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Research Article

Formulation of weather based forecasting model for mustard aphid, *Lipaphis erysimi* kalt. in Tarai region of Uttarakhand

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ABSTRACT
Lipaphis erysimi (Kalt.) infestation on mustard account for significant yield losses in India. Experimental data from sixteen years were used to study the role of weather on the incidence and development of mustard aphid. Temperature was found to regulate the aphid population build-up and arrival . Weather parameters before one week from aphid population observation contribute higher effect than of the same date, two week prior and three week prior observation. In the present investigation regression equation between aphid incidence and using previous week's weather data could be used for formulating the forecasting model for *L. erysimi*, and for taking control measures.
Keywords: *mustard, aphid, forecasting model, weather parameter, regression method.*

INTRODUCTION
Agriculture sector plays an important role in India's social security and overall economic welfare. Oilseeds crops are the second most important determinant of agricultural economy, next only to cereals. India has the 5th largest vegetable oil economy in the worldaccounting for 7.4% world oilseed output, 6.1 % of oil meal production, 3.9% world oil meal export, 5.8% vegetable oil production, 11.2% of world oil import and 9.3% of the world edible oil consumption next to USA, China, Brazil and Argentina. Rapeseed-Mustard is the main oilseed crop for the Rabi season which is planted on more than 80% area covered under oilseeds (Patel *et al.*, 2017). Among abiotic factors, its environmental sensitivity is considered to be foremost i.e. instability of mustard plant under different environmental conditions. Understanding of pest population dynamics in relation to weather factors can help in better management of pests (Patel and Singh, 2017). The data on pest infestation and weather parameters in a particular area over a long period of time can be used to develop pest weather models, which can then be used for agro-ecological pest zoning. Forecasting models are developed based on pest population relation with weather parameters of current or one or two lag weeks. However, peak pest incidence during a season may be the function of weather parameters of several preceding weeks or months Reliable and well-timed forecasts are of vital importance for appropriate and up-to-date planning's especially for agriculture which is full of uncertainties.

The dynamics of insect-pests and diseases will pose considerable threats to rapeseed mustard production. Both biotic and abiotic factors are responsible for pest population dynamics (Singh *et al.*, 2009).

Environmental parameters such as temperature, rainfall, sunshine hours and relative humidity greatly influence the outbreak of the insect population (Siswanto, Dzolkhifli and Elna, 2008). Pest population density solely depends on climatic factors of several preceding weeks or months. It thus becomes mandatory to find out the relationship of pest population with weather parameters of several preceding weeks. Knowledge of the seasonal incidence and population build up trend is essential to ensure timely preparedness to challenge impending pest problems and prevent yield losses (Das *et al*., 2008). Keeping this in view, present research was undertaken to formulate and validate weather-based forecasting model for the Tarai region of Uttarakhand, India.

MATERIALS AND METHODS
Forewarning model based on the weather factors as independent variables at the time of first arrival of aphid on mustard as dependent variables were suited by multiple regressions based on correlation coefficients between dependent variables under study with the respective weather parameter in different weeks. The historical data of eighteen years from 1998-99 to 2014-15 for Tarai region of Uttarakhand collected from annual progress reports of AICRP of rapeseed mustard,

Pantnagar, India. Sixteen years weather data with respect to different parameters was arranged week-wise, starting from onset of aphid population to migration of aphid population, standard week for all the years have used for model development. In order to normalize aphid population, square root transformed values were used in the analysis. Square root transformed peak mustard aphid population over the years were correlated with weekly values of each of the weather parameters separately, beginning with onset of aphid population until week of peak aphid population. In this way, most important week in relation to different weather parameters that influenced aphid population was detected. Values of each of the weather parameters during the most important week thus identified were used to develop a multiple linear pest-weather model. The model was validated through 2- year independent data on weather parameters and mustard aphid population which not be used for developing the model. These data was not be used in model development. The model performance was evaluated by comparing observed and predicted aphid population.

RESULTS AND DISCUSSION

To predict first arrival of aphid population, regression equations were used having high coefficient of determination and low error as well as test of statistical significance. Significant equations have been developed and tested on the basis of R^2 and standard error. It was found that the multiple linear equation developed for the weather data observation one week prior to peak aphid population has higher R^2(0.71) with standard error 2.72 but predicted same population of aphid with corresponding weather conditions, in comparison to the observed data of experimental year 2015-16 and 2016-17(Table 1). Pest–weather model between mustard aphid, *L. erysimi* (Kalt.) and all weather parameters was established as follows (Equation 2, Table 1).

$$Y=31.58+2.08T_{MAX} -2.76T_{MIN} -0.87RH1+0.65RH2-0.03RF-1.50SS+2.13WS$$

Weather parameters explained 70% variability in *L. erysimi* (p = 0.08). However, removal of WS(wind speed) resulted in an appreciable reduction in coefficient of determination (R2 = 0.49) rather it decreased, thereby indicating significant influence of WS on *L. erysimi* population(Equation 2, Table 1). Likewise, exclusion of SSH (sunshine hours) cause a significant reduction in R2 (0.32), suggesting significant role of SSH on mustard aphid population. However, exclusion of RF (rainfall) did not cause any reduction in R2 (0.31) suggesting insignificant role of RF on *L. erysimi* (Equation 3, Table 1). Further, RH1 was excluded and model with Tmax, Tmin, and RH1(relative humidity) could account for only 0.23 % variability in aphid population, thereby suggesting significant role of morning relative humidity (Equation 2.4, Table 1).

The observed and predicted values for aphid population using regression model for one week prior to aphid population have been presented in table 2. It is evident from the data, predicted points were found to be grater close proximity with observed data. RMSE was found to be 3.96 aphids for historical data points and RMSE (4.52 aphids)for observed data. Test of significance of the regression model (R^2 0.71) shows that wind speed and sunshine play a significant role in onset of aphid population after one week. The regression model of weather parameters of two and three weeks prior to aphid observation showed various contradictory data points. Due to erratic weather conditions observed from last sixteen years and also affected aphid population trend. Due to smaller coefficient of determination and higher standard error in model, developed for two and three week prior forecasting was underestimated. A large variation in the R^2 values was found in on same date, one week , two week and three week before. The possible reason for this could be the marked variation in sowing dates and abnormal weather conditions like minimum temperature and morning relative humidity in weather parameters and their partial coefficients determination (R^2) are shown in Table 1.

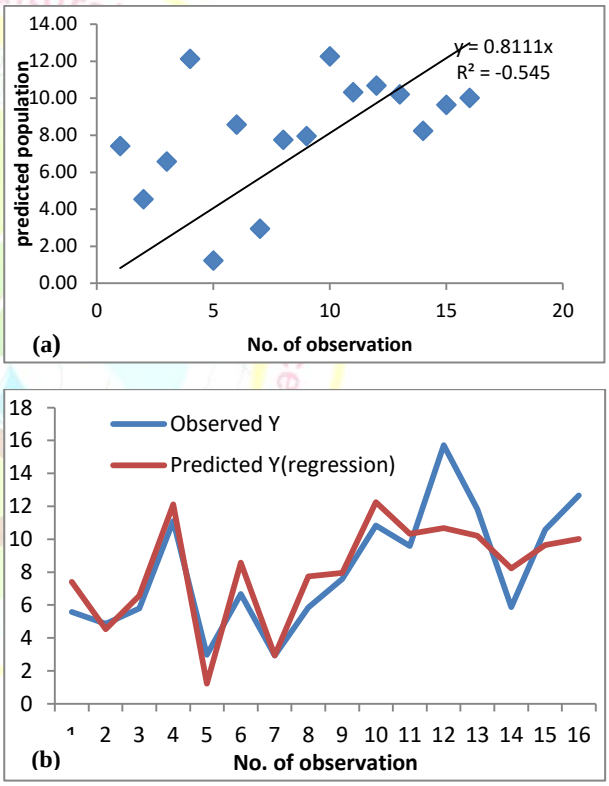

Fig. 1: Observed and predicted aphid population with one week before weather parameters (a,b)

Lowest R^2 value indicates non -significant effect of weather parameters on the same date, two week prior and three week prior population observation. However, during establishment phase, minimum temperature has significant contribution in population build up. Weather parameters before one week from aphid population observation contribute higher effect than of the same date, two week prior and three week prior observation. Where, minimum temperature and morning relative humidity significantly influenced the aphid population. The study is in conformity with the report of Dhaliwal *et al.* (2007) which stated the similar results of R^2 value which was 0.42.

Table 1: Equation developed by taking four time periods of weather variables with aphid population

Eq. no.	Regression equation obtained	R^2	SE	F_{sig}
On same date				
1	$Y= 114.56-1.66X_1+2.65X_2-0.46X_3-0.71X_4-0.01X_5-1.68X_6-0.12X_7$	0.57	3.29	0.27
1.1	$Y= 112.44-1.66X_1+2.61X_2-0.44X_3-0.71X_4-0.02X_5-1.68X_6$	0.57	3.12	0.16
1.2	$Y= 90.64-2.02X_1+2.47X_2-0.37X_3-0.46X_4+0.003X_5$	0.44	3.37	0.24
1.3	$Y= 91.12-2.03X_1+2.5X_2-0.38X_3-0.46X_4$	0.44	3.22	0.13
One week before				
2	$Y= 31.58+2.08X_1-2.76X_2-0.87X_3+0.65X_4-0.03X_5-4.5X_6+2.13X_7$	0.71	2.72	0.08
2.1	$Y= 21.29+2.24 X_1-2.59 X_2-0.65 X_3+0.54 X_4+0.03 X_5-1.7 X_6$	0.49	3.38	0.2
2.2	$Y= 23.42+10.5 X_1-1.38 X_2-0.55 X_3+0.43 X_4+0.01 X_5$	0.32	3.71	0.5
2.3	$Y= 19.45+1.10 X_1-1.42 X_2-0.52 X_3+0.45 X_4$	0.31	3.56	0.33
2.4	$Y= 29.82+1.24 X_1-1.36 X_2+0.4 X_4$	0.23	3.60	0.33
Two week before				
3	$Y= -74.78+1.52X_1-1.06X_2+0.60X_3+0.14X_4-0.03X_5-1.13X_6+0.38X_7$	0.31	4.20	0.80
3.1	$Y= -81.26+1.86X_1-1.14X_2+0.59X_3+0.19X_4-0.03X_5-1.24X_6$	0.30	4.0	0.68
3.2	$Y= -48.44+1.49X_1-0.69X_2+0.16X_3+0.28X_4-0.05X_5$	0.25	3.9	0.65
3.3	$Y= -20.02+1.49X_1-0.88X_2-0.12X_3+0.26X_4$	0.17	3.9	0.69
Three week before				
4	$Y= -132.66-0.34X_1+0.33X_2-0.85X_3-0.44X_4-0.005X_5-1.9X_6-1.35X_7$	0.52	3.50	0.38
4.1	$Y= 101.43-0.65X_1+0.03X_2-0.56X_3-0.36X_4+0.03X_5-1.42X_6$	0.41	3.66	0.45
4.2	$Y= 103.21-1.16X_1+0.28X_2-0.65X_3-0.23X_4-0.02X_5$	0.35	3.64	0.42
4.3	$Y= 109.60-1.25X_1+0.21X_2-0.69X_3-0.25X_4$	0.34	3.49	0.28

Where,

X_1	Maximum temperature (^oC)	X_5	Rainfall (mm)
X_2	Minimum temperature (^oC)	X_6	Sunshine (hours)
X_3	Morning relative humidity (%)	X_7	Wind speed (km/hr)
X_4	Evening relative humidity (%)		

Table 2: Observed and predicted aphid population by regression model (R^2=0.71)

Observation (Year)	Observed Y	Predicted Y	Residuals
1 (1998-99)	5.58	7.46	-1.88
2 (1999-2000)	4.86	4.54	0.32
3 (2000-01)	5.8	6.70	-0.90
4 (2001-02)	11.1	12.13	-1.03
5 (2002-03)	2.98	2.15	0.83
6 (2003-04)	6.67	8.57	-1.90
7 (2004-05)	2.93	7.44	-4.51
8 (2005-06)	5.86	7.48	-1.62
9 (2006-07)	7.58	10.16	-2.58
10 (2007-08)	10.84	12.81	-1.97
11 (2009-10)	9.58	10.26	-0.68
12 (2010-11)	15.71	10.96	4.75
13 (2011-12)	11.82	10.32	1.50
14 (2012-13)	5.88	7.85	-1.97
15 (2013-14)	10.59	9.57	1.02
16 (2014-15)	12.66	10.01	2.65
RMSE=3.96			
An independent data set(Predicted aphid population)			
17 (2015-16)	14.03	14.09	-0.062
18 (2016-17)	12.31	9.49	2.817
RMSE=4.52			

The population aphid exhibited negative correlation with maximum and minimum temperature, rainfall, wind velocity, evaporation and positive with afternoon and morning relative humidity. The values of coefficient of determination (R) were high (0.92 to 0.99), indicated that the population of mustard aphid greatly governed with the weather parameters. The temperature (maximum 18.7 and minimum 5.0 C), relative humidity (morning 91.5 and evening 50.5 percent), rainfall (000.0 mm), evaporation (below 1.55 mm), bright sun shine hours (below 5.8 hr) along with wind speed below 3.4 km/hr were found very conductive for *L. erysimi* (Hasan and Singh, 2010).

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