CLIMATIC FACTORS AFFECTING THE POPULATION DYNAMICS OF LENTIL APHID IN INNER TERAI REGION OF NEPAL

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ABSTRACT
Population dynamics of lentil aphid *Aphis craccivora* (Hemiptera: Aphididae) was assessed in relation with climatic parameters at the research field of National Maize Research Program (NMRP), Rampur, Chitwan during winter season of two consecutive years 2016 to 2018. The experiment was organized in randomized complete block design consisting 20 lentil varieties with three replications. The crop was sown during last week of November in both the years. The daily meteorological parameters like maximum temperature (Tmax), minimum temperature (Tmin), relative humidity (RH) and rainfall (Rf) were recorded at the meteorological station located in NMRP, Rampur, Chitwan and then converted into weekly basis as the standard meteorological week (SMW) with correspondence to weekly population of aphid. The incidence of aphid was started from 2nd SMW of January (2 aphid/plant/10 cm apical twigs) during both experimentation years. Initially the population was low and gradually increased and reached to its peak (49 aphid/plant/10cm apical twigs) on 9th SMW i.e. first week of March with correspondence to weather parameters viz. maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) were 30.80, 15.34, 67.72 and 0, respectively over the years. The aphid population had significant positive correlation with Tmax (r= 0.94) while the Tmin showed highly significant correlation (r=0.99). The relative humidity (RH) had non significant negative correlation (r= -0.90) and rainfall (Rf) showed non significant negative impact (r= - 0.15) with aphid population. The regression model developed could explain 99% variation in aphid population in different cultivars of lentil.

**Keywords:** *Aphis craccivora*, *Lens culinaris*, Temperature, Relative humidity, Rainfall,

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INTRODUCTION

Lentil (*Lens culinaris* Medik) is a major grain and widely distributed legume crop grown under a broad range of climates in many developing countries (Turk et al., 2004). This crop is grown mainly as an inexpensive source of high quality protein in human diets (Salehpour et al., 2009). It is one of the most important and highly commercialized pulse crops among the grain legumes in terms of area (206969 ha), production (254308 mt) and productivity (1229 kg ha\(^{-1}\)) which shares almost 62% of total area and 65% of total production of pulses and also rates the higher consumer preference in Nepal (MoALD, 2017). However, the lentil average yields in our country yet low as compared to other countries due to many constraints like insect pest and diseases incidence, delay sowing and others management practices. Among different insect pests of lentil, aphid (*Aphis craccivora* Koch.) infestation is one of the major problems and widely distributed throughout the world.

Aphid causes damage directly by sucking the phloem from the different parts of the plants (Ali and Rizvi, 2007). Aphids feed on plant sap, disrupting the normal plant growth pattern including reduction in root and nodulation growth. At high aphid densities, plants are deformed; stunted and seed set is reduced (Sharma et al., 2014).

The population dynamics of this pest considered to be highly influenced by prevailing weather condition particularly temperature and relative humidity. Several studies have been indicated that weather plays an important role on the aphid appearance, multiplication and disappearance (Srivastava and Srivastava, 1972; Roy, 1975; Kumar et al., 1999; Srivastava, 1999; Vekaria and Patel, 2000). The efforts have been made by Kishor et al. (2019) to correlate the temperature and relative humidity with the incidence and multiplication of aphid in the lentil crop. The changes in aphid population with change in weather parameters enable to forecast the population of lentil aphid under changing scenarios of climate using statistical approaches. Statistical forecasting model is the best approach that would be helpful to provide the information regarding incidence of pest in an advance based on medium range weather forecast. Thus, an attempt has been made to quantify the relationship between weather parameters and appearance, development of aphids in lentil crop at inner Terai region of Nepal.

MATERIALS AND METHODS

The study was conducted on lentil (2n=14) crop during winter season of two consecutive years 2016 to 2018 at the research field of National Maize Research Program (NMRP), Rampur, Chitwan. Geographically, the location is situated at 27°40' N latitude and 84°19' E longitude at an altitude of 228 m above mean sea level having humid and subtropical climate with cool winter and hot summer. The study was laid down in randomized block design consisting 20 lentil varieties received from Grain Legumes Research Program (GLRP), Banke as a collaborative trial with three replications. The crop was sown during last week of November in both the
years. The plots were maintained following the recommended agronomic practices in same manner for all the treatments. All the plots were kept free from any insecticidal spray throughout the crop period. The number of aphids per 10 cm of the main shoot of the 10 pre-labeled randomly selected plants from each plot was counted at weekly interval from the day of aphid appearance in the field and then was averaged. Twenty varieties were cultivated in each year and each variety was raised in three plots. It means that every year lentil was cultivated in (20×3) 60 plots and every sampling day observation was done on (60×10) 600 plants. The daily meteorological parameters like maximum temperature (Tmax), minimum temperature (Tmin), relative humidity (RH) and rainfall (Rf) were recorded at the meteorological station located in the National Maize Research Program, Rampur, Chitwan and then converted into weekly basis against the standard meteorological week (SMW) with correspondence to weekly population of aphid. The pooled data of aphid population over the years was taken for the correlation and regression analysis. The weekly population of aphid was considered as dependent variable and correlated with corresponding weekly weather parameters as independent variables. On the bases of significant correlation coefficients between aphid population and weather variables, stepwise regression study was performed to develop statistical forewarning model. Aphid populations are influenced not only by a single weather variable, but by the interaction effect of more than one variable. Hence, multiple regression models were developed based on significant correlation coefficients between aphid population and weather variables by using stepwise regression method for predicting aphid population.

The multiple linear regression model used as follows;

\[ y = \beta_0 + \beta_1 w_1 + \beta_2 w_2 + \beta_3 w_3 + \beta_4 w_4 \]

Where \( y \) = Response or dependant variable i.e. aphid per plant

\( \beta_0 \) = Constant, \( \beta_{(1-4)} \) = Un-standardized coefficient for each predictor variables

\( w_1 \) = Average Tmax in °C (During SMW)
\( w_2 \) = Average Tmin in °C (During SMW)
\( w_3 \) = Total Rf in mm (During SMW)
\( w_4 \) = Average RH (%) (During SMW)

Here, the aphid per plant is a response variable where as average Tmax, Tmin, RH and total Rf are the predictor variables. MS-Excel computer package program software version 7 was used for correlation and regression analysis.

RESULTS

Population dynamics of lentil aphid

The incidence of aphid was started from second standard meteorological week (SMW) (2 aphid/plant/10 cm apical twigs) during year 2017 and 2018. Initially the
population was low and gradually increased and reached to its peak (49 aphid/plant/10cm apical twigs) on 9th standard meteorological week. So far as the effect of weather parameters is considered, the maximum aphid population was recorded during 9th SMW when corresponding weather parameters viz. maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) were 30.80, 15.34, 67.72 and 0, respectively over the years 2017 and 2018 (table 2). The meteorological data during crop period (2016-2018) is shown in table 1.

Table 1. Meteorological data during crop period (2016/17-2017/18)

| Year/Month | Max temp(°C) | Min. temp(°C) | Relative humidity (%) | Total rainfall(mm) |
|------------|--------------|---------------|-----------------------|--------------------|
| Nov-16     | 28.5         | 13.7          | 92.5                  | 0                  |
| Dec-16     | 23.8         | 10.1          | 95.8                  | 0                  |
| Jan-17     | 24           | 8.1           | 84.7                  | 13.8               |
| Feb-17     | 26.4         | 12.3          | 79.2                  | 3.4                |
| Mar-17     | 29.5         | 16.7          | 68.7                  | 64.5               |
| Apr-17     | 33.4         | 21.7          | 72.4                  | 77.6               |
| Nov-17     | 29.2         | 15.6          | 91.3                  | 0                  |
| Dec-17     | 25.5         | 11.6          | 94.8                  | 0                  |
| Jan-18     | 20.9         | 8.5           | 95.5                  | 0.6                |
| Feb-18     | 26.4         | 12.6          | 86.8                  | 0                  |
| Mar-18     | 32.6         | 18            | 70.6                  | 26                 |
| Apr-18     | 34.5         | 22.3          | 68.1                  | 35.1               |

Table 2. Population dynamics of aphid on lentil in relation to meteorological parameters during winter season of 2017-2018

| Year: 2017 and 2018(Month) | SMW | Mean no of aphid/plant | Tmax (°C) | Tmin (°C) | RH (%) | Rf (mm) |
|---------------------------|-----|------------------------|-----------|-----------|--------|--------|
| January                   | 2   | 7                      | 22.50     | 6.14      | 90.44  | 0.00   |
| January                   | 3   | 13                     | 23.20     | 7.66      | 90.23  | 0.00   |
| January                   | 4   | 19                     | 23.63     | 9.91      | 87.36  | 14.40  |
| February                  | 5   | 25                     | 24.39     | 10.51     | 86.69  | 0.00   |
| February                  | 6   | 31                     | 24.96     | 12.21     | 84.21  | 0.00   |
| February                  | 7   | 40                     | 26.75     | 12.98     | 81.71  | 0.00   |
| February                  | 8   | 44                     | 27.66     | 14.27     | 79.01  | 3.40   |
| March                     | 9   | 49                     | 30.80     | 15.34     | 67.72  | 0.00   |

Note: SMW- Standard Meteorological Week, Tmax- maximum temperature, Tmin- minimum temperature, RH- relative humidity, Rf-rainfall, °C- degree centigrade, mm- millimeter, %- percentage
Correlation between lentil aphid and weather parameters

The combined correlation analysis of aphid population with meteorological factors over the years 2017 and 2018 showed that the aphid population had significant (P=0.05) positive correlation with maximum temperature $T_{\text{max}}$ ($r=0.94$) while the minimum temperature ($T_{\text{min}}$) showed highly significant (P=0.004) correlation ($r=0.99$). The relative humidity (RH) had non significant (P=0.07) negative correlation ($r=-0.90$) and rainfall (Rf) showed non-significant (P=0.525) negative impact ($r=-0.15$) with aphid population (table 3).

Table 3. Correlation coefficient of aphid/plant population on lentil in relation to meteorological factors during winter season of 2017 and 2018

| Parameters | $T_{\text{max}}$ ($^\circ$C) | $T_{\text{min}}$ ($^\circ$C) | Rf (mm) | RH (%) | Mean aphid/plant |
|------------|-----------------------------|-----------------------------|---------|--------|------------------|
| $T_{\text{max}}$ ($^\circ$C) | 1.00                        |                             |         |        |                  |
| $T_{\text{min}}$ ($^\circ$C) | 0.92                        | 1.00                        |         |        |                  |
| Rf (mm)    | -0.20                       | -0.06                       | 1.00    |        |                  |
| RH (%)     | -0.99                       | -0.89                       | 0.16    | 1.00   |                  |
| Mean aphid/plant | 0.94*                       | 0.99**                      | -0.15   | -0.90  | 1.00             |

Note: $T_{\text{max}}$- maximum temperature, $T_{\text{min}}$- minimum temperature, RH- relative humidity, Rf-rainfall, $^\circ$C- degree centigrade, mm- millimeter, %- percentage, *Significant at 5% level of significance, **Significant at 1 % level of significance

Forecasting model for lentil aphid

\[
\text{Aphid/plant} = -237.28 + 4.80 \times \text{Avg. } T_{\text{max}} ^{^\circ\text{C}} + 3.47 \times \text{Avg. } T_{\text{min}} ^{^\circ\text{C}} - 0.08 \times \text{total Rf (mm)} + 1.25 \times \text{Avg. } RH (\%) 
\]

Here, the aphid per plant is a response variable where as average $T_{\text{max}}$, $T_{\text{min}}$, RH and total Rf are the predictor variables. The forecasting model relies on average max and min. temperature, total rainfall and average relative humidity to assign aphid per plant and the model has an adjusted $R^2$ value of 0.99 and standard error is 1.29 (n=8). The P-value for the full model is 0.0004 which is small enough at both 5% and 1% level of significance to suggest that at least one of the predictor variables may be useful for the prediction (table 4). The adjusted $R^2$ is 0.99 which indicates that the predictor variables explain 99% of the variance in the response variable (Fig. 1).
These models are simple and easy in calculation and could be used to predict aphid population in lentil crop well in advance (table 5).

Table 4. Parameters of aphid population per plant as affected by average atmospheric temperature (max and min °C), total rainfall (mm) and average relative humidity (%)

| Parameter        | Coefficients | SE  | t -Stat | P-value | Lower 95% CI | Upper 95% CI |
|------------------|--------------|-----|---------|---------|--------------|--------------|
| Intercept        | -237.27      | 75.63 | -3.14  | 0.05    | -477.95      | 3.40         |
| Avg. Tmax (°C)   | 4.80         | 1.57 | 3.06    | 0.05*   | -0.18        | 9.79         |
| Avg. Tmin (°C)   | 3.46         | 0.46 | 7.52    | 0.004** | 2.00         | 4.93         |
| Total Rf (mm)    | -0.08        | 0.11 | -0.72   | 0.53    | -0.44        | 0.28         |
| Avg. RH (%)      | 1.25         | 0.471| 2.65    | 0.07    | -0.24        | 2.75         |

Note: SE- Standard error, CI- Confidence interval, Avg.-Average, Max-Maximum, Min-Minimum, T-Temperature, Rf- rainfall, RH-relative humidity, (°C) – degree centigrade, mm- Millimeter, *-Significant, **- Highly significant
Table 5. Residual output of the forecasting model for lentil aphid

| Month/week          | Observed aphid/plant | Predicted aphid/plant | Residuals |
|---------------------|-----------------------|-----------------------|-----------|
| January second week | 7                     | 5.48                  | 1.0       |
| January third week  | 13                    | 13.81                 | -1.3      |
| January 4th week    | 19                    | 18.92                 | 0.1       |
| February first week | 25                    | 25.03                 | -0.5      |
| February Second week| 31                    | 30.51                 | 0.0       |
| February Third week | 40                    | 38.66                 | 1.3       |
| February fourth week| 44                    | 43.85                 | -0.3      |
| March first week    | 49                    | 48.75                 | -0.2      |

DISCUSSION

Global warming has great importance regarding to population size, growth, distribution and outbreak of insect pests (Sable and Rana, 2016). The major climatic factors like temperature, light, humidity etc. can be assessed by observation of the rate of change rather than describing direct change in a specific physiological reaction (Overgaard and Sorenson, 2008; Karl et al., 2011). These factors can affect the mortality, fecundity, generation time, multiplication rate, sex ratio and somewhat mutation of any insect species. For instance, with the range of temperature, speed of development can be enhancing but production of deformities and larval mortality will also increased (Chown et al., 2011). Species richness and insect activity varies due to temperature and water availability. In multi climatic factors particularly temperature can extend or reduce the life cycle of insects (Régnière et al., 2012). High thermal threshold influence the insects cycle stage, growth or some internal metabolic activities. Tropical species of insects considered to be the high risk of microclimatic variation and behavioral optimization than the temperate regions. Low temperature have a great effect to disturb the physiological, mechanical and behavioral of the various insects (Overgaard and Sorenson, 2008; Karl et al., 2011). It can change the chemical ingredients and causing dehydration of the cells or maintaining body fluids keeping liquids below melting point (Sinclair et al., 2003). Insects could not bear the challenge against high and low thresh hold temperatures. High mortality was observed and somewhat developmental rate was affected and also performed the successful insect modeling that can aid to analyze the insect population response and behavior against climatic change (Karl et al., 2011; Régnière et al., 2012). New research shows that insect species living in warmer areas are more likely to undergo rapid population growth because they have higher metabolic rates and reproduce more frequently. Lower winter mortality of insects due to warmer winter temperatures could be important in increasing insect populations (Harrington et al., 2001).
The finding of this experiment was supported by Hossain et al. (2006) who reported that lentil aphid appeared in the field during first week of January and the maximum aphid population was recorded in the first week of February, but the population reached to the peak in the last week of January, subsequently rainfall caused a sudden reduction of aphid population in latter dates. Aphid population and infestation increased with the delayed dates of sowing. Hossain et al. (2006) reported that the lentil crop sown in November received less aphid infestation and consequently produced higher yield than the crop sown in December. The present findings supported by the reports of the Dalwadi et al. (2007) who worked out the correlation coefficient between weather parameters and pest population and reported that maximum and minimum temperature had significant positive correlation with aphids population whereas relative humidity and rainfall showed negative association. Prasad et al. (2008) reported that aphid population had significant positive association with maximum temperature, minimum temperature and negative association with relative humidity and rainfall. In the earlier work Hasan et al. (2009) reported that among the different environmental factors maximum temperature and minimum temperature positively correlated with aphid population while rainfall and relative humidity negatively correlated with aphid population.

CONCLUSION
The result of present findings concluded that weather parameters like temperature, rainfall and humidity were found to significant influence on initiation and development of lentil aphid in inner terai region of Nepal. Predictions from insect forewarning models under changing scenarios of climate, pest population could be managed efficiently through ecological manageable practices like timely application of insecticides, adjustment of sowing time and selection of varieties etc. that would be helpful to obtained higher yield.

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