices during flowering to maturity stage of the crop. The regression model taking disease variable as dependent and suitable independent variables such as weather variables, crop stages, initial PDI is used following Agrawal *et al.* (2004). The form of the model is

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + e$$

where, β_0, β_1, β_2,…β_p are regression coefficients, X_1, X_2, …, X_p are independent variables and e is error term. Keeping in view the five-day weather forecast available from India Meteorological Department (IMD), the weather data of five days preceding date of recording of disease was considered.

3. Results and discussion

3.1. *Incidence and development of downy mildew and Alternaria blight diseases*

In both the crop seasons (2009-10 and 2010-11), incidence of downy mildew and *Alternaria* blight in leaves were more in M-27 as compared to TS-36. Disease development expressed in terms of PDI for both the diseases increased gradually with delay in sowing and as the age of the crop increased (Figs. 1 & 2).

Downy mildew symptoms as minute brown to black spots on older leaves appeared 45-55 days after sowing in both the crop seasons and cultivars. The maximum PDI recorded in M-27 leaves ranged from 25 to 35 and 27 to 37 per cent during 2009-10 and 2010-11, respectively. However, the highest PDI was lesser in case of TS-36 leaves, which varied from 23 to 29 and 24 to 31per cent during first and second crop seasons respectively. Thus, incidence of downy mildew disease was more in second
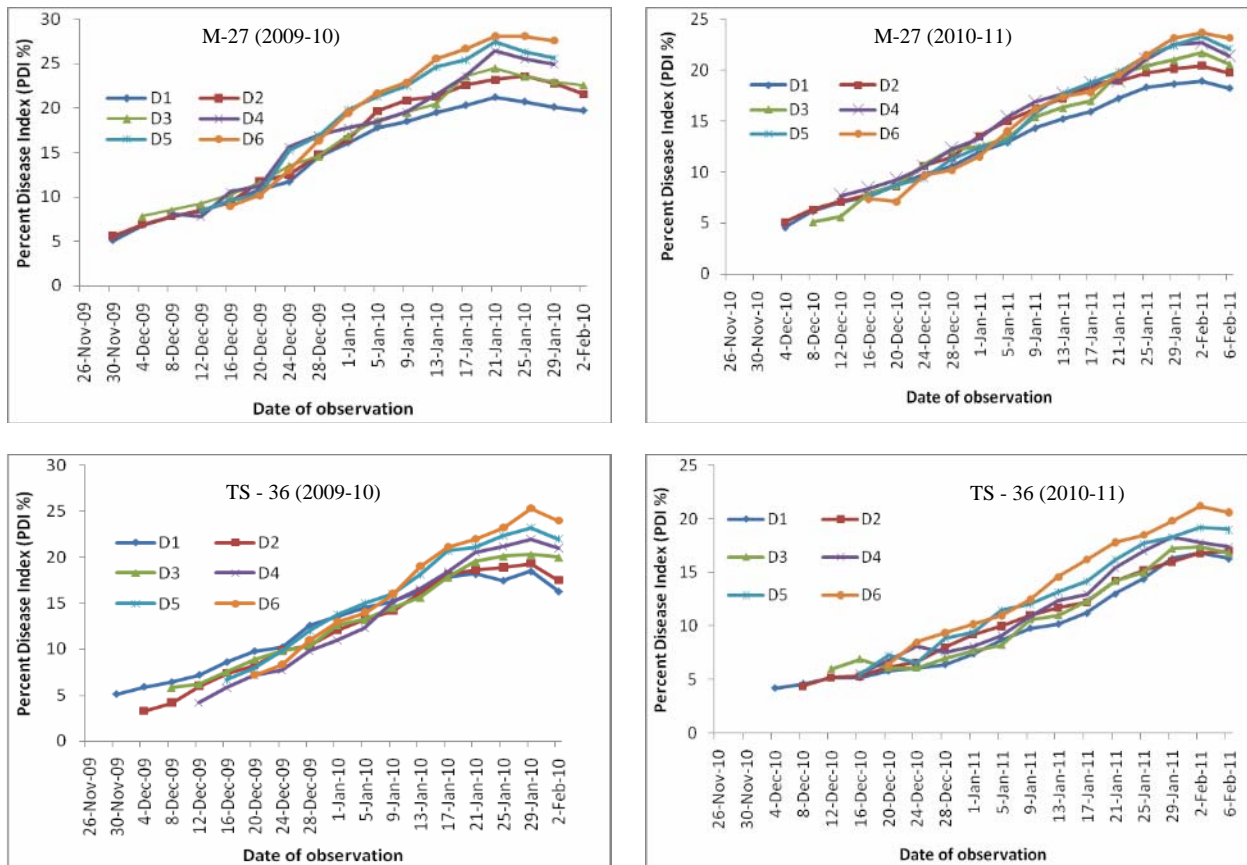
Fig. 2. Per cent disease index (PDI) of Alternaria blight in TS-36 and M-27 cultivar in different sowing dates during rabi (post rainy) 2009-10 and 2010-11
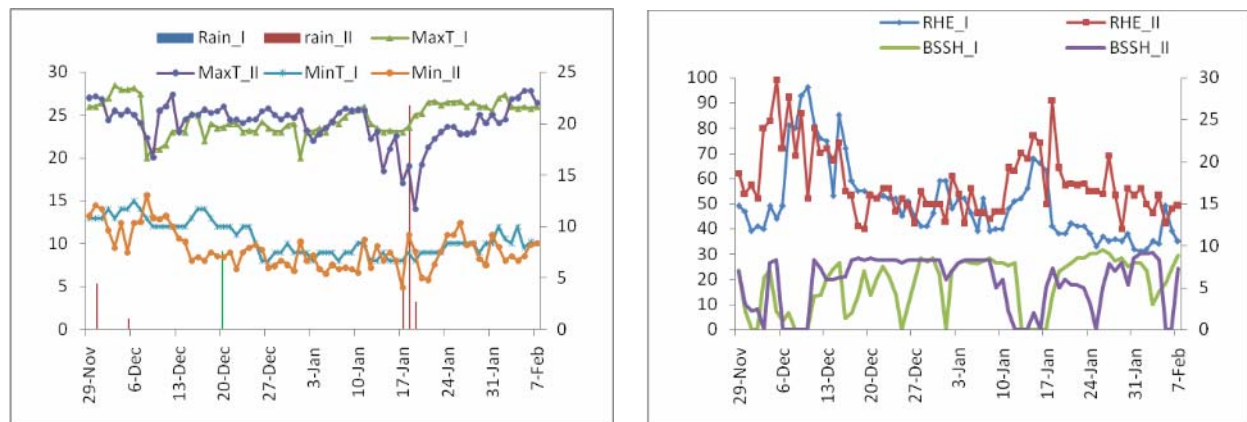

Fig. 3. Daily maximum temperatures, minimum temperatures and rainfall (A) and evening humidity and bright sunshine hours (B) during the period of development of diseases of *rabi* (post rainy) 2009-10 (I) and 2010-11 (II)

crop season as compared to first crop season in both the cultivars.

Unlike downy mildew the infestation of the crop with *Alternaria* blight was more in first crop season (2009-10) in both cultivars. Towards the end of the first

crop season the infected leaves with *Alternaria* blight were almost blightened and dried. The highest PDI recorded in case of M-27 varied from 19 to 27 and 17 to 25 per cent; while in case of TS-36 it varied from 16 to 24 and 17 to 22 per cent during first and second crop seasons respectively.

TABLE 2

Percent Disease Index (PDI) of *Alternaria* blight and downy mildew diseases in the leaves of TS-36 and M-27 (pooled for different sowing dates) and average weather condition and GDD accumulated in previous five days of the date of record of diseases during 2009-10 (I) and 2010-11 (II)

Date of observation	PDI (pooled for different sowing dates) of leaves								Temperature (ºC)				Accumulated GDD (°Days)		Relative humidity (%)				BSSH (hrs)		Rainfall (mm)	
	Alternaria Blight				Downy Mildew				Maximum		Minimum				Morning		Evening					
	M-27		TS-36		M-27		TS-36															
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
30-Nov	5.4	-	5.1	-	4.9	-	3.3	-	26.5	28.4	13.3	13.2	74.4	79.1	77.0	86.5	49.5	54.5	5.5	7.9	17.1	0.0
4-Dec	7.2	5.9	4.6	4.6	4.7	5.9	4.0	4.2	27.0	26.0	13.3	12.4	75.6	70.8	75.8	79.0	41.8	60.8	2.1	2.5	0.0	4.4
8-Dec	8.1	6.9	6.6	5.6	6.3	6.4	5.3	5.6	27.9	24.9	14.3	11.6	80.4	66.1	91.5	66.8	55.8	86.5	3.1	4.1	0.0	1.0
12-Dec	8.5	7.8	7.1	5.9	6.1	7.2	6.3	6.6	20.9	23.5	12.3	13.7	57.8	67.8	91.8	87.8	87.5	71.8	1.0	2.1	0.0	0.0
16-Dec	9.7	8.8	7.7	6.6	6.8	8.2	7.4	7.7	23.6	25.0	12.3	10.2	64.6	62.9	90.3	86.5	72.3	70.8	6.3	6.4	0.0	0.0
20-Dec	11.0	10.2	8.2	6.9	7.8	9.8	8.1	8.5	23.6	25.3	13.3	8.5	67.2	59.4	89.3	85.8	60.3	47.3	3.6	7.9	0.0	0.0
24-Dec	13.6	11.6	9.3	7.9	9.3	11.1	9.4	9.9	23.7	24.7	11.8	8.4	63.5	57.7	88.8	81.5	52.8	54.3	6.0	8.4	7.6	0.0
28-Dec	15.7	12.7	11.0	8.6	10.6	13.0	11.5	12.1	23.5	25.1	9.5	9.0	57.4	60.0	80.8	84.3	48.3	47.5	3.3	8.2	0.0	0.0
1-Jan	17.8	13.9	12.7	9.7	12.4	16.1	15.1	15.9	22.8	24.9	9.2	8.0	54.9	57.3	83.4	77.4	49.2	49.6	6.3	7.8	0.0	0.0
5-Jan	19.6	15.7	13.2	11.2	15.3	22.5	16.5	17.3	23.1	17.4	8.8	7.5	54.7	37.3	87.3	87.3	49.5	53.3	7.8	7.9	0.0	0.0
9-Jan	20.7	16.8	14.3	12.1	21.4	24.3	18.1	19.0	24.6	25.2	8.8	7.2	58.4	55.9	81.5	81.5	42.5	45.8	8.1	7.5	0.0	0.0
13-Jan	22.2	17.7	15.9	12.9	23.1	27.3	19.1	20.1	24.8	24.1	9.0	8.5	59.4	56.4	84.5	84.5	47.8	61.0	5.9	2.1	0.0	0.0
17-Jan	23.7	18.9	17.4	15.0	26.0	29.4	20.7	21.8	23.1	19.7	8.3	7.0	53.3	41.7	89.3	89.3	63.3	67.3	0.0	1.8	0.0	5.2
21-Jan	25.1	20.2	20.0	16.2	28.0	30.9	23.0	24.1	25.1	18.4	8.8	8.0	59.6	40.8	80.0	80.0	39.8	67.5	6.7	5.9	0.0	24.4
25-Jan	24.6	20.9	20.5	17.5	29.4	32.3	24.0	25.2	26.5	23.1	9.5	9.7	64.9	56.9	73.8	73.8	38.3	56.3	8.8	3.3	0.0	0.0
29-Jan	24.0	21.4	21.4	18.5	30.7	31.92	26.1	27.4	26.3	23.4	9.8	10.1	65.1	58.8	76.5	76.5	35.8	54.0	8.8	7.0	0.0	0.0
2-Feb	24.0	20.4	20.1	18.2	30.4	31.0	25.5	26.8	26.5	24.4	10.7	9.0	67.8	58.5	77.3	77.3	33.3	53.8	7.6	8.0	0.0	0.0

TABLE 3

Correlation coefficient between weather parameters and percent disease index (PDI) of *Alternaria* blight and downy mildew in TS -36 and M-27 sowing on different dates during *rabi* (post rainy) 2009-10 (I) & 2010-11 (II)

Weather	*Alternaria* blight (pooled for all sowing dates)				Downy Mildew (Pooled for all sowing dates)				*Alternaria* blight (pooled for all sowing dates and crop seasons)		Downy mildew (pooled for all sowing dates and crop seasons)	
	M27		TS 36		M27		TS 36					
Season	I	II	I	II	I	II	I	II	M-27	TS-36	M-27	TS-36
Tmax	-0.06	-0.57*	0.12	-0.52*	0.13	-0.63*	0.10	-0.54*	- 0.44	- 0.32	- 0.40	- 0.35
Tmin	-0.91*	-0.67*	-0.78*	-0.54*	-0.79*	-0.72*	-0.80*	-0.60*	-0.84*	-0.71*	-0.75*	-0.75*
RH I	-0.27	-0.13	-0.42	-0.21	-0.40	-0.08	-0.42	-0.18	-0.28	-0.39	-0.30	-0.37
RH II	-0.50*	-0.38	-0.56*	-0.30	0.52*	0.39	0.57*	0.25	-0.49	-0.47	0.42	0.50*
Rainfall	-0.39	0.26	-0.38	0.27	-0.33	0.44	-0.40	0.45	0.29	0.31	0.29	0.33
BSSH	0.47	0.01	0.54*	-0.03	0.46	-0.16	0.55*	0.01	-0.02	0.00	0.07	-0.04
Cum GDD	-0.51*	-0.66*	-0.62*	-0.74*	-0.62*	-0.74*	-0.51*	-0.66*	-0.57*	-0.63*	-0.64*	-0.61*

* Significant at 5% probability level
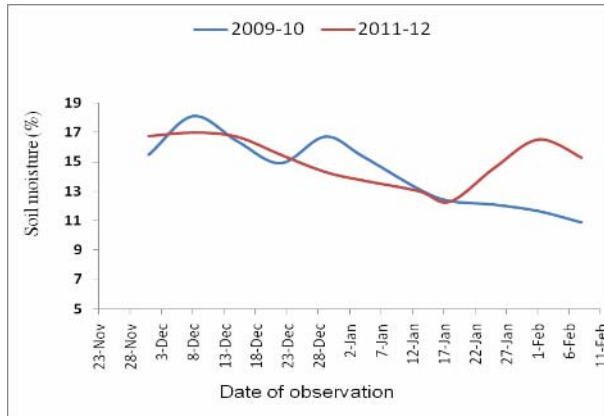
Fig. 4. Variation of average soil moisture (%) in upper 30 cm of soil profile during *rabi* (post rainy) 2009-10 and 2010-11

3.2. *Weather diseases relationship*

Weather conditions during the period of development diseases in both the cultivars and seasons were studied critically (Fig. 3). Incidence and development of downy mildew and *Alternaria* blight diseases of leaves was recorded from 15 November to the first week of February in both the cultivars and seasons. The PDI gradually increased and the highest PDI was reached during the first week of February in both the cultivars and seasons. The maximum and minimum temperatures during development of the diseases in both the cultivars and seasons varied from 4.9 to 15.6 °C and 14.0 to 28.0 °C, respectively. During the period of disease development, both the cultivars were exposed to higher daily maximum and minimum temperatures in case of first crop season as compared to the second crop season. The second crop season was relatively more humid and received 35.0 mm rainfall during disease development period. On the other hand, the first crop season received only 7.6 mm rainfall during the same period and was relatively dry. During the period of development of diseases, as expected, the moisture content in the upper 30 cm depth of soil was comparatively lower in the first crop season as compared to the second season (Fig. 4).

3.3. *Correlations studies with meteorological parameters*

The PDI (pooled data for different sowing dates) for downy mildew and *Alternaria* blight and the corresponding average maximum and minimum temperatures, morning and afternoon relative humidity, bright sunshine hours, rainfall (total) and accumulated GDD in preceding 5 days of date of observations are presented in Table 2. These data were used for calculating correlation coefficients.

TABLE 4

Model equations for predicting PDI (Y) of the diseases in leaves for toria cultivars TS-36 and M-27

Variety	Diseases	Models	R^2	±SE
TS -36	*Alternaria* blight	Y = 33.445 + 0.150 *Cum GDD - 2.897* Tmin	0.60	3.7
	downy mildew	Y = 41.916 +0.257 *Cum GDD -4.235 * T_{min}	0.58	5.5
M-27	*Alternaria* blight	Y = 28.44 + 0.162 * Cum GDD - 2.623* T_{min}	0.51	4.0
	downy mildew	Y = 49.338 + 0.361 * Cum GDD - 5.344*T_{min}	0.53	6.5

TABLE 5

Model equations for predicting PDI (Y) of the diseases in leaves for toria cultivars TS-36 and M-27 including Initial PDI

Variety	Diseases	Models	R^2	±SE
TS -36	*Alternaria* blight	Y = 5.03 + 0.04*Cum GDD - 0.043*T_{min}+0.838*IPDI	0.97	1.1
	downy mildew	Y = 5.22+0.03*Cum GDD - 0.453*T_{min}+ 0.917*IPDI	0.99	1.0
M-27	*Alternaria* blight	Y = 3.45 + 0.05*Cum GDD - 0.377*T_{min}+0.877*IPDI	0.97	1.0
	downy mildew	Y = 8.7 + 0.047*Cum GDD- 0.806*T_{min}+0.899*IPDI	0.98	1.3

Correlation coefficients obtained between PDI of downy mildew and *Alternaria* blight diseases and weather parameters for TS-36 and M-27 for two crop seasons is presented in Table 3. It was found that in both the crop seasons, PDI of both the diseases were negatively and significantly correlated (r = 0.67 to 0.91) with average minimum temperatures of previous 5 days of date of record of disease.

The interesting finding is that the afternoon relative humidity was negatively correlated to development of *Alternaria* blight diseases; however it was positively correlated to development of the downy mildew disease in both the crop seasons and cultivars. Though afternoon relative humidity was not significantly correlated with PDI during second crop season, value of '*r*' was substantially high even during this crop season.

No consistent relationship was observed between the PDI of the diseases and maximum temperature, morning relative humidity, rainfall and bright sunshine hours in both the seasons and cultivars.

PDI of both the diseases in leaves during the two growing seasons were significantly and negatively correlated to growing degree days accumulated during previous five days of date of record of diseases (*r* = 0.51 to 0.74).

3.4. *Development of regression models*

Based on significant correlation coefficients of selected parameters, *viz.* average minimum temperatures (T_{min}) and GDD accumulated (Cum GDD) in preceding five days of date of record of diseases during flowering to maturity stage of the crop were clubbed together for developing multiple regression models. The model equations were developed from pooled data (for all the sowing dates and both the crop seasons) for predicting PDI (Y) of the diseases for two cultivars separately and they are presented as Table 4.

Initial PDI (IPDI), which were calculated before five days of the day of forecast, when included in the equations, the accuracy of the forecast increased significantly (r^2 = 0.97 to 0.99 and SE = 1.0 to 1.3). Model equations developed using IPDI, minimum temperature and GDD are presented as Table 5.

Seasonal incidence of two important diseases and the role of weather parameters on disease development were studied in two cultivars of rapeseed. In both the seasons and cultivars, disease development was initially slow and increased gradually. The favourable ranges of minimum and maximum temperature for development of both the diseases were identified as 5.0 to 16.0 and 14.0 to 27.5 °C, respectively. Within these ranges, as temperatures decreased, PDI of the diseases increased in case of both the cultivars. Late sown crops got exposed to comparatively lower day and night temperatures. That is why they were more infected with the diseases as compared to early sown crops. Existence of cloudy weather coupled with rain or high evening relative humidity is congenial for development of most of the diseases. Prevailing high evening humidity (> 70%) from the first week of January possibly favoureds the development of downy mildew disease. In both the seasons, M-27 was infected more by both the diseases, which might be due to lower genetic resistance of the cultivar to the diseases.

The second crop season was relatively more humid with more number of rainy days and rainfall amount. As expected soil moisture content during second crop season was higher. On the other hand situation was reversed in the first crop season. During first crop season there was higher infection of both TS-36 and M-27 with *Alternaria* blight; while in the second crop season both the cultivars were infected more with downy mildew disease. It can be inferred that less evening humidity coupled with high day temperatures and less soil moisture prevailed during the first crop season, which might have accelerated the incidence of *Alternaria* blight in both the cultivars. On the other hand, prevailing high afternoon humidity, more recharge of soil moisture and comparatively lower day temperatures due to more number of rainy days favoured the development of downy mildew diseases in both cultivars in the second crop season. Correlation studies also revealed that the afternoon relative humidity was negatively correlated to development of *Alternaria* blight diseases; however it was positively correlated to development of the downy mildew disease in both the cultivars. In both the cultivars, diseases were significantly but negatively associated with average minimum temperatures in previous few days indicating that within favourable range, decrease in minimum temperature might have caused increase in growth rate of pathogens. Significant negative association of accumulated GDD in previous few days with the diseases in both the cultivars can be explained by the fact that decrease of incidence of diseases with decrease of thermal units accumulations in past few days might be due the lower minimum temperatures (on clear days) or maximum temperatures (on cloudy days) during disease development period in both the cultivars and seasons.

Our results are confirmatory with the earlier findings of Sangeetha and Siddaramaiah (2007), who reported that maximum downy mildew incidence was within minimum and maximum temperatures ranges of 4-16 °C and 26-29 °C, respectively. They also reported that maximum temperature of 27-28 °C minimum temperature of 14-15 °C and average relative humidity more than 65% was found favourable for *Alternaria* blight development. Our results are also supported by the findings of Saharan and Saharan (2001), who reported that *Alternaria* blight of cluster bean was negatively and significantly correlated with minimum temperatures. Our results are in support of earlier findings of Bose *et al.* (2010) and Kumar *et al.* (2010), who reported that minimum temperatures and GDD were negatively and significantly related to development of downey mildew disease in pearl millet. Similar to our findings, Kumar *et al.* (2010) revealed that mean temperature and growing-degree-day-based regression models explained up to 52 - 74 per cent variability in progress of downy mildew disease in pearl millet. A real-time forewarning regression models suggested in our paper need to be tested at different locations

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