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Progression of Powdery Mildew of Indian Mustard (*Brassica juncea* L.) in Relation to Weather Parameters

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Authors' contributions

This work was carried out in collaboration among all authors. Author PKV performed the experiment, statistical analysis and managed the literature searches. Author HSN designed the study and wrote the protocol as major advisor. Author GK wrote the first draft of the manuscript. Author RK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The work entitled "Progression of powdery mildew of Indian mustard (*Brassica juncea* L.) in relation to weather parameters" was carried out in Agriculture Research Farm, Banda University of Agriculture & Technology, Banda, Uttar Pradesh, India during *Rabi* 2020-21 season. As infection and development of a disease depends on the favourable environmental conditions hence, relationship between powdery mildew of Indian mustard and weather factors was evaluated in Ganga, Varuna, Giriraj and RH-0749 varieties of Indian mustard in which maximum temperature between 25-30°C, minimum temperature >10°C with minimum relative humidity (RH) <50% favoured the development of powdery mildew in all the four varieties Indian mustard varieties. Individual and combined effects of different weather parameters on development of powdery

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mildew was evaluated using correlation and regression analysis. Percent disease index (PDI) of powdery mildew was positively correlated with the maximum and minimum temperature whereas, it was negatively correlated with maximum RH, minimum RH and rainfall in Indian mustard varieties Ganga, Varuna, Giriraj and RH-0749. Coefficient of determination (R^2) explained that 96, 96, 95 and 96 % powdery mildew development was influenced by the maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and rainfall in Indian mustard varieties Ganga, Varuna, Giriraj and RH-0749, respectively. Multiple linear regression equation was developed to find out the expected PDI of the disease based on the predictor weather variables. Correlation analysis explained that warmer temperature and lesser humidity favoured the development of powdery mildew in Indian mustard. Multiple linear regression model developed in current investigation may be utilized for development of powdery mildew prediction model in Indian mustard.

Keywords: Indian mustard; powdery mildew; weather parameters; PDI.

1. INTRODUCTION

Indian mustard (*Brassica juncea* (L.) Czern. and Coss.) is an important cruciferous oilseed crop belonging to the family Brassicaceae. Mustard is renowned as the third most important oilseed crop in the world after soybean and palm oil. Indian mustard is an important source of edible oil especially in northern India with the lowest amount of saturated fats. Mustard leaves are a rich source of vitamins, minerals, fiber and antioxidants. Mustard seed and oil are used as a condiment in the preparation of pickles and for flavoring various dishes. The crop is also utilized for the manufacturing of various industrial products like soaps, hairs oils, paints, varnishes, textiles, lubricants, auxiliaries and various other products. Indian mustard holds nearly 38 to 57% erucic acid, 4.7 to 13% linolenic acid, 27% oleic acid and 10-12% linoleic acid with a higher amount of vegetable oil ranging between 38 to 49% [1].

In India, only 50 per cent of the domestic need of edible oil of the country is met with the current production of all oilseeds in the country and the deficit need is being covered with import of palm oil. The productivity of most of the oilseed crops in India is less than the word and the demand of edible oil in India is increasing at faster rate and it is estimated that to meet out the edible oil demand by the year 2030, it will be required to produce 32.35 million tons of oilseeds [2]. Presently, India produced 11.75 million tones rapeseed-mustard oilseed from an area of 8.06 million ha with productivity of 14.58 q/ha and is ranked third largest rapeseed-mustard growing country in the world [3].

One of the main reasons behind low productivity of the rapeseed-mustard in the country is powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell. Symptoms of the powdery mildew appears as dirty white circular floury patches on both sides of lower leaves which later increases in size with rise in temperature and coalesce to cover all leaves, pods and stem. Under severe condition, pods remain small in size and produce a few undersized and shriveled seeds. Powdery mildew has been reported from several parts of the world and is considered as one of the constraints in Indian mustard production in India and yield loss upto 17% has been reported in powdery mildew infected mustard crop [4]. Yield losses ranging between 10-90 per cent has also been reported from all across India [5,6].

Weather factors like temperature, relative humidity, rainfall etc. plays an important role in the development and spread of powdery mildew disease in Indian mustard. Relationship between environmental factors and disease development of *E. cruciferarum* was investigated on Indian mustard (*B. juncea*) and reported maximum disease development at average temperature ranging between 17.7 to 21.5°C with average relative humidity between 67 to 77 per cent [7]. Significant positive relationship of temperature with disease was also recorded through multiple regression analysis.

Since not much study on the weather parameters and powdery mildew of Indian mustard development has been done in the Bundelkhand region of Uttar Pradesh therefore, this investigation was carried out study the influence of weather factors on development of powdery mildew disease of Indian mustard so that their relationship could be found out which would be beneficial to know the role of weather factors in

disease development and devising timely disease prediction models.

2. MATERIALS AND METHODS

The experiment was conducted in the field of Agricultural Research Farm of Banda University of Agriculture & Technology (BUAT), Banda, UP, India during *Rabi* 2020-2021. Four varieties of Indian mustard viz. Ganga, Varuna, Giriraj and RH-0749 were sown on 27th October 2020 to evaluate the relationship of the development of disease with respect to average maximum and minimum temperature (°C), maximum and minimum relative humidity (%) and average rainfall (mm) under natural epiphytotic conditions. Each variety was sown in three uniform plots of 5×3 m^2 size and plant population was maintained with 30×10 cm^2 spacing in all plots. Recommended dose of fertilizers with NPK @ 50:40:40 Kg/ha was applied through urea, single super phosphate and muriate of potash, respectively. No disease management measures for any disease were taken during the course of evaluation. Daily data on weather parameters were obtained from the meteorological observatory of BUAT Banda and average of seven days was calculated to evaluate the role of different weather parameters in progression of the studied disease. Data on disease severity was recorded every week by calculating PDI after appearance of first symptom of the disease on the four Indian mustard varieties. Data was collected from randomly selected five plants from each of the three plots/ variety and scored on the basis of percentage of leaf area covered by the disease on fifteen leaves (5th lower, 5th middle and 5th upper leaves) in each selected plant. Per cent disease index (PDI) was calculated using 0-9 scale for powdery mildew [8] as given below (Table 1).

The per cent disease index was calculated according to [9].

Disease index (%) = (Sum of all disease ratings / (Total number of samples observed × Maximum disease grade)) × 100

Correlation coefficient (r), coefficient of determination (R^2) and multiple linear regression equation was analyzed using R software to know the individual and combined effects of different weather parameters on development of powdery mildew in varieties Ganga, Varuna, Giriraj and RH-0749. Multiple linear regression equation was formulated using equation as below:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5$$

Where,

Y = PDI
α = Intercept (constant)
βi = Regression coefficient associated with each Xi
i =1, 2, 3, 4, 5 are the weather variables
X_1 = Maximum temperature (ºC)
X_2 = Minimum temperature (ºC)
X_3 = Maximum relative humidity (%)
X_4 = Minimum relative humidity (%)
X_5 = Rainfall (mm)

Table 1. Rating scale for assessment of powdery mildew of Indian mustard

Rating scale	Infection on leaf (% area)
0	No lesion
1	Non-sporulating pinpoint size or small pustules/ patches, less than 5% leaf area covered by pustules/ patches.
3	Small roundish slightly sporulating larger creamy white pustules/ patches, about 1-2 mm in diameter with a distinct margin, 5-10% leaf area covered by pustules/ patches.
5	Moderately sporulating, non-coalescing larger creamy white pustules/ patches, about 2-4 mm in diameter with a distinct margin, 11-25% leaf area covered by pustules/ patches.
7	Moderately sporulating, coalescing larger creamy white pustules/ patches, about 4-5 mm in diameter, 26-50% leaf area covered by pustules/ patches.
9	Profusely sporulating, rapidly coalescing creamy white pustules/ patches measuring more than 6 mm in diameter without margins covering more than 50% leaf area.

3. RESULTS AND DISCUSSION

3.1 Effect of Weather Parameters

First symptom of powdery mildew in Ganga, Varuna, Giriraj and RH-0749 appeared on 4th meteorological weak i.e. 14th weeks after sowing during which the average maximum temperature recorded was 21.17ºC, average minimum temperature was 9.40ºC, average maximum RH was 93.42% and average minimum RH was 56.42% with no rainfall. Lower minimum humidity of 56.42% and increasing maximum and minimum temperature might have provided the congenial environmental conditions for infection of *Erysiphe cruciferarum* on mustard. The disease severity raised exponentially from 15th to 16th WAS and after 17th week it became static in all the four varieties. The highest disease severity was observed in 17th week in all the four varieties during which average maximum temperature, average minimum temperature, average maximum RH and average minimum RH were 29.48ºC, 14.0ºC, 80.42% and 37.71%, respectively. During the exponential phase of the disease, average maximum temperature, average minimum temperature, average maximum RH and average minimum ranged between 25.28- 29.48°C, 11.57- 14.0°C, 80.42- 91.25% and 36.14- 48.57%, respectively with 12.30 mm rainfall during the span of two weeks. Maximum powdery mildew severity of 44.5%, 41.09%, 39.06% and 38.73% was recorded in variety Ganga, varuna, RH-0749 and Giriraj, respectively (Fig. 1). The data indicates that maximum temperature between 25- 30°C, minimum temperature >10°C with maximum relative humidity <50% favoured the development of powdery mildew in all the four varieties. Similarly [10] also concluded that the severity of powdery mildew of Indian mustard progressed maximum at temperature above 22°C and relative humidity below 55 per cent. Severity of powdery mildew in Indian mustard cultivars Varuna and GM-2 was favoured by >2 days of morning relative humidity of <90 per cent, afternoon relative humidity 24-50 %, minimum temperature >5°C and maximum temperature in range of 24-30°C [11]. Similar results were reported by [12], they found humidity ranging 30.2- 48.8% and temperature ranging 12.2- 22.8°C favoured the development of powdery mildew of mustard and concluded that the disease did not respond to high humidity and required a dry environment with lower temperature. The workers also reported lower temperatures (5-10ºC) and higher temperatures (35-45°C) retarded the conidial production as well as germination whereas, higher conidial production with successful germination was observed at temperature of 25-30°C.

3.2 Correlation and Regression Analysis

PDI of powdery mildew of mustard was significant and positively correlated with the average maximum and minimum temperature whereas, it exhibited significantly negative correlation with the average maximum and minimum relative humidity in all the four varieties whereas, rainfall was non-significant and negatively correlated with development of powdery mildew. Thus, indicating that warmer temperature and lower relative humidity favours the development of podery mildew in mustard. Regression coefficients between PDI of powdery mildew variety Ganga, Varuna and RH-0749 were significant with maximum temperature and maximum RH whereas PDI in Giriraj was non-significant with both the weather variables. Regression coefficients of PDI of powdery mildew with minimum temperature, minimum RH and rainfall were statistically non-significant in all the four varieties (Table 2).

Coefficient of determination (R^2) was statistically significant for all the four varieties and explained that 96, 96, 95 and 96% disease development was influenced by the maximum temperature, minimum temperature, maximum RH, minimum RH and rainfall in varieties Ganga, Varuna, Giriraj and RH-0749, respectively (Table 3). Multiple linear regression equations developed (Table 3) for PDI and weather variables were statistically significant and showed that in variety Ganga, a unit change in maximum temperature could influence the PDI of powdery mildew upto an extent of 7.050 units, minimum temperature by 0.180 units, maximum RH by 1.583 units, minimum RH by 0.102 units and rainfall by -1.174 units In Varuna, a unit change in maximum temperature could influence the PDI of powdery mildew upto an extent of 6.534 units, minimum temperature by 0.162 units, maximum RH by 1.479 units, minimum RH by 0.089 units and rainfall by -1.090 units. In Giriraj, a unit change in maximum temperature could influence the PDI of powdery mildew upto an extent of 6.221 units, minimum temperature by 0.138 units, maximum RH by 1.427 units, minimum RH by 0.078 units and rainfall by -1.040 units. In RH-0749, a unit change in maximum temperature could influence the PDI of powdery mildew upto an extent of 6.200 units, minimum temperature by 0.156

units, maximum RH by 1.399 units, minimum RH by 0.087 units and rainfall by -1.034 units. Positive relationship of temperature with development of powdery mildew of mustard was also recorded by [7]. Similarly, [11] also reported that maximum temperature and minimum RH had positive and negative correlation to disease severity, respectively. Prediction equations explained 70%-97% powdery mildew development in mustard was influenced by the

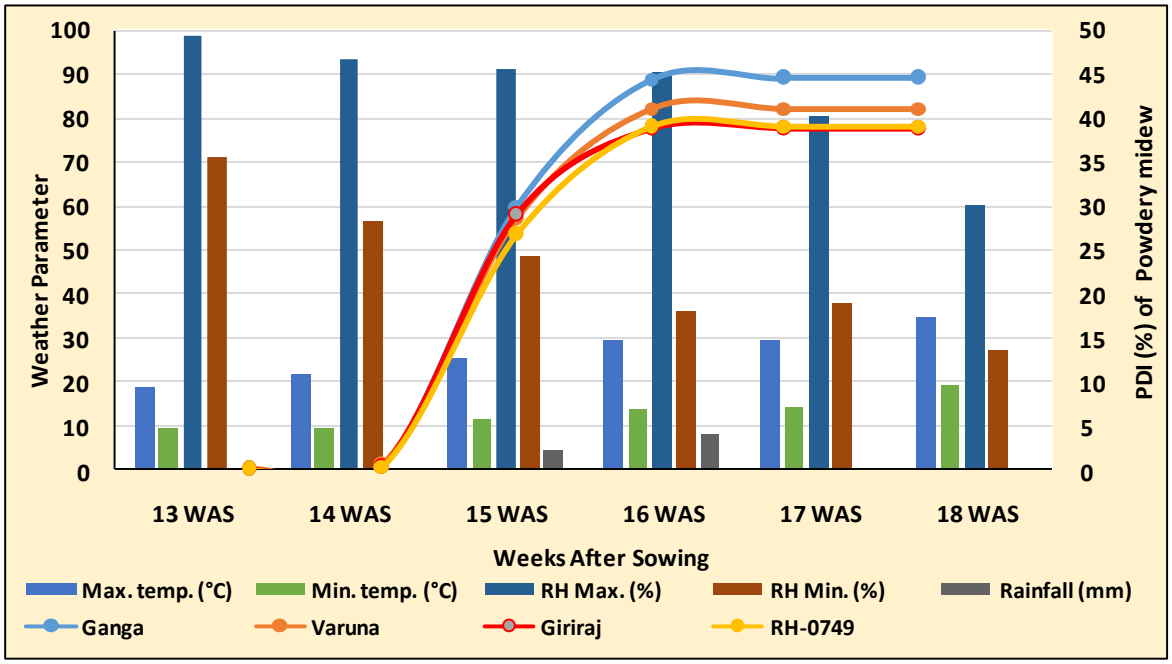

Fig. 1. Effect of weather parameters on powdery mildew in mustard (Ganga, Varuna, Giriraj and RH-0749)

Table 2. Correlation between weather variables and PDI of powdery mildew in mustard

Weather parameters	Correlation coefficient 'r'			
	PDI of Powdery mildew			
	Ganga	Varuna	Giriraj	RH-0749
Maximum Temperature (°C)	0.923**	0.921**	0.915**	0.922**
Minimum Temperature (°C)	0.759*	0.756*	0.748*	0.757*
Maximum RH (%)	-0.705*	-0.702*	-0.694*	-0.704*
Minimum RH (%)	-0.907**	-0.906**	-0.901**	-0.907**
Rainfall (mm)	-0.243	-0.243	-0.241	-0.244

** Significant at 5%, and ** Significant at 1% level*

Table 3. Multiple linear regression equation for development of powdery mildew in relation to weather parameters

Variety	Multiple linear regression equation	Coefficient of determination (R^2)
Ganga	Y= - 298.961 + 7.050 (Tmax)* + 0.180 (Tmin) + 1.583 (RHmax)* + 0.102 (RHmin) -1.174 (Rainfall)	0.96
Varuna	Y= - 277.730 + 6.534 (Tmax)* + 0.162 (Tmin) + 1.479 (RHmax)* + 0.089 (RHmin) -1.090 (Rainfall)	0.96
Giriraj	Y= - 265.484 + 6.221 (Tmax) + 0.138 (Tmin) + 1.427 (RHmax) + 0.078 (RHMin) -1.040 (Rainfall)	0.95
RH- 0749	Y= - 263.245 + 6.200 (Tmax)* + 0.156 (Tmin) + 1.399 (RHmax)* + 0.087 (RHMin) -1.034 (Rainfall)	0.96

** Significant at 5% level*

maximum temperature, RH (morning and evening) and average evening vapour pressure [13]. Optimum temperature (maximum 25ºC, minimum 7.1ºC with an average of 16ºC), low humidity (65%), minimum rainfall (0.6 mm) and dry weather in the month of February-March were most favorable conditions for the development of powdery mildew disease in mustard in Haryana, India on normal sown (October) crop [14]. Disease progression was also reported maximum in four Indian mustard varieties during mid of March when weather parameters viz., temperature (max.) 32.5^{0}C, temperature (min.) 12.7^{0}C, RH (M) 94.5%, RH (E) 38.5%, Avp. (M) 12.30 mm, Avp. (E) 14.30 mm were prevailing [15]. Similar findings on correlation and regression among powdery mildew of mustard and weather parameters have also been reported other workers [16,17,18].

4. CONCLUSION

It may be concluded from the experiments that, warmer temperature and lesser humidity were responsible for development of powdery mildew in Indian mustard. By utilizing the multiple linear regression equation, prediction model can be developed for powdery mildew of Indian mustard that would be helpful for timely prediction of the disease that would save the crop from losses by powdery mildew disease of Indian mustard.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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